THE INTEGRITY OF WATER

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THE INTEGRITY OF WATER

a symposium

SYMPOSIUM COORDINATORS:
R. Kent Ballentine and Leonard J. Guarraia
Water Quality Criteria Staff, EPA
Washington, D.C.

OPENING SESSION

Chairman: Kenneth M. Mackenthun, Acting Director, Technical Standards Division, Office of Water and Hazardous Materials, EPA, Washington, D.C.

Speakers: Kenneth M. Mackenthun

James L. Agee, Assistant Administrator, Office of Water and Hazardous Materials, EPA, Washington, D.C.

Thomas Jorling, Director, Center for Environmental Studies, Williamstown, Massachusetts

Donald Squires, Director, State University of New York Sea Grant Program, Albany, New York

CHEMICAL INTEGRITY

Chairman: Dwight G. Ballinger, National Environmental Research Center, EPA, Cincinnati, Ohio

Speakers: Bostwick Ketchum, Director, Woods Hole Oceanographic Institute, Woods Hole, Massachusetts

Arnold Greenberg, Chief, Chemical and Radiological Laboratories, State of California Department of Public Health, Berkeley, California

Jay Lehr, Executive Secretary, National Water Well Association, Columbus, Ohio

PHYSICAL INTEGRITY

Chairman: Richard K. Ballentine, Water Quality Criteria Staff, EPA, Washington, D.C.

Speakers: Donald J. O'Connor, Professor of Environmental Engineering, Manhattan College, New York, New York

Donald R. F. Harleman, Professor of Civil Engineering and Director, Parson's Laboratory for Water Resources, Massachusetts Institute of Technology, Cambridge, Massachusetts

John M. Wilkinson, A. D. Little, Inc., Cambridge, Massachusetts

BIOLOGICAL INTEGRITY— A QUALITATIVE APPRAISAL

Chairman: Leonard J. Guarraia, Water Quality Criteria Staff, EPA, Washington, D.C.

Speakers: David G. Frey, Indiana University, Bloomington, Indiana

George Woodwell, Brookhaven National Laboratories, Upton, Long Island, New York

Charles Coutant, Oak Ridge National Laboratory, Oak Ridge, Tennessee

Ruth Patrick, Chief, Curator of Limnology, Academy of Natural Sciences, Philadelphia, Pennsylvania

BIOLOGICAL INTEGRITY— A QUANTITATIVE DETERMINATION

Chairman: David G. Frey, Indiana University, Bloomington, Indiana

Speakers: Ray Johnson, National Science Foundation, Washington, D.C.

John Cairns, Virginia Polytechnic Institute and State University, Blacksburg, Virginia

Gerald T. Orlob, Resource Management Associates, Lafayette, California

J. P. H. Batteke, Chief, Social Sciences Division, Environment Canada, Burlington, Ontario

INTEGRITY—AN INTERPRETATION

Chairman: Martha Sager, Effluent Standards and Water Quality Information Advisory Committee, EPA, Washington, D.C.

Ronald B. Robie, Director, Department of Water Resources, The Resources Agency, Sacramento, California

Ronald B. Outen, National Resources Defense Council, Washington, D.C.

R. M. Billings, Director of Environmental Control, Kimberly-Clark, Neenah, Wisconsin

Gladwin Hill, National Environmental Correspondent, New York Times, New York

Following each presentation, Symposium participants were encouraged to question the speaker. These discussions were recorded by a professional reporting service and appear at the conclusion of each paper. They have been minimally edited, simply for clarification of the spoken word in print.

FOREWORD

"The Integrity of Water" results from the formal papers and comments presented at an invitational symposium by recognized water experts representing a variety of disciplines and societal interests. The focus of the symposium was on the definition and interpretation of water quality integrity as viewed and discussed by representatives of State governments, industry, academia, conservation and environmental groups, and others of the general public. The symposium was structured to address quantitative and qualitative characteristics of the physical, chemical, and biological properties of surface and ground waters.

It is recognized that streams, lakes, estuaries, and coastal marine waters vary in size and configuration, geologic features, and flow characteristics, and are influenced by climate and meteorological events, and the type and extent of human impact. The natural integrity of such waters may be determined partially by consulting historical records of water quality and species composition where available, by conducting ecological investigations of the area or of a comparable ecosystem, and through modeling studies that provide an estimation of the natural ecosystem based upon information available. Appropriate water quality criteria present quality goals that will provide for the protection of aquatic and associated wildlife, man and other users of water, and consumers of the aquatic life.

This volume adds another dimension to our recorded knowledge on water quality. It brings into sharp focus one of the basic issues associated with the protection and management of this Nation's valued aquatic resource. It highlights, once again, our unqualified dependence upon controlling water pollution if we are to continue to have a viable and complex society. The Congress has provided us with strong and comprehensive water pollution control laws. In accordance with the advances in research and development and with our increased knowledge about the environment, these laws will receive further congressional consideration and modification as appropriate. It is through the efforts of those who participated in making this volume possible that attention is focused once again on the basic goals of water quality to support the dynamic needs of this generation and of others to come.

Douglas M. Costle, Administrator
U.S. Environmental Protection Agency
June, 1977

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BIOLOGICAL INTEGRITY OF WATER—AN HISTORICAL APPROACH

DAVID G. FREY
Department of Zoology
Indiana University
Bloomington, Indiana

To a considerable extent the topics assigned to us have unreasonably artificial boundaries, because an ecologist cannot talk about the physics, chemistry, or biology of water separately, nor about the qualitative aspects of water and its biotas separately from the quantitative aspects. Moreover, in a meeting such as this of persons with disparate backgrounds and interests, effective communication can be a problem. We all tend to use words that have special meanings within our own disciplines and we assume a certain understanding of premises, principles, and laws when we use them. To make certain that we all are operating on the same wave length I shall present several principles of ecology that must guide our thinking about water, its management, and the potential effects on it of various manipulative processes, then give my own definition of the integrity of water, and finally address the topic assigned me. The principles to be discussed apply to all aquatic systems, but the examples I shall present will be concerned chiefly with lakes, as they, along with the oceans, provide in their sediments the only record of past events not covered by written observations or the memory of persons still living.

(1) Lakes and rivers are integral parts of larger systems—the watersheds or catchment areas that are drained by the rivers or drain through the lakes. Besides water itself, the catchment area contributes dissolved and particulate substances, both mineral and organic. In addition, usually lesser quantities of various substances are contributed directly to the water from the atmosphere by precipitation and dry fallout. Together with such process-regulating variables as light, temperature, current velocity, et cetera, these various substances comprise the abiotic portion of the aquatic environment and help control the diversity and abundance of aquatic organisms.

(2) Those substances that are used directly by aquatic organisms and are necessary in their metabolism—usually called essential nutrients—are recycled in the system by biological mechanisms. Storage in living biomass, in wood or sediments, or in the deep water of a stratified lake can delay the reutilization of these nutrients for varying periods of time. Because inputs and outputs, including storage, are generally in balance, an aquatic system to remain functional requires a continuous input of nutrients. The quantities of nutrients and other substances contributed by a watershed vary with the geological nature of the substrate and its overlying soils, the vegetational cover of the land, and climate. Since all of these tend to form regional patterns, it is not surprising that rivers and lakes also tend to form regional patterns or clusters in their chemistry, productivity, and biotic diversity.

(3) Besides nutrients there must also be a source of fixed energy, mostly in organic compounds. The latter derive both from photosynthesis accomplished within the aquatic part of the system and from organic materials, such as leaves, pollen, and leachates produced in the terrestrial part of the system. In some systems, such as lakes with small, nonforested watersheds, virtually 100 percent of the available energy derives from autochthonous photosynthesis, whereas in other systems, such as small, headwater streams in heavily forested regions, almost all the fixed energy derives from organic detritus of terrestrial origin. But whatever its origin, the fixed energy in organic substances is the driving force that enables the organisms present to metabolize and carry on their life processes. As the energy is used in metabolism it is transformed into heat and dissipated from the system. Hence, unlike nutrients, energy cannot be recycled. It is a one-way street, but like nutrients there must be a continuous supply for the ecosystem to function.

(4) Taking into consideration regional differences in water chemistry and nutrient supply and differences between water bodies in energy availability and efficiency of nutrient recycling, each aquatic system has accumulated over time a diversified biota consisting of many species of organisms ad-

justed to the particular set of conditions in the water body in question. For purposes of analysis and construction of models, these organisms are often clustered into such functional groups as primary producers, herbivores, detritivores, carnivores, decomposers, et cetera, but all are interrelated. That particular species occur in a given lake or river is partly a matter of the species pool of the region and the dispersal capabilities of the individual species, partly a function of the biotic and abiotic relationships in the water body. Although we consider these systems to be in a steady state, intuitively we expect the biota to adjust to long term changes in climate, vegetation, soil development, and internal trends within the system itself, and we also expect the system to be able to accommodate and eventually recover from such short term natural stresses as scouring flushouts in rivers, episodes of volcanism, landslides, and so forth. Homeostasis is restored.

This, to me, is what is meant by the integrity of water—the capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having a composition and diversity comparable to that of the natural habitats of the region. Such a community can accommodate the repetitive stresses of the changing seasons. It can accept normal variations in input of nutrients and other materials without disruptive consequences. It displays a resistance to change and at the same time a capacity to recover from even quite major disruptions.

My assignment is to consider what history tells us about the response of aquatic systems. Anything that happened in the past is history. Even the words I speak become a part of history as soon as they are spoken. But most of history is unrecorded and hence unavailable for interpretation. In the case of aquatic systems there are anecdotal accounts of particular events or conditions that may have some comparative value. There may be time series of accumulated data for particular rivers or lakes that document what happened during these intervals. And, in the case of lakes (and oceans), the accumulated sediments constitute an historical record of changing climate and watershed conditions and the integrated response of the lake to these changes. Where no previous studies on particular lakes exist and likewise no isolated anecdotes about particular events, the only means we have of interpreting previous conditions is from the sediments. For rivers this possibility does not exist at all, as there is no long term sequential accumulation of sediments. Hence, here we are completely dependent on the written record, except for the geomorphic and hydrologic changes that can be interpreted from the landscape and residual sediments of the valley.

I do not intend to say much about rivers. Their response to point source additions of domestic and industrial wastes is the establishment of a longitudinal gradient involving a succession of chemical processes and organisms, which for organic wastes is sufficiently predictive that a series of zones—the sabrobic system—has been set up to help describe and interpret the process of recovery. Other zone designations have been devised for various kinds of industrial wastes and the responses they elicit.

Organisms vary greatly in their sensitivity to environmental changes accompanying pollution. Fishes together with a majority of insects and molluscs are most sensitive. Blue-green algae and a few miscellaneous animals from several groups are most resistant. These differences in tolerance lead to a greatly simplified community at the point of maximum impact, with the organisms tolerating the conditions here often occurring in tremendous numbers, and then to a gradual buildup in diversity of species and equitability in numbers of individuals downstream. Various diversity indices have been proposed to help quantify these changes. Diatoms are particularly useful in stream studies and their truncated log-normal distributions are useful in assessing the severity of pollution. The experienced investigator can often determine quite easily from the macroinvertebrates present what the stage of recovery is, and can also detect residual effects of pollution, as from lead mines in Wales, that are no longer detectable chemically.

Lakes are fundamentally different from rivers in a number of respects that affect the integrity of water as I have defined it. In the first place, their water movements are not gravity-controlled, unidirectional flows which continually flush out the channel with new water from above, but rather wind-induced circulations. Typically in summer, when the wind is not adequate to overcome the differences in density set up by surface warming, the lake becomes divided into an upper circulating epilimnion and a lower zone, the hypolimnion, cut off from the surface by a steep density gradient and as a result subject to generally much weaker water movements than the epilimnion. During periods of calm weather those lakes that circulate continuously over summer can become temporarily stratified and even the epilimnion of the others can develop secondary stratifications under these circumstances. Regardless of the duration of such stratification, the hypolimnion, or its equivalent in temporary stratification, experiences cumulative chemical changes, most important of which is the gradual depletion of dissolved oxygen by biological activity. The longer the duration of stratification and the greater the amount of biological activity, the more severe will be the oxygen depletion with its attendant stresses on organisms requiring certain levels of dissolved oxygen for their survival.

Unlike rivers, lakes accumulate sediments progressively and sequentially. One effect of these sediments is gradually to reduce the volume of the hypolimnion over time and hence the total volume of dissolved oxygen it contains when stratification becomes established in spring or summer. Consequently, even without any increase in biological activity, the hypolimnion will experience a gradual reduction in oxygen concentration over time, which brings about the extinction and replacement of various deepwater organisms as their tolerances for low oxygen are exceeded.

The sediments constitute a storage for energy and nutrients. Some of this is utilized by bacteria which can continue their activity even to considerable depths in the sediments, or by various animals, which because of their need for molecular oxygen are confined generally to the uppermost few centimeters. Whether the sediments are functioning chiefly as a sink or as a reservoir for nutrients is important in problems concerning eutrophication and its management.

The sediments also constitute a chronological record of processes in the lake and conditions in its watershed, including climate. A perceptive reading of the record—its chemistry, physics, and paleontology—gives us much insight into the stability of lake systems when subjected to various stresses, including those resulting from man's activities, and their rates of recovery.

A third major difference between rivers and lakes is that the water in lakes has a certain residence time, up to 100 years or more in some of the large lakes, determined by the relationship between the input of water from the catchment area and direct precipitation and the total volume of the lake. This allows for the recycling of nutrients in the same place, subject to the constraints imposed by stratification, and the buildup of a diverse community of small floating organisms—the plankton. And even apart from any storage function of the sediments, the residence or replacement time means that there is an inherent lag in response of the system to any increase or decrease in inputs of nutrients or other substances having biological effects. In streams the response to input changes can be almost immediate. Any storages in the sediments are mostly temporary, as the sediments can be swept downstream during the next flood stage.

What I should like to do now is present a few examples of the kinds of responses made by lakes to various stresses.

It was almost axiomatic in limnology until quite recently that lakes increase in productivity over time through natural causes, a process that has been termed natural eutrophication. This idea seemed to be substantiated by some early studies in paleolimnology which showed that the organic content of the sediments increased exponentially over time from a very low level initially to a certain plateau level—the trophic equilibrium—which was then maintained essentially unchanged almost to the present. The trophic equilibrium was regarded as a state in which production was no longer limited by nutrient supply but rather by such factors as light penetration that affect the efficiency of utilization and recycling of nutrients within the system.

The sedimentary chlorophyll degradation products (SCDP) in sediments originate almost entirely from photosynthetic plants, chiefly algae, in the lake itself. Present evidence suggests that these organic compounds are relatively stable in sediments. Hence, the quantitative changes over time of these substances can give an indication of the magnitude and changes in productivity experienced by a lake. One core from Pretty Lake, Ind., (Figure 1), shows low SCDP and hence low productivity in late glacial time and then an exponential increase to a maximum, maintained essentially at plateau level almost to the present. This corresponds to the classical interpretation of the trophic equilibrium in lake ontogeny. But the second core from shallower water shows a decline in SCDP after the maximum following the exponential increase, which does not fit the model.

We now know from this and other studies in paleolimnology that change in productivity over time is not unidirectional from low to high in all lakes, but that some lakes had a period of high productivity initially and then became less productive subsequently. Others had discrete episodes of higher productivity from whatever cause. For example, Lake Trummen in southern Sweden (Digerfeldt, 1972) had high accumulation rates of organic matter, nitrogen, and phosphorus at the beginning of postglacial time approximately 10,000 years ago. These subsequently declined and remained low up to very recent time, when industrial organic effluents completely changed the character of the lake (Figure 2). These relationships are interpreted as reflecting the high early availability of nutrients from the youthful soils of the regional till sheets, with the subsequent decline resulting from the progressive impoverishment of the soil by leaching and by the reduction of subsurface inflow into the lake as basin-sealing sediments accumulated.

Hence, the productive status of a lake is depend-

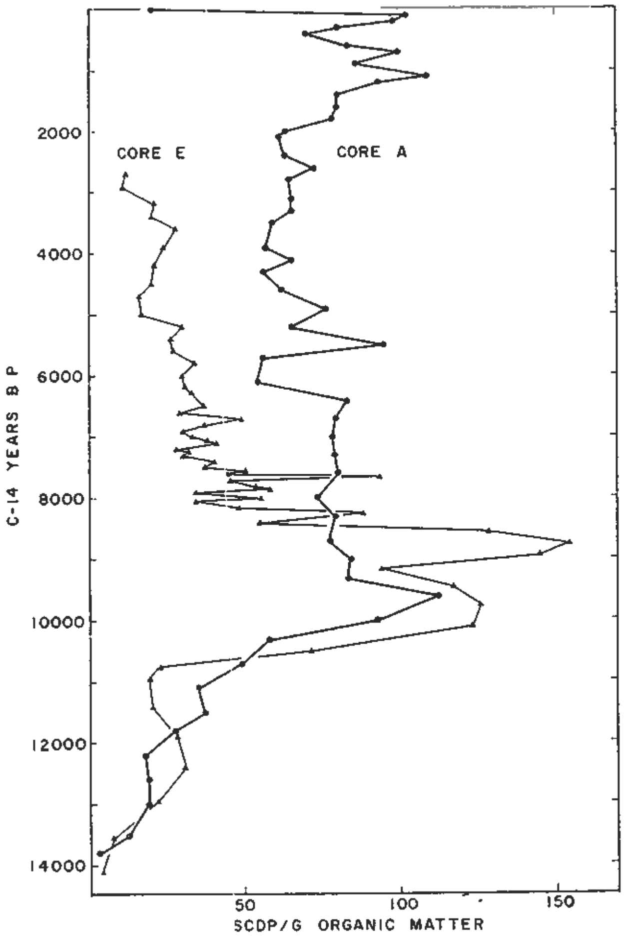


FIGURE 1

ent on the magnitude of its nutrient inputs, subject to the internal controls of the system. If we can decrease the nutrient supply, we can expect a more or less commensurate decrease in productivity. Various attempts are being made to model the magnitude of the response expected from any reduction in nutrient loading, but the rate of response is still unpredictable. The rapid reduction of phosphorus and productivity in Lake Washington following the elimination of secondary sewage effluents (Edmondson, 1972) is encouraging, although some other components of the system, such as nitrogen, did not behave in the same dramatic way. Other examples to be presented suggest that the response time of the total system, or perhaps better the rebound time from a stressed condition, can be much longer than in Lake Washington.

The responses of a lake to the decreasing oxygen concentration of the hypolimnion over time are instructive and significant. Western Lake Erie is so shallow that it stratifies only temporarily in summer during calm weather. Already by 1953 the oxygen demand of the sediments had become such that during a brief period of temporary stratification in late summer the oxygen content of the water overlying the bottom was sufficiently reduced to cause the wholesale death of the nymphs of the burrowing mayfly, one of the most abundant organisms here and a very important fish food (Britt, 1955). The mayflies never reestablished their populations but they have been replaced by smaller oligochaete worms capable of enduring quite low concentrations of dissolved oxygen. Thus, a single event, although obviously with antecedent conditions, led to a complete change in one portion of the biotic community.

The cisco is another case in point, although perhaps less spectacular. If we want to talk about endangered species, or at least endangered populations, this is one. It is a fish that lives in deep water with requirements for both low temperature and high oxygen. If either of these limits is exceeded, the fish perishes. As the summer oxygen concentration of the hypolimnion gradually decreases over time, the cisco, in order to meet its oxygen needs, is forced upward into strata with progressively higher temperatures. Eventually the combination of low oxygen in deep water and high temperatures toward the surface eliminates the habitat suitable for the cisco and the population is extinguished. In 1952 Indiana had 41 lakes with known cisco populations (Frey, 1955a). It is certain that a number of these populations have been completely extirpated since then, and it is not at all certain how long the others will survive.

The species of midge larvae associated with deep-water sediments have different requirements for dissolved oxygen, so that as the oxygen content of the hypolimnion gradually declines over time, the composition of the midge community likewise changes progressively in favor of species capable of tolerating lower oxygen concentrations. This led early in limnology to the establishment of a series of lake types based on the dominant species of offshore midges and presumably representing stages in a successional series. Fortunately the head capsules of the midge larvae, which are well preserved in lake sediments, suffice to identify the organisms to the generic and sometimes to the species levels. In general, the pattern of succession in an individual lake corresponds to the model, with species requiring high levels of oxygen occurring early in the history of the lake; these subsequently are replaced by species more tolerant of reduced oxygen; they in turn are replaced by species still more tolerant, and so on until the only species left is a mosquito-like larva *Chaoborus*, which can endure

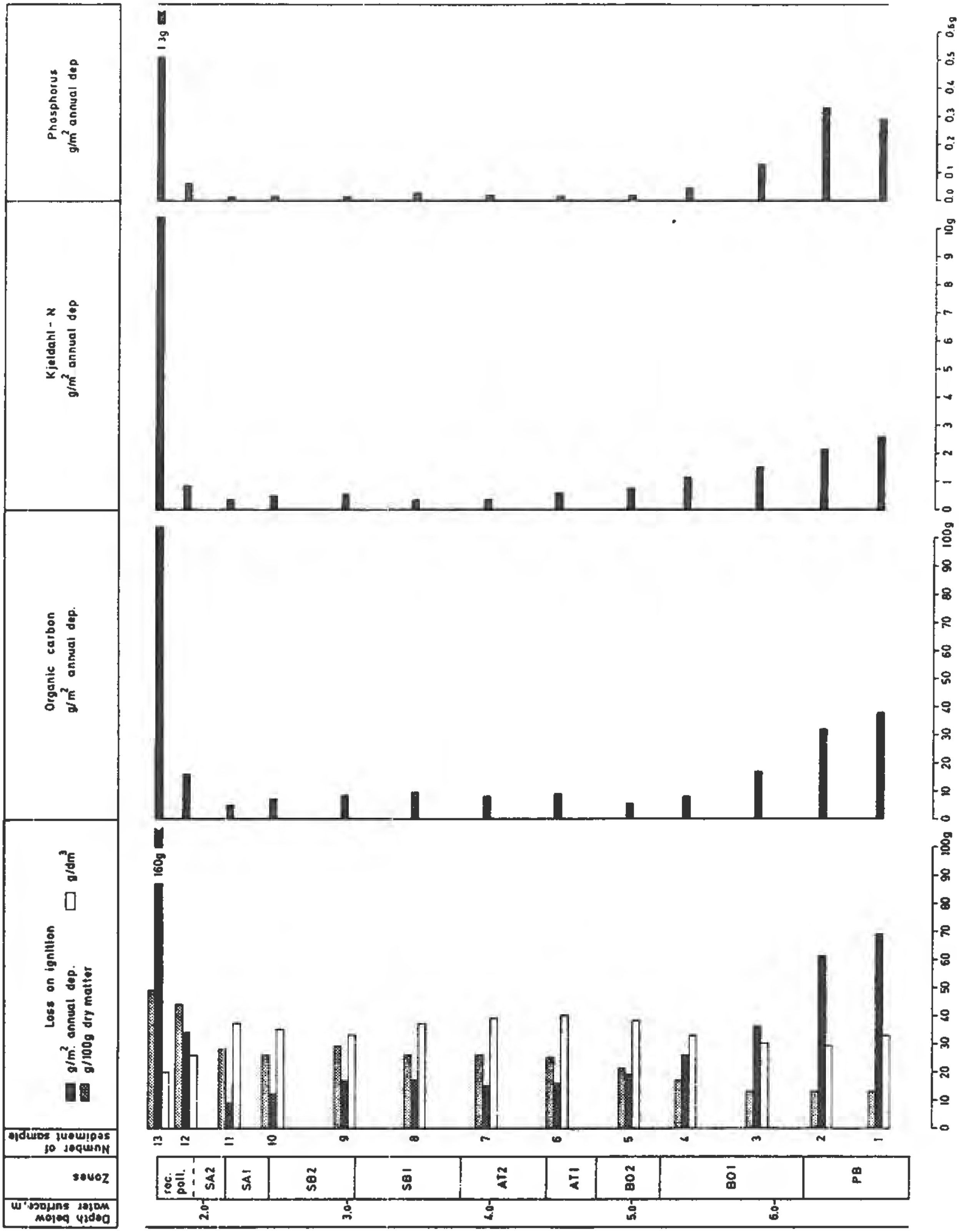

Phosphorus g/m² annual dep
Kjeldahl - N g/m² annual dep
Organic carbon g/m² annual dep.
Loss on ignition
g/m². annual dep.
g/100g dry matter
g/dm³
Number of sediment sample
Zones
Depth below water surface, m
rec. poll.
SA2
SA1
SB2
SB1
AT2
AT1
BO2
BO1
PB
160g
1.3g

FIGURE 2

anaerobiosis for a while, but eventually even it is eliminated if conditions continue to deteriorate.

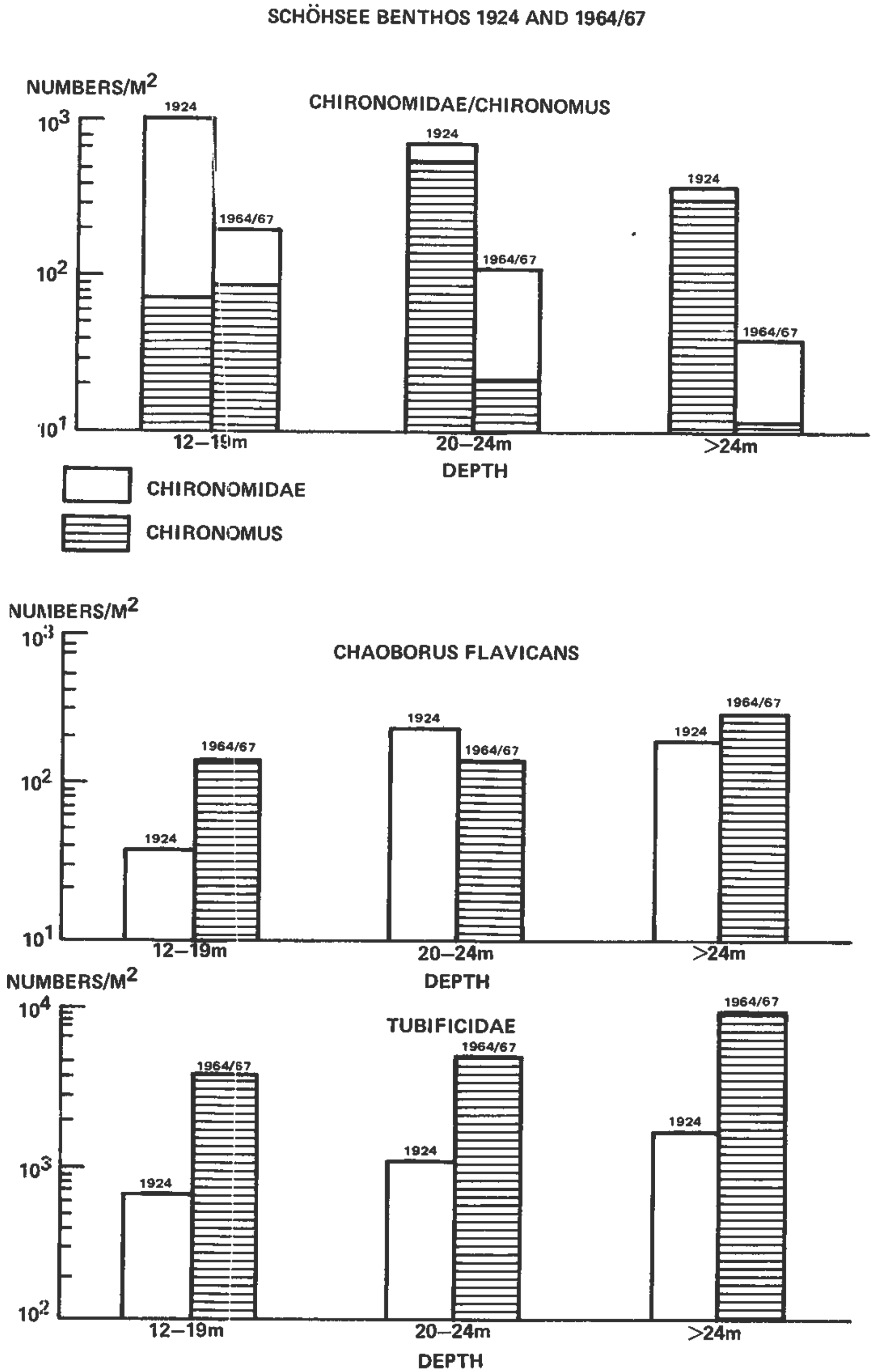
The most incisive study to date is that of Hofmann (1971) on Schöhsee in northern Germany. A midge community associated with moderate oligotrophy dominated the offshore community until early sub-Boreal time about 1500 B.C. This was followed by a transitional community lasting perhaps 2,500 years, and this in turn by a eutrophic community for the last 1,000 years. The whole story is much more complex than indicated by this too-brief summary in that throughout the 10,000 years of lake history there were migrations of originally shallow-water species into deep water, extinction of deepwater species, and successional dominance of one species or another as conditions gradually changed. Actual quantitative studies of the benthos in 1964-67 compared with similar studies in 1924 show that the populations are still changing (Figure 3). In this interval the population of chironomids, especially *Chironomus*, has declined drastically, being replaced by an increasing population of oligochaetes. *Chaoborus* remained about the same. This situation is reminiscent of western Lake Erie, where oligochaetes took over after the big killoff of mayflies in 1953.

Settlers first moved into the Bay of Quinte region of Lake Ontario about 1784. Government reports describe the devastation of thousands of acres by lumbering and the erosion problems resulting. The initial impact of this land disturbance on the Bay was to change the deepwater sediment from silt dominance to clay dominance and to bring about a marked decrease in organic content through dilution by clay (Warwick, 1975). Subsequently, the organic content increased gradually, although it is still less than pre-impact level, but now there is a pronounced decline in oxygen content of the deep water in summer. The initial response of the midge community was somewhat surprising; it became more oligotrophic than it had been before but then it proceeded through several successional phases to a quite strongly eutrophic stage at present (Figure 4). Unlike previous investigators, Warwick believes that the earliest stages in midge succession are controlled by food supply more than by the minimum annual concentration of oxygen in the hypolimnion. The latter is important chiefly in the later stages of succession. Besides the shift in lithology from silt to clay, the sediments deriving from the impact period are marked by the appearance of the pollen of *Ambrosia* (ragweed), the abundance of which in the sediments roughly parallels but lags somewhat behind the curve showing increase in population of the region. *Ambrosia* provides an excellent time-stratigraphic marker in eastern North America for forest clearance and the initiation of agriculture.

Man's effect on our water resources is nothing recent. Figure 5 is a pollen diagram of Längsee in southern Austria (Frey, 1955b), a lake that presently has a layer of water at the bottom that does not participate in the circulation of the rest of the lake in spring and autumn—a condition known as partial circulation or meromixis. At a particular level in the sediments, which is obvious in the diagram, there are sudden changes in the non-tree pollens, including the appearance of various agricultural weeds and occasional grains of such cultivated plants as cereals and walnut, as well as a disruption in the development of the forest vegetation. At this same level discrete bands of clay occur, separated by a black reduced sediment completely unlike the stable sediment deposited prior to this but identical to what occurs above. Quite obviously, this is when agriculture began in the region about 2,300 years ago, and just as obviously the clearance of the land for agriculture resulted in the inwash of large quantities of clay into the lake, triggering the condition of partial circulation, now maintained by biological means. Hence, the sudden import of large amounts of clay into a lake can have different consequences for different systems.

Lago de Monterosi, a small volcanic lake in central Italy about 40 km from Rome, had an initial small burst of productivity when formed about 25,000 years ago, then a long phase of low productivity up to Roman time, when the construction of a road, the Via Cassia, in 171 B.C. completely changed the input of nutrients and other substances from its small watershed (Hutchinson, et al. 1970). The lake responded by dramatic increases in productivity and sedimentation rates which did not peak until almost 1,000 years after the disturbance (Figure 6). Since then, productivity, as inferred from the accumulation rates of such substances as organic matter, nitrogen, et cetera, has subsided to a level not much greater than that existing before the disturbance. The lag in response and the long duration of the response are probably related to the fact that Monterosi is a closed basin with no permanent streams draining its very small watershed and with output only via seepage.

Grosser Plöner See is a lake in northern Germany famous for the many studies in limnology conducted there by August Thienemann and his associates. In 1256 A.D. a dam constructed at the outlet raised the water level about 2 meters, overflooding much flatland in the process and greatly increasing the extent of the littoral zone. The response of the lake was spectacular (Ohle, 1972). The sedimentation rate, which had increased slowly from about 0.1


SCHÖHSEE BENTHOS 1924 AND 1964/67
NUMBERS/M2
CHIRONOMIDAE/CHIRONOMUS
10³
10²
10¹
1924
1964/67
12–19m
20–24m
>24m
DEPTH
CHIRONOMIDAE
CHIRONOMUS
NUMBERS/M2
CHAOBORUS FLAVICANS
10³
10²
10¹
1924
1964/67
12–19m
20–24m
>24m
DEPTH
NUMBERS/M2
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10⁴
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20–24m
>24m
DEPTH

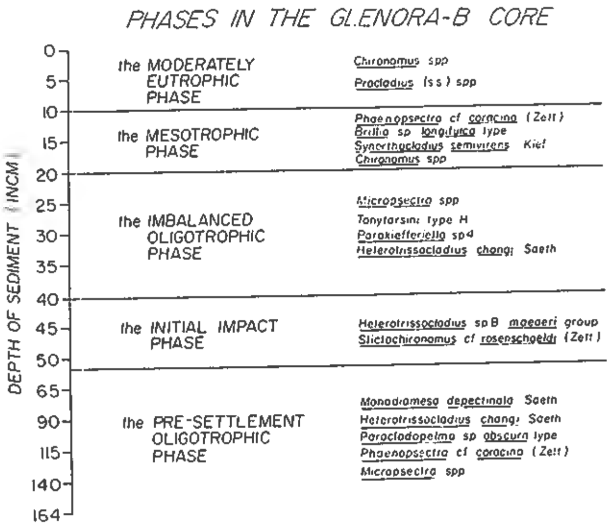

FIGURE 4

mm per year at the beginning of postglacial time to only about 0.5 mm per year 9,000 years later, suddenly jumped 20-fold to more than 10 mm per year. This has resulted in half the 15 meters of sediment in the lake deriving from only the last 700 years of the lake's existence. The big increases at this time in the accumulation rates of such substances as zinc, copper, cobalt, and aluminum reflect the increased input of mineral substances to deep water from the overflooded land and probably from the watershed also. Correspondingly big increases in the accumulation rates of organic matter, chlorophyll derivatives, and diatom silica reflect the big increase in production within the system resulting from this changed regime (Figure 7).

The lake level had been raised to power a mill dam, as was common in northern Germany at this time, and also to facilitate the production of eels, but the concomitant flooding of valuable agricultural lands resulted in a long-continuing strife be-

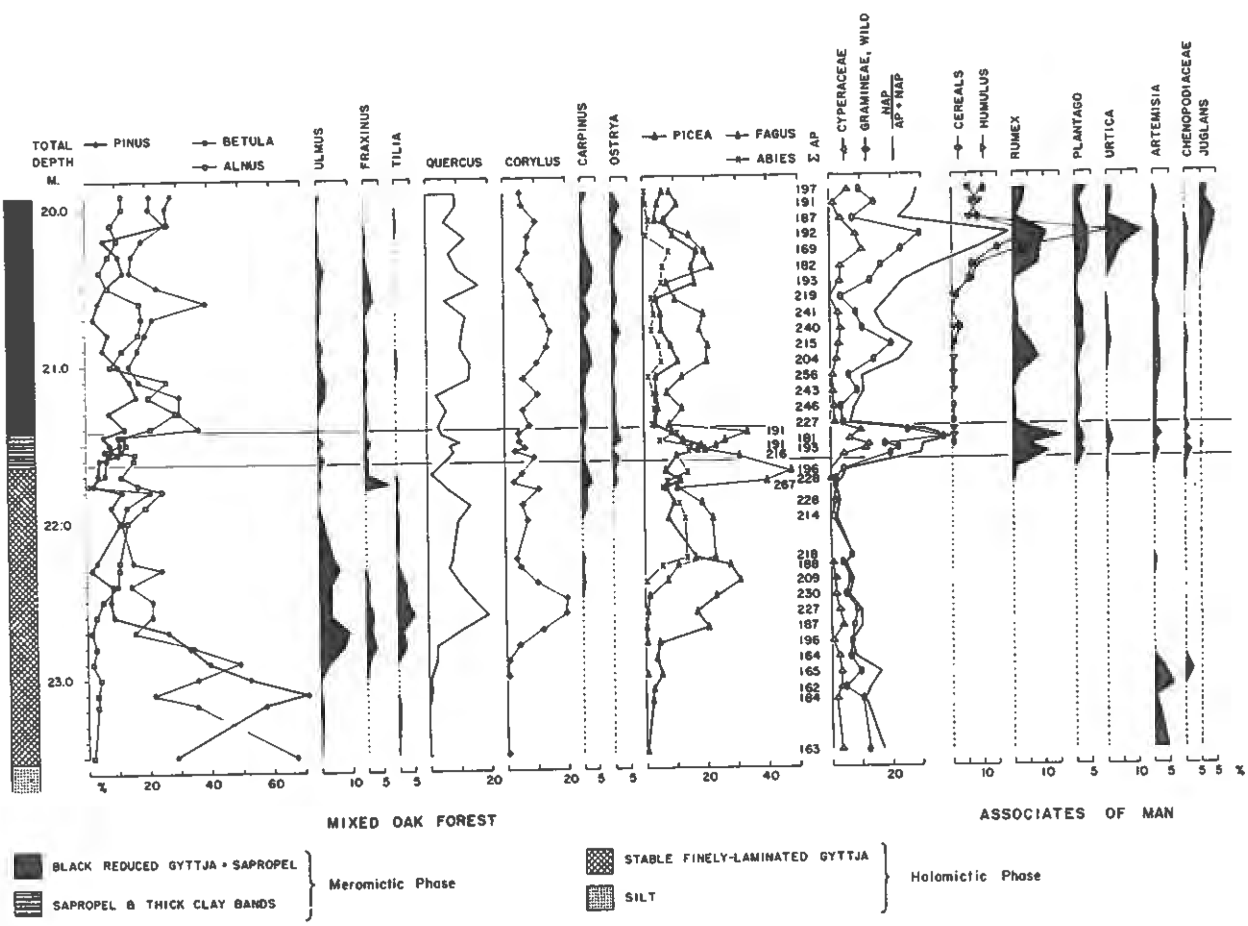

FIGURE 5

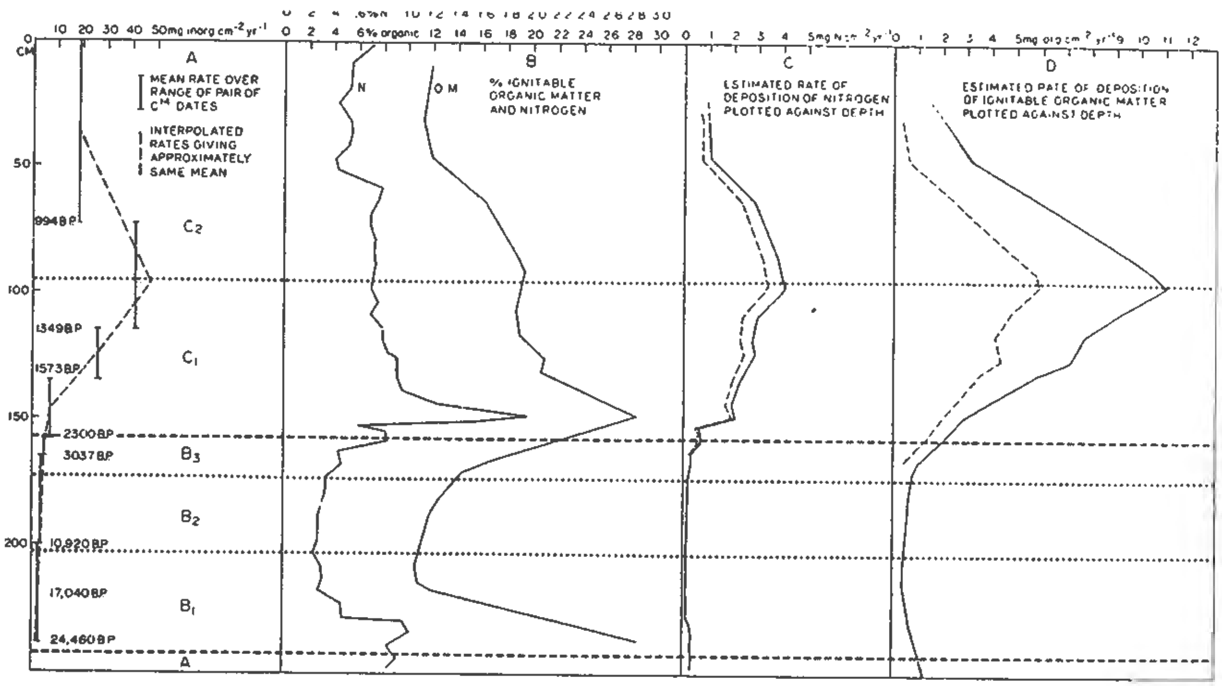

FIGURE 6

tween the mill operators and fishermen on the one hand and the manor owners and farmers on the other. Finally, in 1882 the lake level was lowered by 1.14 m. Up to this time the accumulation rates of most mineral substances had been declining irregularly, and likewise the indicators of biological activity. The sudden lowering in lake level resulted in the erosion and deposition offshore of sediments that had accumulated in shallow water, yielding a discrete horizon of coarse-grained sediments and associated sharp peaks of various mineral constituents. Accumulation rates of chlorophyll derivatives and diatom silica declined at this time, perhaps through light limitation of production by increased inorganic turbidity. The large increase in chlorophyll derivatives in very recent time, reflecting high productivity, is attributed to the heavy use of agricultural fertilizers and phosphate detergents and to the draining of the surrounding wetlands. Such an increase of organic matter and other indicators of production toward the surface is commonplace among lakes being stressed by man, frequently resulting in a completely different type of sediment than anything deposited earlier.

Grosser Plöner See is but one of a number of instances where the productivity of a lake has been markedly increased by raising its water level. The present high productivity of Grosser Plöner See is shared by many lakes of the region, all accomplished within the past few decades in direct response to man's increasing impact on the systems. Ohle (1973) has used the term "rasante Eutrophierung" (racing eutrophication) for this rapid response of lakes to cultural influences, in contrast to the generally slow, balanced development occurring naturally.

The most abundant animal remains in lake sediments are the exoskeletal fragments of the Cladocera, particularly the family Chydoridae (Frey, 1964). They are abundant enough for the construction of close-interval stratigraphies similar to those of pollen and diatoms and for the calculation of various diversity indices and distribution functions. Since the deepwater sediments represent an integration over time and habitat, the population of remains recovered from the sediments is partly artificial, in that all the species represented probably did not co-occur at the same time and place. Yet the diversity indices of the chydorids do show certain demonstrable relationships to such variables as productivity and transparency and, as shown in Figure 8, the relative abundance of the various species in an unstressed situation conforms almost precisely to the MacArthur broken stick model for contiguous but non-overlapping niches (Goulden, 1969a). Hence, the species distribution predicted by this model can be used to assess the extent of imbalance in the system.

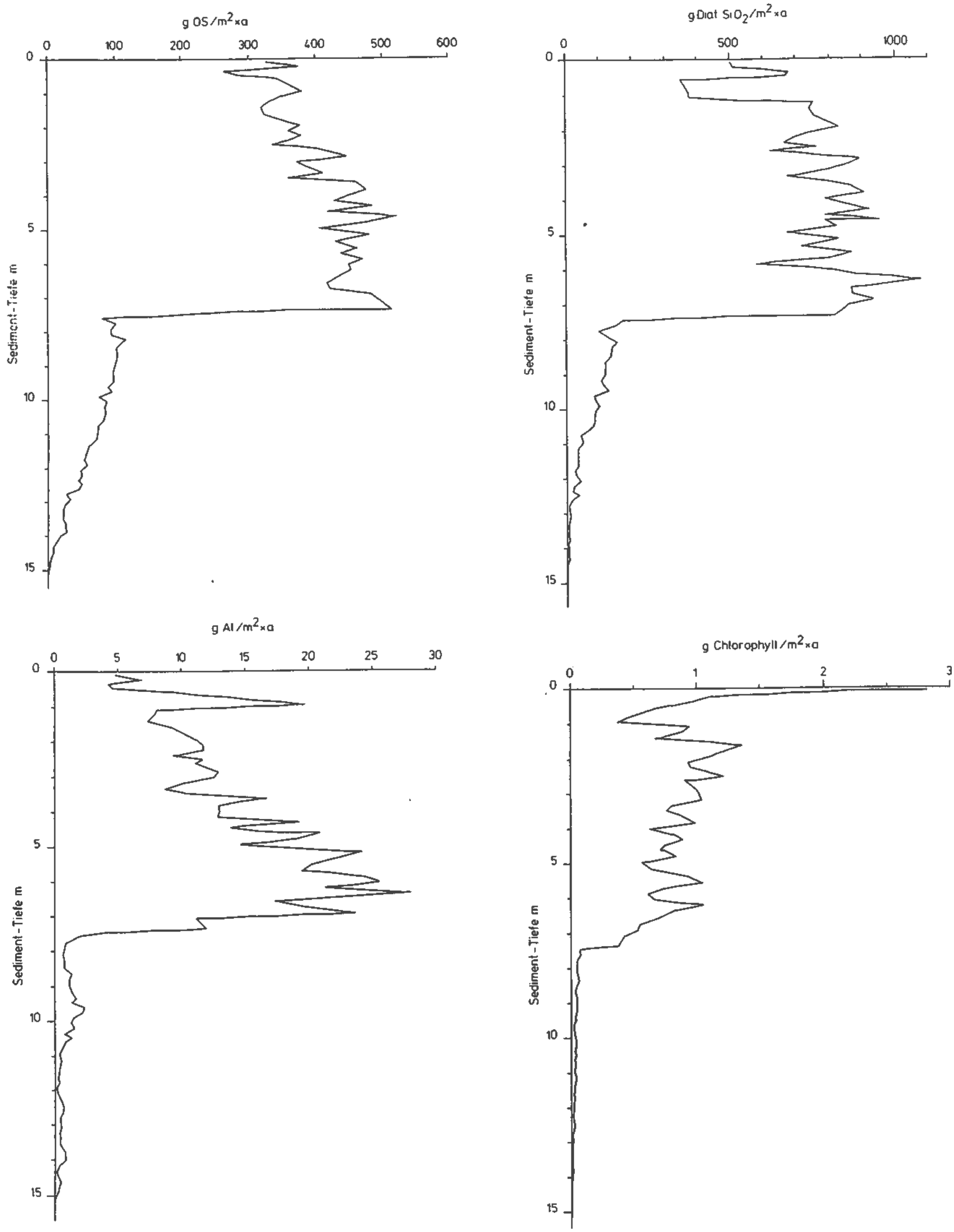
$g\ OS/m^2 \times a$
0 100 200 300 400 500 600
0 5 10 15
Sediment-Tiefe m
$g\ Diat\ SiO_2/m^2 \times a$
0 500 1000
0 5 10 15
Sediment-Tiefe m
$g\ Al/m^2 \times a$
0 5 10 15 20 25 30
0 5 10 15
Sediment-Tiefe m
$g\ Chlorophyll/m^2 \times a$
0 1 2 3
0 5 10 15
Sediment-Tiefe m

FIGURE 7

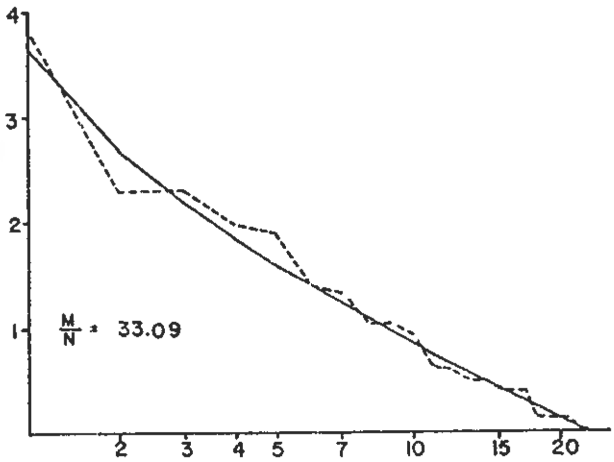

FIGURE 8

In a series of 21 lakes in Denmark for which measurements of annual phytoplankton photosynthesis by radiocarbon uptake are available (Whiteside, 1969), there is a direct relationship between species diversity and transparency and an indirect relationship between species diversity and productivity. There is also an inverse relationship between transparency and productivity. The interpretation of these relationships is that as lakes become more productive, they become less transparent from the development of larger phytoplankton populations, and with higher productivity the chydorid community is thrown out of balance, quite possibly from a reduction of habitat diversity through the curtailment of species diversity and areal extent of the aquatic plants which form the major habitat of the chydorids. And since the chydorids are but one component of a complex community, one can assume that the community as a whole has been stressed by an increase in productivity.

In another study in Denmark, Whiteside (1970) attempted to establish the predictive value of chydorid communities for lake type, and then attempted to use these results in interpreting changes in lake type in postglacial time in response to climate and vegetational patterns of the watersheds. A hard water, eutrophic lake (Esrom Sø) was sufficiently buffered internally that it went placidly about its business during postglacial time almost regardless of external stresses that would be expected to have repercussions on the system, whereas a soft water, oligotrophic lake (Grane Langsø) reacted nervously to even small external stresses. Thus, the response to a given stress can be expected to vary greatly from lake to lake depending on its particular suite of ecological conditions and balances.

The MacArthur predictive model has been used to assess community stresses resulting from the rapid climatic change of the last interstadial (Goulden, 1969a), from episodes of Mayan agriculture in Central America (Goulden, 1966), and from volcanic ash falls in a lake in Japan (Tsukada, 1967). The last study (Figure 9) is interesting in showing that a single instantaneous but massive perturbation, as from an ashfall, can have marked and long-lasting effects on the community structure of a lake.

There are quite a few other studies on the responses of lakes to stresses that might be cited, but I should like to give just one more. The paleolimnology of North Pond in northwestern Massachusetts is being studied intensively by Tom Crisman, a graduate student at Indiana University. Many major changes, almost as precipitous as those in Grosser Plöner See, occurred in the lake shortly after the pine forest represented by pollen zone B was replaced by deciduous hardwoods. Productivity in the lake, as evidenced by the quantity of chlorophyll derivatives in the sediments, increased dramatically at that time, along with nitrogen and phosphorus. A species of planktonic Cladocera, *Bosmina coregoni*, which is usually considered characteristic of more oligotrophic situations, was replaced almost instantaneously by *Bosmina longirostris*, characteristic of more eutrophic situations (Figure 10). Since there is no clear evidence for any major fluctuation in water level and since it is unlikely the Amerindians could have modified the watershed to any appreciable extent, the only correlate and possible cause is the shift in forest composition. But this is difficult to reconcile with the data, because watershed studies to date have demonstrated that deciduous forests are more parsimonious than coniferous forests in releasing nutrients from the system.

Let me attempt to summarize some of the major points developed. Lakes change biologically during their existence from changing inputs of nutrients and energy and from changing internal control mechanisms, associated in part with stratification and depletion of oxygen content in deep water. The biological changes in many instances have been gradual, although in others they have been sudden, associated with natural catastrophes, major changes in water level, or even changes in the dominant vegetation type in the watershed.

Lakes vary in their sensitivity to external stress and in their rapidity and magnitude of response. Man's chief impact is to stress the systems so severely that they are thrown out of balance and the

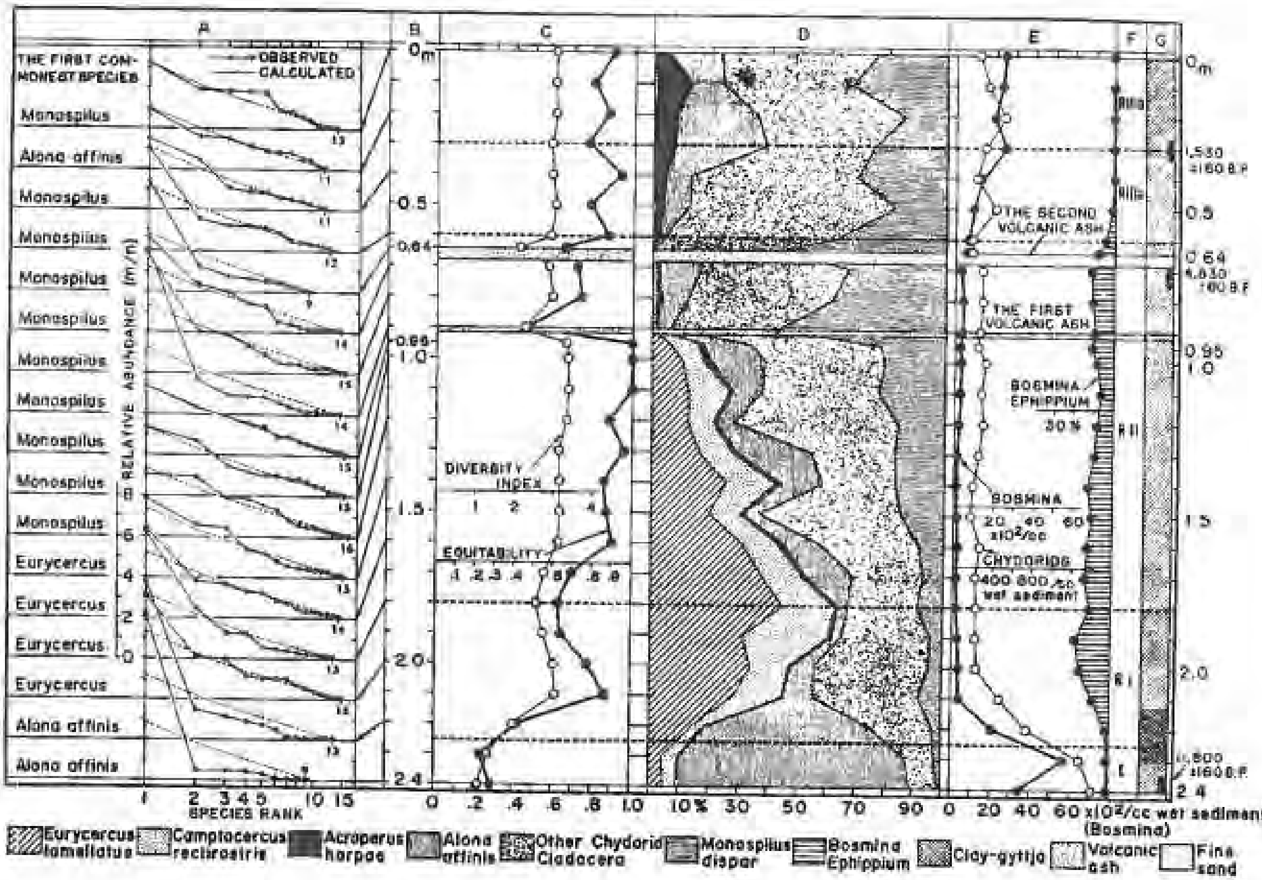

FIGURE 9

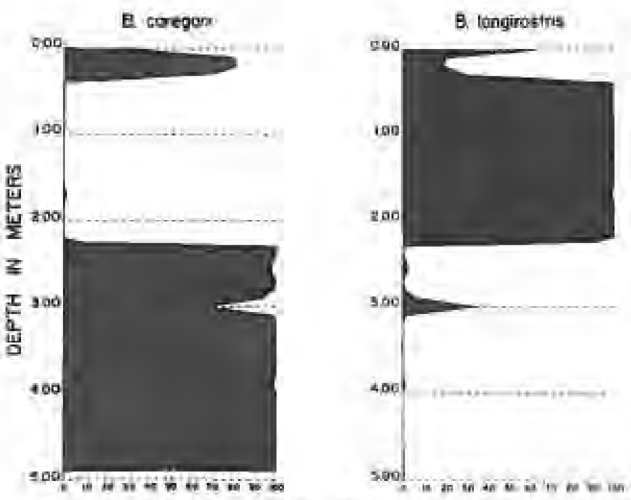

FIGURE 10

rate of change is accelerated—what Ohle calls "rasante Eutrophierung." Both for natural and man-induced stresses, the response of the total system may be fast or slow, and likewise the rate of recovery. The lag may be considerably greater than predicted from the water replacement time, amounting to hundreds of years even in small lakes if our examples from the past have been correctly interpreted. Hopefully, the response time, particularly of recovery, will be fairly short, but faced with the unpredictability of the response time, we should be much more solicitous about the stresses placed on our lakes, as even with massive engineering input they may not recover as rapidly as hoped.

Eutrophication occurs naturally, but so does the contrary process of oligotrophication. That is, a lake can become less productive with time, if its nutrient budget is decreased. Paleolimnology has not yet been able to resolve what the major controls of productivity have been in the past for any particular lake, except by inference from our knowledge of present controls. But since phosphorus, more than any other single substance, is the dominant control of productivity in temperate lakes, it is essential to keep phosphorus inputs at a minimum if we are to have any hope at all of maintaining the integrity of our lakes.

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DISCUSSION

Comment: Your definition of the integrity of water seems to be the capability of maintaining and supporting a composition of organisms that can exist in its natural state. In your discussion you described varying natural states and change of process. How does that translate to a useful definition today?

Dr. Frey: We had an example a couple of weeks ago when two young Ph.D.'s who were modeling ecosystems gave seminars at Indiana University. They had linear models which didn't allow for any change over time. However, in any particular lake there will be changes over time, induced by changes in climate and vegetation, soil development, and so forth. The response of the aquatic community to these changes will probably be adaptive adjustments in species composition and in the relative abundance of species, controlled in part by the mobility of the species. I think a definition of integrity has to include the concept of a balanced, integrated, adaptive community.

Comment: Did you go into these?

Dr. Frey: No, they are objectives.

Comment: Have you made any comparisons with other organisms over an historical period? Would you be able to use changes in the plankton population to detect changes in the water, as you pointed out is possible with fish populations? Would the changes be subtle or quite apparent?

Dr. Frey: I didn't go into any of the long term studies, because even the best of these are less than 100 years old. I know, for example, that there are records for the Chicago water supply which document the kinds and quantities of plankton in southern Lake Michigan over many decades. Probably the longest and most nearly continuous record of all is that for Lake Zürich in Switzerland. Here the deepwater sediments have been accumulating as discrete annual layers since the late 1800's. As the lake became more eutrophic under man's influence, various species of algae invaded the lake and developed to bloom proportions. These are documented by studies of the plankton. Significantly, the blooms of the various species, particularly the diatoms, are also recorded in the appropriate annual layers, so that Lake Zürich constitutes to some extent a calibration system for the interpretation of real events and changes in a lake from what is recoverable from the sediments.

Most of these long term data series have been reported elsewhere at various times. I didn't attempt to summarize them, but instead concentrated on the kinds of interpretations that can be made from the sedimentary record.

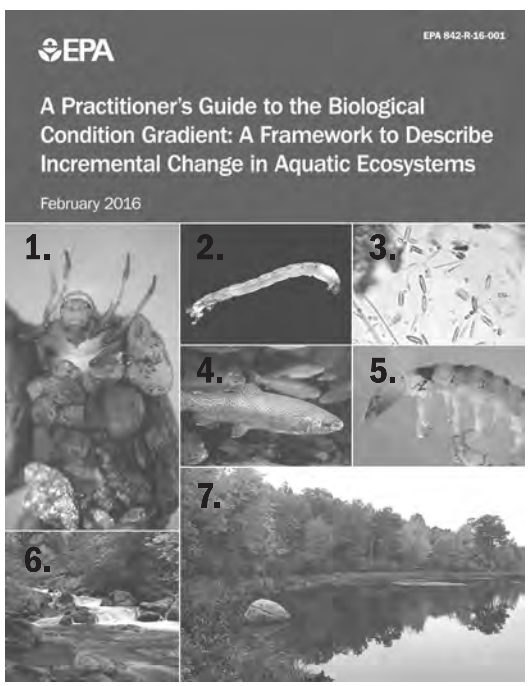
Comment: I'd like to ask you a philosophical question stemming from your definition of integrity. In your opinion, are efforts to reverse a naturally occurring trend toward eutrophication counter to the integrity of that lake?

Dr. Frey: I had to leave out a number of pages of my prepared text because of time limitations (but these are included in the published paper). For the chydorid cladocerans, which are well represented in lake sediments, the species diversity of the community declines as the productivity of the lake increases, indicating that the system is being stressed. This should not be interpreted to mean that all productive lakes are out of balance because the rate of change is probably the important consideration. Where the increased productivity is the result of man or of some essentially instantaneous event such as a volcanic ash fall, the rate of change in nutrient budgets or other environmental conditions is so great that the community cannot keep pace with orderly and adaptive adjustments. But where the forcing variables change slowly over time the aquatic biota is able to maintain an internal balance. Hence, I am in favor of either reversing the trend toward increasing productivity in our natural waters, except where this is specifically desired, or at least sufficiently reducing the rate at which eutrophication is occurring so that the system is not stressed unduly.

EPA 842-R-16-001

A Practitioner's Guide to the Biological Condition Gradient: A Framework to Describe Incremental Change in Aquatic Ecosystems

February 2016



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A Practitioner's Guide to the Biological Condition Gradient: A Framework to Describe Incremental Change in Aquatic Ecosystems

Contact Information

For more information, questions, or comments about this document, please contact Susan Jackson, U.S. Environmental Protection Agency, at Office of Science and Technology, Office of Water, U.S. Environmental Protection Agency, 1200 Pennsylvania Avenue, Mail Code 4304T, Washington, DC 20460 or by email at jackson.susank@epa.gov.

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Contributing Authors

Susan Jackson, USEPA Office of Water, Office of Science and Technology, Washington, DC
Jeroen Gerritsen, PhD, Tetra Tech, Inc., Owings Mills, Maryland
Susan Davies, Midwest Biodiversity Institute, Columbus, Ohio[*]
Lucinda Johnson, PhD, Associate Director and Senior Research Associate, Natural Resources Research Institute, University of Minnesota Duluth, Minnesota

Appendix B Case Study Authors

B1. *Upper Mississippi River: Development of a Biological Condition Gradient for Fish Assemblages of the Upper Mississippi River and a "Synthetic" Historical Fish Community*
Ed Rankin, Midwest Biodiversity Institute, Columbus, Ohio

B2. *Narragansett Bay: Development of a Biological Condition Gradient for Estuarine Habitat Quality*
Emily Shumchenia, PhD, E&C Enviroscape, LLC; Giancarlo Cicchetti, PhD, and Marguerite C. Pelletier, PhD, USEPA Office of Research and Development, National Health and Environmental Effects Research Laboratory–Atlantic Ecology Division, Narragansett, Rhode Island

B3. *Caribbean Coral Reefs: Benchmarking a Biological Condition Gradient for Puerto Rico Coral Reefs*
Patricia Bradley[**] and Deborah Santavy, PhD, USEPA Office of Research and Development, National Health and Environmental Effects Research Laboratory–Gulf Ecology Division, Gulf Breeze, Florida

B4. *New England: Using the Biological Condition Gradient and Fish IBI to Assess Fish Assemblage Condition in Large Rivers*
Chris Yoder, Research Director, Midwest Biodiversity Institute, Columbus, Ohio

Technical Editors

Susan B. Norton, PhD, USEPA Office of Research and Development, National Center for Environmental Assessment, Alexandria, Virginia
Douglas Norton, USEPA Office of Water, Office of Wetlands, Oceans and Watersheds, Washington, DC
Clair Meehan, Tetra Tech, Inc., Fairfax, Virginia

[*] Formerly with the Maine Department of Environmental Protection and state co-chair for the expert workgroup that developed the conceptual Biological Condition Gradient Framework. See Davies and Jackson 2006.

[**] Patricia Bradley retired from USEPA in October 2015. Since that time, she has joined Tetra Tech, Inc.

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State, Territorial, and Tribal BCG Workgroup Members and Pilots (2000–2015)
Alabama Department of Environmental Management – Lisa Huff
Alabama Geological Survey – Patrick O'Neill
Arizona Department of Environmental Quality – Patti Spindler
California Department of Fish and Game – Jim Harrington
Colorado Department of Public Health and Environment – Robert McConnell, Paul Welsh
Connecticut Department of Energy and Environmental Protection – Chris Bellucci
Florida Department of Environmental Protection – Russ Frydenborg, Ellen McCarron, Nancy Ross
Idaho Department of Environmental Quality – Mike Edmondson
Kansas Department of Health and Environment – Robert Angelo, Steve Haslouer, Brett Holman
Kentucky Department for Environmental Protection – Tom VanArsdall
Maine Department of Environmental Protection – David Courtemanch, Susan Davies, Leon Tsomides, Tom Danielson, Jeanne DeFranco
Maryland Department of the Environment – Richard Eskin, George Harmon, Matthew Stover
Maryland Department of Natural Resources – Scott Stranko
Minnesota Pollution Control Agency – Will Bouchard, Greg Gross
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New Jersey Department of Environmental Protection – Kevin Berry, Thomas Belton
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North Carolina Department of Environment and Natural Resources – David Lenat, Trish MacPherson
Ohio Environmental Protection Agency – Jeff DeShon, Dan Dudley
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*** Affiliations of each individual are those at the time of participation in the BCG development and/or pilots. Since that time, a number of these individuals have changed affiliations or have retired.

U.S. Environmental Protection Agency
Office of Water: Chris Faulkner, Thomas Gardner, Susan Holdsworth, Susan Jackson, Kellie Kubena, Douglas Norton, Christine Ruff, Robert Shippen, Treda Grayson, William Swietlik, Lester Yuan

Regional (R) Offices: Peter Nolan, Margherita Pryor, Hilary Snook, Diane Switzer (R1), Jim Kurtenbach, Thomas Belton, Eveylyn Huertas, David Cuervas (R2), Maggie Passmore, Gregory Pond, Louis Reynolds (R3), Ed Decker, Jim Harrison, David Melgard, Eve Zimmerman (R4), Ed Hammer, David Pfeifer (R5), Philip Crocker, Charlie Howell (R6), Gary Welker (R7), Tina Laidlaw, Jill Minter (R8), Gary Wolinsky, Terry Fleming (R9), Gretchen Hayslip (R10)

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Charles Hawkins, Utah State University
Donald Huggins, Central Plains Center for Bioassessment
Bob Hughes, Oregon State University
Lucinda Johnson, University of Minnesota Duluth
James Karr, University of Washington
Dennis McIntyre, Great Lakes Environmental Center
Gerald Niemi, University of Minnesota
Jan Stevenson, Michigan State University
Denice Wardrop, Pennsylvania State University
Edward Rankin and Chris Yoder, Midwest Biodiversity Institute

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Executive Summary

The Clean Water Act (CWA) established a long-term objective to restore and protect the biological integrity of the nation's waters. In the more than 40 years since the passage of the CWA, there has been considerable progress in the science of aquatic ecology and in the development of biological monitoring and assessment techniques to support implementation of the Act. The U.S. Environmental Protection Agency (EPA) published its first guidance document on biological assessments and criteria in 1990. Since then, aquatic science and its application in state water quality programs has advanced significantly. States, territories, and authorized tribes (herein identified as "states") now routinely use biological information to directly assess the biological condition of their aquatic resources, track changes in their condition, and develop biological criteria to set expectations for maintaining biological integrity.

This document is designed for scientists engaged in biological assessments of water bodies. It outlines a conceptual framework, the Biological Condition Gradient (BCG), for states to use to more precisely define and interpret baseline biological conditions, help evaluate potential for improvement in degraded waters, and measure and document incremental changes in condition along a gradient of anthropogenic stress. The conceptual framework can be populated with state or regional data to develop a quantitative model and establish numeric thresholds. The BCG is intended to complement existing biological assessment and criteria methods and approaches.

What is the Biological Condition Gradient?

The BCG is a conceptual, scientific framework for interpreting biological response to increasing effects of stressors on aquatic ecosystems. The framework was developed based on common patterns of biological response to stressors observed empirically by aquatic biologists and ecologists from different geographic areas of the United States. Scientists from 21 states, one interstate basin association, and one tribe were involved in BCG development, in addition to scientists from EPA, the U.S. Geological Survey, universities, and the private sector. The framework describes how 10 characteristics of aquatic ecosystems change in response to the increasing levels of stressors, from an "as naturally occurs" condition (e.g., undisturbed/minimally disturbed condition) to severely altered conditions. The characteristics, defined in this document as "attributes," include aspects of community structure, organism condition, ecosystem function, and connectivity. The BCG framework can be considered analogous to a field-based dose-response curve where the dose (x-axis) represents increasing level of anthropogenic stress, and the response (y-axis) represents biological condition.

Who Will Use the Biological Condition Gradient and For What Purpose?

Currently most states are using biological assessment information to support their water quality management programs. The BCG contributes to the EPA biological assessment and criteria "toolbox," which includes biological indices, models, statistical approaches, and guidance. The BCG builds upon and complements these approaches to provide a more refined and detailed measure of biological condition and can help water quality management programs to:

- More precisely define and measure biological condition for specific waters;
- Identify and protect high quality waters;
- Evaluate potential for improvement in degraded waters;
- Track changes in condition;

- Develop biological criteria; and
- Clearly communicate the likely impact of water quality management decisions to stakeholders.

These applications support CWA programs such as 305(b) assessments and reports, 303(d) listing of impaired waters, and the Total Maximum Daily Load program implementation. The document includes examples of how states are using, or are considering using, the BCG to support their water quality management programs.

Why Now?

As the first BCG projects have been completed, there has been increasing interest in the BCG by other state water quality management programs. Based on informal discussion with state water quality managers and scientists who have been directly engaged in BCG development, their primary motivation for using a BCG has been to more precisely define baseline conditions, better understand the quality of their reference sites, identify high quality waters as candidates for additional protection, help evaluate the potential for restoration of degraded waters, and document incremental improvements as best management practices are implemented. In all cases, the states have emphasized the value of the BCG to help communicate to the public the biological condition of their waters in context of the CWA integrity objectives and the likely outcomes of water quality management decisions.

Because of the interest in BCGs, it is important now to document the status of model development, discuss current strengths and limitations, and provide examples of how states are developing and applying the BCG. This document provides a template and step-by-step process for constructing robust BCGs, drawing from the lessons learned during a decade of testing by interstate, state, territorial, and local government water quality management programs. As BCG development and calibration continues, it is expected that the BCG process will be refined and improved.

Biological Condition Gradient Development: Decision Rules

This document describes the steps that entail convening an expert panel in order to construct narrative descriptions and quantitative rules for assigning sites to BCG levels. Different approaches to developing quantitative rules are discussed (e.g., mathematical set theory, derivation and calibration of biological indices, and multivariate statistical and/or predictive modeling approaches). The core objective of the panel process is to elicit expert judgment on defining ecologically significant change in the biotic community and to document the underlying rationale for the judgments. By using a process to elicit expert judgment, first narrative and then quantitative rules emerge and are tested and refined based on the current state of the science, expert knowledge, and available data. The intended end product is a set of well-vetted and transparent decision rules that can be readily understood and implemented by state water quality program managers and scientists. Routine use of a quantitative BCG model by state water quality management programs requires well documented and transparent decision rules so that assessments can be made for newly sampled water bodies without reconvening the expert panel.

Specifically, the document presents:

- An approach to quantify the conceptual BCG framework and develop a numeric model. This approach is based on elicitation of the experts' decision criteria and incorporation those of criteria into a numeric decision model using a mathematical set theory approach (e.g., fuzzy logic). This approach has been tested and refined in most of the BCG projects to date.

- Considerations and approaches for relating the BCG with the state's existing biological assessment methods and tools such as multimetric biological indices. To date, most states have developed biological indices.
- An example of a state approach to quantify the conceptual BCG. This approach involves development of statistical models that predict (or simulate) the expert decisions and may or may not use elicited expert reasoning or rules.

Building on these initial efforts, it is expected that additional methods to quantify the conceptual BCG will be identified and tested.

The Stress Axis

The x-axis of the BCG framework, the Generalized Stress Axis (GSA), conceptually describes the range of anthropogenic stress that may adversely affect aquatic biota in a particular area. It is a theoretical construct. As multiple stressors are usually present in a system, the GSA seeks to represent the cumulative stress that may influence biological condition. Typically, states have defined a stress gradient using single or a combination of known, measurable stress gradients that in reality represent a portion of the stressors impacting a water body. The conceptual GSA provides a framework to assist in development of as comprehensive and robust a quantitative stress gradient as possible to support BCG development. A well-defined, quantitative GSA, and the underlying data used to develop it, may serve as a nexus between biological and causal assessments, thereby linking management goals and selection of management actions for protection or restoration. However, a systematic testing of technical approaches to define and apply a GSA to BCG development has not been conducted. This document discusses technical issues to consider and provides examples of approaches to quantify a GSA. Opportunities in the future may include piloting methods for application of national, regional, or basin scale databases and methods to support state efforts to quantify a GSA for a specific geographic region and water body type.

Document Organization

Chapters 1 and 2 explain the purpose and scientific underpinnings of the BCG. Chapters 3 and 4 present methods on how to define and quantify the BCG biological axis, the biological levels of condition that span undisturbed to severely altered conditions. Chapter 5, supported by Appendix A, provides an overview, framework, and examples to describe the stress axis of the BCG model, the GSA. Examples of how states have developed and applied the BCG are presented in Chapter 6. To date, use of the BCG to support water quality management has primarily been for fresh water, perennial streams. However, work underway is presented in Appendix B on BCG development for large rivers, estuaries, and coral reefs.

Chapter 1. Introduction to the Biological Condition Gradient

1.1 Document Purpose

The Clean Water Act (CWA) established a long-term objective to, among other things, restore and protect the biological integrity of the nation's waters (Figure 1). In the more than 40 years since the passage of the CWA, there has been considerable progress in the science of aquatic ecology and in the development of biological monitoring and assessment techniques to support implementation of the Act (USEPA 2011a, 2013a). Since the U.S. Environmental Protection Agency (EPA) published its first guidance document on biological assessments and criteria, aquatic science and its application in state water quality programs has advanced (USEPA 1990, 2002, 2011a, 2013a). States, territories, and authorized tribes (herein referred to as "states") now routinely use biological information to directly assess the condition of their aquatic resources, track changes in biological condition, and develop biological criteria to set expectations for maintaining biological integrity.

Figure 1. Stream and wadeable river.

Under the CWA, states have the primary authority to implement their water quality programs with EPA review for consistency with the CWA requirements, which include implementing regulations. As a consequence, states have independently developed technical approaches to assess biological condition and establish thresholds (Hawkins 2006; USEPA 2002). Although these different approaches have fostered innovation, they have complicated a nationally consistent approach to interpreting the condition of aquatic resources. A consistent approach to interpreting biological condition will allow scientists, water resource managers, and stakeholders to share a common understanding and language to describe the condition of their waters, as well as share data and information across jurisdictional boundaries (Davies and Jackson 2006).

In addition to using a variety of approaches for assessing and interpreting biological condition, states have created a range of different aquatic life use (ALU) classes to describe the expected biological condition of their waters. At one end of the spectrum, states have adopted a general narrative statement that replicates the ALU goal identified in the CWA (e.g., protection and propagation of fish, shellfish, and wildlife). At the other end are more detailed approaches that describe the expected species, assemblages, or habitats (e.g., salmonids, warmwater habitat, coldwater fisheries) or that specify levels of condition (e.g., excellent, good, fair). Currently, most states have established one general ALU class, with a single threshold for assessing attainment. A limitation of a single ALU class is that the full range of biological conditions along a human disturbance gradient is limited to only two categories: pass and fail. Water bodies assigned to a single ALU class could include a range of biological conditions found in undisturbed to moderately disturbed landscapes, or, in some cases even include highly disturbed conditions where anthropogenic impacts are widespread and pervasive. As a result, a water body supporting biological conditions characteristic of higher quality waters could degrade to a lower level of water quality yet still be categorized as meeting its ALU. In contrast, for water that is severely degraded, the designated ALU might not be achievable in the short term, and therefore incremental improvements due to management actions will not be measured or acknowledged. A scientific framework that describes incremental biological changes along the full gradient of human disturbance helps water quality managers identify and protect high quality waters and track incremental improvements in degraded waters.

This document outlines a conceptual framework, the Biological Condition Gradient (BCG), that states can use to more precisely describe existing, or baseline, biological condition; help evaluate potential for improvement in condition; and measure incremental changes in condition along a gradient of human disturbance, i.e., anthropogenic stress. The conceptual framework can be populated with state or regional data to develop a quantitative model. It is intended to complement existing biological assessment and criteria methods and approaches.

This document reports on the current status of quantitative model development and application. As BCG development and calibration continues, it is expected that the BCG process will be further refined and improved.

1.2 Background: When and Why?

In 2000, EPA convened a technical expert workgroup to identify scientifically sound and practical approaches that would help states use biological assessments to better determine existing conditions and potential for improvement, more precisely define ALUs, and develop biological criteria. The workgroup consisted of scientists from federal, state, and tribal water programs, an interstate basin association, the academic research community, and the private sector (see Davies and Jackson 2006 for a list of workgroup members). The overarching objective of this effort was to develop a common framework and language for interpreting biological condition. In the subsequent four years, the workgroup met annually with drafts of the framework undergoing review and preliminary testing between meetings. The effort was primarily guided by the practical experience of scientists and water quality program managers from the 21 states, the interstate basin association and tribe participating in the workgroup. The workgroup developed the conceptual BCG framework to describe levels, or tiers, of biological response to increasing levels of stressors. The conceptual BCG was developed and tested through a series of data exercises using a diverse array of data sets with initial focus on freshwater perennial streams and wadeable rivers.

The workgroup activities coincided with a National Research Council (NRC) review of EPA's Total Maximum Daily Load (TMDL) program and publication of its report *Assessing the TMDL Approach to Water Quality Management* (NRC 2001). Among other recommendations, the NRC recommended the use of biological assessments to better understand water quality and the establishment of a more precise, descriptive approach to goal-setting as a step towards improving decision making and establishing appropriate ALU goals. For example, rather than stating that a water body needs to be "fishable," the ALU would ideally describe the expected fish assemblage or population (e.g., salmonid, coldwater fishery, warmwater fishery), as well as the other biological assemblages necessary to support that fish population. Additionally, levels of expected condition would be defined based on potential of a water body to achieve a higher level of condition (e.g., salmonid spawning versus migration; undisturbed and minimally disturbed conditions versus moderately or highly disturbed). The NRC recommendation to more precisely define designated ALUs was taken into account by the BCG workgroup as they developed the BCG framework. Since completion of the conceptual BCG framework (Davies and Jackson 2006), many states have further developed and refined quantitative BCG models (see Table 4, Chapter 3). In conjunction with other water quality management technical tools, the state programs that have developed and applied the BCG have done so to help:

- Set scientifically defensible, ecologically-based aquatic life goals based on existing conditions and potential for improvement;
- Determine baseline conditions and measure impacts of multiple stressors or system altering conditions (e.g., climate change) on aquatic life;
- Further the use of monitoring data for the assessment of water quality standards (WQS) and tracking changes in biological condition;
- Identify high quality waters for protection (e.g., Tier III antidegradation); and
- Communicate to stakeholders the likely impact of decisions on protection and management of aquatic resources.

When asked about the most immediate, value-added benefits to their water quality management programs from the development of a quantitative BCG model, state water quality program managers and scientists cited the ability to measure and document incremental improvements due to management actions and better identify and protect high quality waters.

The BCG conceptual framework, quantitative model development, and implementation reflects an improved understanding of aquatic ecosystems and their biota resulting from more than 40 years of assessment data and advances in use of these data in state water quality management programs. This document represents the culmination of four years of workgroup deliberations, including four workgroup meetings and two workshops to "road test" the conceptual BCG framework, followed by ten years of development and application of quantitative BCG models in state programs. Over the past ten years, the BCG has been developed for perennial streams, including headwater streams, using expert consensus to develop narrative and numeric decision rules to assign sites to BCG levels. The use of the BCG to complement or refine existing state measures such as Indices of Biotic Integrity (IBIs) is being explored. Application of the BCG to water bodies other than perennial streams is underway for large rivers, estuaries, and coral reefs. These latter efforts show promise for expanding the application of the BCG beyond streams to more complex systems.

1.3 The Biological Condition Gradient: Brief Overview

The conceptual BCG is a scientific framework for interpreting biological response to increasing effects of stressors on aquatic ecosystems (Figure 2). The framework was developed based on common patterns of biological response to stressors observed empirically by aquatic biologists and ecologists from different geographic areas of the United States (Davies and Jackson 2006). It describes how characteristics of aquatic ecosystems that are typically measured by state water quality management programs change in response to increasing levels of stress (see Table 1). The characteristics, defined as attributes, include properties of the communities (e.g., tolerance, rarity, native-ness) and organisms (e.g., condition, function) and are more fully described in Chapter 2.

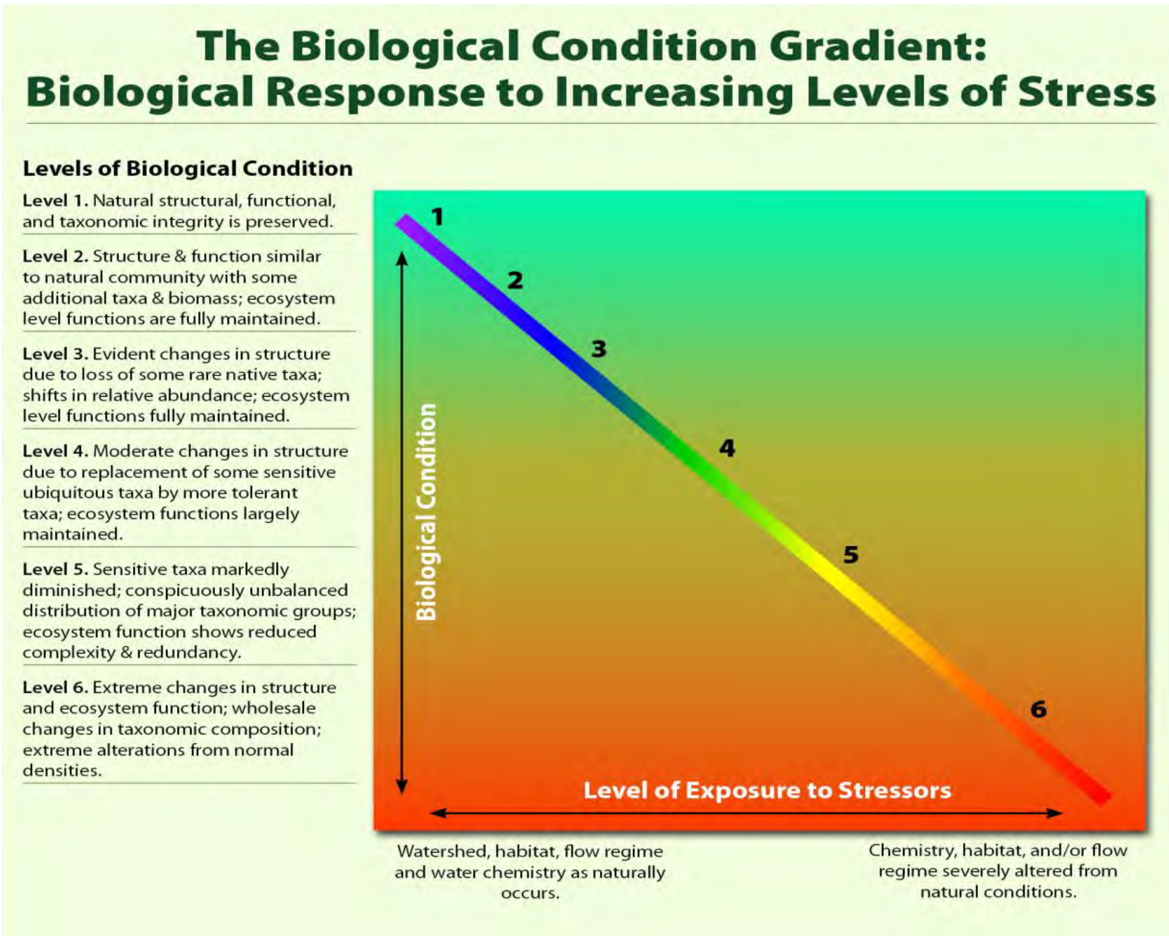

Figure 2. Conceptual model of the BCG. Although in reality the relationship between stressors and their cumulative effects on the biota is likely nonlinear, the relationship is presented as such to illustrate the concept.

The BCG can be considered analogous to a field-based dose-response curve where the dose (x-axis) represents increasing levels of stressors, and the response (y-axis) represents biological condition. Stressors are physical, chemical, or biological factors that induce an adverse response from aquatic biota (USEPA 2000b). For example, high concentrations of certain metals, nutrients, or sediment can adversely impact, or stress, aquatic biota. Loss of suitable aquatic habitat or presence of aquatic invasive species can also adversely impact the aquatic biota expected for a specific water body. These stressors can cause aquatic ecosystems to change from natural conditions and exhibit altered compositional, structural, and functional characteristics. The degree to which stressors affect the biota depends on the magnitude, frequency, and duration of the exposure of the biota to the stressors. Developing a BCG for a given system characterizes the general relationship between its stressors in total and a water body's overall biological condition. Multiple stressors are usually present, and thus, the stress x-axis of the BCG seeks to represent their cumulative influence as a Generalized Stress Axis (GSA),[1] much as the y-axis generalizes biological condition. The x and y axes of the BCG serve as a framework to organize, relate, and help reconcile the mosaic of factors and interactions that exist, parts of which will be characterized and measured using biological, chemical, physical, and/or land use/land cover indicators.

Table 1. Ecological characteristics (i.e., attributes) used to develop the BCG

Attribute	Description
I	Historically documented, sensitive, long-lived, or regionally endemic taxa
II	Highly sensitive taxa*
III	Intermediate sensitive taxa
IV	Intermediate tolerant taxa
V	Tolerant taxa
VI	Non-native or intentionally introduced species
VII	Organism condition
VIII	Ecosystem function
IX	Spatial and temporal extent of detrimental effects
X	Ecosystem connectance

*Note: Identified as *Sensitive-rare taxa* in Davies and Jackson 2006.

The BCG differs from the standard dose-response curve in that the BCG does not represent the laboratory response of a single species to a specified dose of a known chemical, but rather the *in-situ* response of the resident biotic community to the sum of stressors to which that community is exposed. Thus, it is an outcome-based measure and something that can express complex water quality goals such as biological integrity. In this document EPA proposes a BCG that is divided into six levels of biological condition along a generalized stressor-response curve, ranging from observable biological conditions found at no or low levels of stressors (level 1) to those found at high levels of stressors (level 6). States may propose to consolidate or aggregate these levels into fewer levels or further refine and increase the number of levels. Regardless of how many levels a quantitative BCG may ultimately include, it can be crosswalked with the conceptual model. Chapter 6 and Appendix B illustrate examples of ecoregional or state-specific BCGs and how they may be "mapped" onto the conceptual BCG.

Between 2000 and 2005, the original framework was tested at annual workgroup meetings and then at two regional workshops in the Great Plains and in the Arid Southwest. It was tested by determining how consistently the scientists assigned samples of benthic macroinvertebrates or fish to the different levels

[1] For more information on the Generalized Stress Axis, see Chapter 5.

of biological condition in freshwater streams. Workgroup members identified similar sequences of biological response to increasing levels of stressors regardless of geographic area and predicted that the framework in principal should be applicable to other water body types. These results support the development and application of the BCG as a nationally applicable framework for interpreting the biological condition of aquatic systems (Davies and Jackson 2006).

Understanding the links between stressors (and their sources) with the response of the aquatic biota will help water quality managers to more accurately determine both the existing and potential conditions of the aquatic biota in a specific water body and help predict the stressors that affect that condition (Figure 3). This information will assist water quality program managers in determining the most effective recourse to address biological impairment. There are different approaches and new studies, methods, and large data sets that can assist states to better define and quantify the causal sequence between stressors and their sources and biological responses once biological impairment is identified.[2] Ultimately, the goal of the EPA biological criteria program is to build a stronger technical bridge between biological condition assessments, causal assessments, and the actions taken to protect and restore biological condition. A well-defined BCG x-axis, the GSA, and the science underlying it may help achieve this objective. In Chapter 5, information on approaches and technical challenges to define the GSA are discussed, with examples of a conceptual GSA framework and potential stress indicators included in Appendix A.

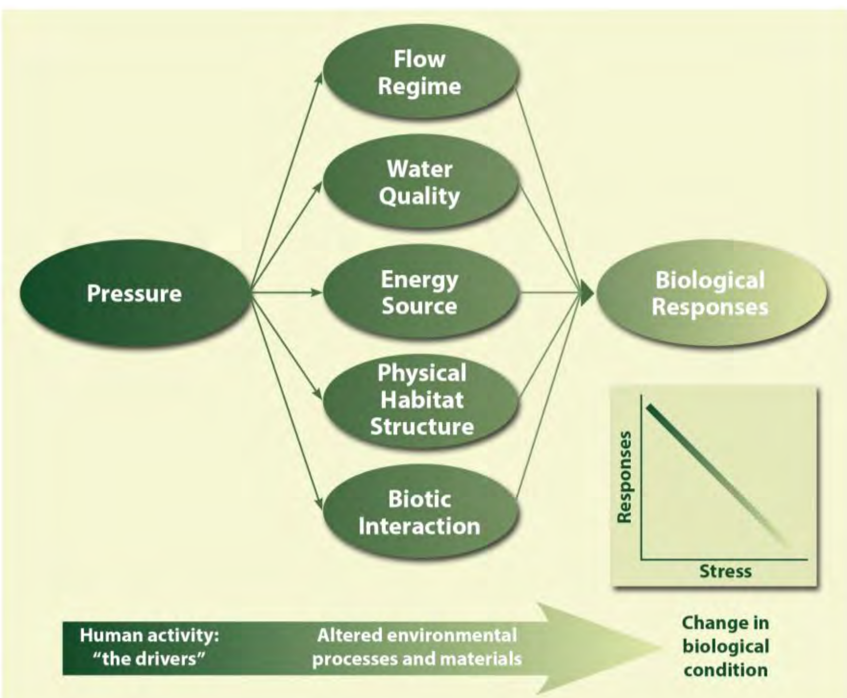

Figure 3. Model illustrating the multiple pathways through which human activities may exert pressure on an aquatic system by altering fundamental environmental processes and materials, creating stressors that may adversely affect the aquatic biota (Source: Modified from figure courtesy of David Allen, University of Michigan).

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[2] See http://www3.epa.gov/caddis/ and http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/recovery/overview.cfm. Accessed February 2016.

1.4 Use of the Biological Condition Gradient to Support Water Quality Standards and Condition Assessments

The full objective of section 101(a) of the CWA is to restore and maintain the chemical, physical, and biological integrity of the Nation's waters. In the scientific literature, an aquatic system with chemical, physical, and biological integrity has been described as being capable of "supporting and maintaining a balanced, integrated, adaptive community of organisms having a composition and diversity comparable to that of the natural habitats of the region" (Frey 1977).

Over the intervening years, the understanding of how to define and measure the integrity of aquatic systems has advanced considerably. The term "integrity" has been further refined in the literature to mean a balanced, integrated, adaptive system having a full range of ecosystem elements (e.g., genera, species, assemblages) and processes (e.g., mutation, demographics, biotic interactions, nutrient and energy dynamics, metapopulation dynamics) expected in areas with no or minimal human disturbance (Karr 2000). The aquatic biota residing in a water body are the result of complex and interrelated chemical, physical, and biological processes that act over time and on multiple scales (e.g., instream, riparian, landscape) (Karr et al. 1986; Yoder 1995). By directly measuring the condition of the aquatic biota, one is able to more accurately define the aquatic community that is the outcome of all these factors.

To help achieve the integrity objective, the CWA also established an interim goal for the protection and propagation of fish, shellfish, and wildlife and recreation in and on the water. EPA has interpreted the "protection and propagation" interim goal for aquatic life to include the protection of the full complement of aquatic organisms residing in or migrating through a water body. As explained in EPA's *Water Quality Standards Handbook* (USEPA 2014a), the protection afforded by WQS includes the representative aquatic community (e.g., fish, benthic macroinvertebrates, and periphyton):

> The fact that sport or commercial fish are not present does not mean that the water may not be supporting an aquatic life protection function. An existing aquatic community composed entirely of invertebrates and plants, such as may be found in a pristine tributary alpine stream, should be protected whether or not such a stream supports a fishery. Even though the shorthand expression 'fishable/swimmable' is often used, the actual objective of the Act is to restore the chemical, physical and biological integrity of our Nation's waters (section 101(a)). The term 'aquatic life' would more accurately reflect the protection of the aquatic community that was intended in section 101(a)(2) of the Act.

The representative community of aquatic organisms residing in, or migrating through, a water body will vary depending on the water body type. For example, fish, benthic macroinvertebrates, and periphyton are aquatic assemblages measured by states and tribes when assessing the biological condition of most streams and rivers. However, in headwater streams and many wetlands, amphibians are an important component of the biotic community, and fish may be absent. Large river and estuarine assessments typically include both benthic invertebrates and fish community measures. In coral reefs, coral, sponge, and fish communities are key assemblages to measure and assess. The BCG offers a framework to provide more detailed and descriptive statements of the aquatic community expected in an undisturbed or minimally disturbed aquatic community, as well as potential incremental changes that might be expected in community characteristics with increasing levels of anthropogenic stress.

1.4.1 Use of the Biological Condition Gradient to Support Aquatic Life Use Assessments

While section 101(a) of the CWA establishes the objective to restore and maintain the chemical, physical, and biological integrity of the nation's waters, other sections of the CWA establish the programs and authorities for implementation of this objective. Section 303(c) provides the basis of the WQS program. WQS are components of state (or, in certain instances, federal) law that define the water quality goals of a water body, or parts of a water body, by designating the use or uses of the water body and by setting criteria necessary to protect the uses (in addition to antidegradation requirements).

Although the CWA gives EPA an important role in determining appropriate minimum levels of protection and providing national oversight, it also gives considerable flexibility and discretion to state water quality managers to design their own programs and establish levels of protection above the national minimums. CWA section 303 directs states to adopt WQS to protect the public health and welfare, enhance the quality of water, and serve the purposes of the CWA. "Serve the purposes of the Act" (as defined in sections 101(a), 101(a)(2), and 303(c) of the CWA) means that WQS should include provisions for restoring and maintaining chemical, physical, and biological integrity of state waters; provide, wherever attainable, water quality for the protection and propagation of fish, shellfish, and wildlife and recreation in and on the water (i.e., "fishable/swimmable"); and consider the use and value of state and tribal waters for public water supplies, propagation of fish and wildlife, recreation, agricultural and industrial purposes, and navigation. Further requirements for WQS can be found at 40 *Code of Federal Regulations* (CFR) Part 131.

State WQS provide the foundation for water quality-based pollution control programs. With the public participating in their adoption (see 40 CFR 131.20), such standards serve the dual purposes of (1) establishing the water quality goals for a specific water body and (2) providing the regulatory basis for the establishment of water quality-based treatment controls and strategies beyond the technology-based levels of treatment required by sections 301(b) and 306 of the CWA. The WQS serve as, among other things, the basis for ALU attainment decisions, National Pollutant Discharge Elimination System (NPDES) permit limits, and the targets for TMDLs.[3]

40 CFR Part 131.10(a) of the WQS regulation requires that states specify appropriate water uses to be achieved and protected. A water body's designated uses are those uses specified in WQS, whether or not they are being attained (40 CFR 131.3(f)). *The designated use of a water body is the most fundamental articulation of the water body's role in the aquatic environment as defined by society*. All of the water quality protections established by the CWA follow from the water body's designated use. As designated uses are critical in determining the water quality criteria that apply to a given water body, determining and clearly defining the appropriate designated use is of paramount importance in establishing criteria that are appropriately protective of that designated use. In addition, the regulations establish a rebuttable presumption that the uses of protection and propagation of fish, shellfish, and wildlife and recreation in and on the water are attainable and must apply to a water body, unless it has been affirmatively demonstrated that such uses are not attainable.

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[3] For more information about Water Quality Standards, see the WQS Regulation at http://water.epa.gov/lawsregs/lawsguidance/wqs_index.cfm (Accessed February 2016) and EPA's *Water Quality Standards Handbook* at http://water.epa.gov/scitech/swguidance/standards/handbook/ (Accessed February 2016).

Biological assessments can be effectively used to help subcategorize the ALU designations. For example, states may adopt subcategories of a use and set the appropriate criteria to reflect varying needs of such subcategories of uses to differentiate between coldwater and warmwater fisheries (see 40 CFR 131.10(c)). States may also adopt seasonal uses, such as the use of streams or rivers for migratory or spawning purposes (40 CFR 131.10(f)). One major challenge in assigning designated uses for aquatic life to surface waters is separating the natural differences inherent in aquatic ecosystems and appropriately classifying them by type (e.g., naturally coldwater vs. warmwater streams) and location (e.g., ecoregion) from the differences that result from exposure to anthropogenic stressors. Natural or "naturally occurring" conditions can be interpreted as comparable to the range of physical, biological, and chemical conditions observed in undisturbed to minimally disturbed reference sites (Stoddard et al. 2006). When developed using reference data sets from long term biological monitoring and assessment programs, the boundaries for the upper BCG levels can be described in a narrative form and quantified to document the observed natural conditions. The BCG thus provides a descriptive framework to help biologists and water quality managers interpret their aquatic life goals relative to natural conditions. By more fully accounting for natural differences in aquatic ecosystems, designating more specific ALUs helps to reduce a major source of uncertainty and error in water quality management.

The BCG can be used by state programs not only to develop detailed narrative descriptions of ALU goals in terms of the expected biological community, but also to help develop numeric biological criteria for measuring attainment of the goals (USEPA 1990, 2011a). Water quality *criteria* are elements of state WQS expressed as constituent concentrations, levels, or narrative statements representing a quality of water that supports a particular use. When criteria are met, water quality is expected to protect the designated use (40 CFR 131.3). Once adopted into standards, criteria can serve as the basis for (1) controls on point and nonpoint source pollution concentrations to protect aquatic life, (2) statements of expectations for the condition of aquatic life in a water body, and (3) guidelines helpful in water quality planning (e.g., tracking of cumulative loads of point and nonpoint source pollutants). Biological criteria have been defined as narrative expressions or numeric values of the biological characteristics of aquatic communities based on appropriate reference conditions.

1.4.2 Use of the Biological Condition Gradient to Define Levels of Condition

By designating uses and articulating narrative and numeric criteria, states can establish environmental goals for their water resources and measure attainment of these goals. When designating uses, a state may weigh the environmental, social, and economic consequences of different use designations. Water quality regulations allow the state, with public participation, flexibility in weighing these considerations and adjusting designated uses over time. Clearly defining the uses that appropriately reflect the current and potential future uses for a water body, determining the attainability of those goals, and appropriately evaluating the consequences of a designation can be a challenging task.

A principal function of designated uses in WQS is to communicate the desired condition of surface waters to water quality managers, the regulated community, and the public. For designating ALUs, an effective approach is one that readily and transparently translates narrative biological descriptions of the ALU into quantitative measures, such as biological index values. The index values can be adopted into the WQS as biological criteria and thresholds established for assessing attainment. The indices should respond in predictable ways to stress so that degradation can be detected early and incremental improvements tracked. States that have developed robust biological assessment programs typically strive to distinguish different levels of biological condition. States have either made these levels explicit in their WQS by adopting detailed biological descriptions of ALUs, or they have implicitly done so by recognizing levels of condition in their monitoring protocols for assessing attainment of ALU.

Although the benefits of specificity might apply to any of the designated uses described in CWA section 303, the benefits are particularly relevant for ALUs, because a broad range of biological conditions can be interpreted as supporting an ALU. For example, biological conditions in a minimally disturbed stream in a wilderness area would likely support a biotic community close to what would naturally be expected, whereas the biological condition in a stream in a more developed watershed might be measurably impacted relative to the wilderness stream, the degree of impact dependent upon effectiveness of best management practices (BMPs) that have been implemented. Under non-specific ALU classification with a single ALU threshold, both streams might be judged as meeting the designated ALU, and a threshold might be set that does not protect the higher biological conditions in the wilderness stream from degrading. By specifically articulating ALU goals for systems with different levels of human disturbance, deterioration can be detected and preventive management actions can be triggered earlier in the process prior to serious and irretrievable degradation. The BCG provides a framework for defining management goals and designated uses for water bodies having different levels of biological condition.

Chapter 2. The Biological Condition Gradient: Fundamental Concepts

The BCG is a scientific framework that supports more refined interpretation of biological condition even when assessment approaches may differ. The BCG combines scientific knowledge with the practical observations and experience of biological assessment practitioners (Figure 4) with the needs of resource managers. In conjunction with other environmental data and information, it can be used by environmental practitioners to help:

- Determine the environmental conditions that exist, relative to naturally-derived conditions—The BCG provides a common language with which to interpret and communicate current ecological conditions relative to baseline conditions that are anchored in level 1 of the BCG, "as naturally occurs."
- Decide what environmental conditions are desired—The BCG can be used with expert groups and stakeholders to set easily communicated environmental goals.
- Plan for how to achieve these conditions—The BCG provides a scientific basis for planning, restoration, protection, and monitoring by providing a common language and a pathway to shared quantitative goals.

Figure 4. Biologists conducting stream and lake assessments.

The BCG translates the theoretical and empirical work of researchers and practitioners to create a nationally-applicable model that helps to link management goals for resource condition with the quantitative measures used in biological assessments. As discussed in Chapter 1, the conceptual BCG was developed and tested by an expert workgroup that included scientists from 21 states, an interstate basin association, and a tribe. The BCG was designed to describe ecological response to anthropogenic stressors in sufficient detail so that a site can be placed into a level[4] along the BCG continuum through use of the core data elements collected by most state monitoring programs (USEPA 2013a). This framework can be used to organize biological, chemical, physical, and land cover data and information to interpret changes in assemblage composition and structure, spatial and temporal size of disturbance, and declines in function and connectivity relative to a baseline of undisturbed or minimally disturbed conditions.

[4] A full description of the BCG levels is provided in section 2.3.

The BCG provides an interpretative framework explicitly linking science and monitoring information to goals in water quality standards and criteria and, thus, aids in management decision making (Davies and Jackson 2006). Each of the proposed six levels of the BCG is described via a detailed narrative that communicates ecological characteristics associated with that condition level. In this way, the descriptive gradient can be used to interpret numeric metric scores into a fuller understanding of their ecological meaning and importance. Once calibrated to local data, the BCG creates a bridge between biological metric scores and the condition levels with which they are commonly associated.

2.1 The Scientific Foundation of the Biological Condition Gradient

The practice of using biological indicators to assess water quality is over a century old, and the scientific foundation of the BCG is based on many decades of biologists' accumulated experience with biological assessment and monitoring. The Saprobien System is a concept based on organism tolerance proposed by Lauterborn in 1901 and further developed by Kolkwitz and Marsson (Davis 1995). This system uses benthic macroinvertebrates and planktonic plants and animals as indicators of organic loading and low dissolved oxygen (DO). It has been updated since its initial development and is currently used in several European countries. The limnologists Thienemann and Naumann developed the concept of trophic state classification for lakes in the 1920s (Cairns and Pratt 1993; Carlson 1992). Both the Saprobien System and lake trophic state classifications describe a response gradient (or response classes for lakes) to nutrient pollution. The Saprobien System was explicitly developed to assess human pollution in rivers, but the trophic state concept was originally developed to describe natural conditions in lakes and only later became a concept to describe pollution-induced eutrophication (e.g., Vollenweider 1968). The 1950s marked the development of Beck's biotic index in the U.S. and Pantle and Buck's Saprobic Index in Europe, both of which were directly based on the Saprobien System (Beck 1954; Pantle and Buck 1955). The Saprobic Index, which led to the development of the widely used Hilsenhoff Index (e.g., Hilsenhoff 1987a, 1987b) in the U.S., could be considered the predecessor of today's biotic indices (Davis 1995). Later studies used diversity indices based on information theory to describe changes in community structure, richness, and dominance (evenness) as a measure of pollution effects (e.g., Wilhm and Dorris 1966).

Biological information from monitoring programs has been frequently synthesized by constructing biotic indices, such as the IBI (Karr 1981; Karr et al. 1986). The IBI integrates the concept of anchoring the measurement system in undisturbed reference conditions with the measurement of several indicators intended to reflect ecological components of composition, diversity, and ecosystem processes. It thus combines a conceptual model of ecosystem change in response to increasing levels of stressors with a practical measurement system. The BCG is also grounded in the concepts of stress ecology articulated by Odum et al. (1979), Odum (1985), Rapport et al. (1985), and Cairns et al. (1993), describing "natural" conditions and the change in biological condition caused by stressors. To achieve maximum potential application nationwide, the BCG levels were developed based on state biologists' experiences with water quality management (Courtemanch et al. 1989; Yoder and Rankin 1995a), as well as the practical experience of a diverse group of aquatic scientists from different bio-geographic areas (Davies and Jackson 2006). The BCG:

- Describes a scale of six condition levels, from undisturbed (level 1) to highly disturbed conditions (level 6).
- Synthesizes existing field observations and generally accepted interpretations of patterns of biological change within a common framework.

- Incrementally measures how a system may have departed from undisturbed condition, based on observable, ecological attributes.

In its initial development, the description of biological attributes that make up the model applied best to permanent, hard-bottom streams that are exposed to increases in temperature, nutrients, fine sediments, and other pollutants. This is the stream-type and stressor regime originally described by the model and the one most developed to date, for example, in Alabama, Connecticut, Maine, Maryland, Minnesota, New Jersey, Ohio, and Vermont. The model has been further tested with states in different parts of the country and increasingly in different water body types (e.g., headwater streams, coastal plains freshwater streams, rivers, wetlands, estuaries, and coral reefs) to evaluate the national applicability of the model (see Appendix B for examples). Results have shown good correlation with some necessary refinement of the model attributes to accommodate regional and water body differences. For example, for the southern great plains region, attribute II, originally defined as sensitive-rare taxa, was redefined as *highly sensitive taxa* because rarity of a taxon in the region was not associated with sensitivity to stress. In this region, many rare, native taxa might be highly tolerant to stressors, such as low DO and high temperature. Through similar developmental processes, the BCG, as initially developed and tested, is applicable to other aquatic ecosystems and stressors with appropriate modifications. The BCG should be viewed as a scientific framework that can readily incorporate future advances in scientific understanding. The model building was initially based on expert consensus and then further tested and refined following procedures detailed in Chapter 3. Quantitative approaches for translating the narrative model into numeric values are discussed in Chapter 4.

The value of a conceptual framework such as the BCG is not only that it documents experimentally established knowledge, but that it also promotes a more rigorous testing of empirical observations by clearly stating them in a provisional model (Davies and Jackson 2006). Conceptual models formalize the state of knowledge and guide research. Empirically-based generalizations have led to conceptual models that describe the behavior of biological systems under stress (Brinkhurst 1993; Fausch et al. 1990; Karr and Dudley 1981; Margalef 1963, 1981; Odum et al. 1979; Rapport et al. 1985; Schindler 1987). For example, Brinkhurst (1993) observed that "Everyone knew [in 1929] that increases in numbers and species could be related to mild pollution, that moderate pollution could produce changes in taxa so that diversity remained similar but species composition shifted, and that eventually species richness declined abruptly and numbers of some tolerant forms increased dramatically." Such ecosystem responses to stressor gradients have been portrayed as a progression of stages that occur in a generally consistent pattern (Cairns and Pratt 1993; Odum 1985; Odum et al. 1979; Rapport et al. 1985). Establishing and validating quantifiable thresholds along that progression with empirical data is a priority need for resource managers (Cairns 1981).

2.2 The Biological Condition Gradient Attributes

The BCG framework depicts ecological condition in terms of observable or measurable changes in an aquatic system in response to anthropogenic stress. The characteristics, described as "attributes" in this document, were selected because they corresponded to the characteristics used by state workgroup members to measure biological condition and develop biological criteria. The 10 attributes are discussed below and listed in Table 1. In biological assessments, most information is collected at the spatial scale of a site or reach and the temporal scale ranging from a season to as short as a single sampling event. Many of the attributes that make up the BCG are based on these scales. Site scale attributes include aspects of taxonomic composition and community structure (attributes I–V), organism condition (attribute VI), and organism and system performance (attributes VII and VIII). At larger temporal and spatial scales, physical-biotic interactions (attributes IX and X) are also included because of their importance to state water quality management programs in evaluating longer-term impacts, determining restoration potential, and tracking recovery in specific water bodies.

Information used to assess the ten attributes may be acquired from two sources. Sample-based data from instream monitoring using standardized sampling protocols can produce the most reliable, reproducible form of information and are best used for attributes II–V. Knowledge-based information, such as evidence from natural history surveys, agency records and reports (e.g., stocking reports), academic studies and journal publications, expert observations, and so on, can contribute significantly to BCG development even when methods are inconsistent. Since many of the attributes rely on the positive observation (i.e., presence) of an organism and its relative occurrence in the community, any reliable sources of information can be used to develop and calibrate the BCG for a specific water body and/or region. Attributes I–X are described below (from Davies and Jackson 2006).

Attribute I: Historically Documented, Sensitive, Long-lived, or Regionally Endemic Taxa

Attribute I can be developed using both sample-based and knowledge-based sources. Taxa that are *historically documented* refer to those known to have been supported in a water body or region according to historical records. This attribute was derived to cover taxa that are s*ensitive or regionally endemic* that have restricted, geographically isolated distribution patterns (occurring only in a locale as opposed to a region), often due to unique life history requirements. They may be long-lived and late maturing and have low fecundity, limited mobility, multiple habitat requirements as with diadromous species, or require a mutualistic relationship with other species. They may be among listed Endangered or Threatened (E/T) or special concern species. Predictability of occurrence is often low, and therefore requires documented observation. The presence or absence of a population might provide significant information in an assessment, but there are typically insufficient data to develop the stress response relationships needed to assign these taxa to attributes II through V (as discussed below). Recorded occurrence may be highly dependent on sample methods, site selection, and level of effort, thus requiring use of knowledge-based sources in addition to actual instream sampling. The taxa that are assigned to this category require expert knowledge of life history and regional occurrence of the taxa to appropriately interpret the significance of their presence or absence. Long-lived species are especially important as they provide evidence of multi-annual persistence of habitat condition. For example, many species of freshwater mussels in the Southeast U.S. are highly endemic and have been extirpated in many areas. The presence of freshwater mussels in a stream might signify high quality conditions, but their absence does not necessarily indicate poor conditions if overharvesting of the mussels is the cause.

Attribute II: Highly Sensitive Taxa

Highly sensitive taxa typically occur in low numbers relative to total population density, but they might make up a large relative proportion of richness. In high quality sites, they might be ubiquitous in occurrence or might be restricted to certain micro-habitats. Many of these species commonly occur at low densities, so their occurrence is dependent on sample effort. They are often stenothermic (i.e., having a narrow range of thermal tolerance) or cold-water obligates, and their populations are maintained at a fairly constant level, with slower development and a longer life-span. They might have specialized food resource needs, feeding strategies, or life history requirements, and they are generally intolerant to significant alteration of the physical or chemical environment. They are often the first taxa lost from a community following moderate disturbance or pollution.

In earlier descriptions of the BCG, highly sensitive taxa were called *sensitive-rare* taxa (Davies and Jackson 2006), but experience with calibrating the BCG showed that some highly sensitive species are found at many exceptional sites, and some were occasionally highly abundant (e.g., Snook et al. 2007). The distinguishing characteristic for this attribute category was found to be sensitivity and not relative rarity, although some of these taxa might be uncommon in the data set (e.g., very small percent of sample occurrence or sample density)

Attribute III: Intermediate Sensitive Taxa

Intermediate sensitive taxa were formerly labeled sensitive-ubiquitous taxa (Davies and Jackson 2006), but subsequent development revealed that the experts relied upon the sensitivity of a species to stress rather than whether it was "ubiquitous," though intermediate sensitive taxa are ordinarily common and abundant in natural communities. They tend to have a broader range of tolerances than highly sensitive taxa, and they usually occur in reduced abundance and reduced frequencies at disturbed or polluted sites. These taxa often comprise a substantial portion of natural communities.

Attribute IV: Intermediate Tolerant Taxa

Attribute IV taxa commonly comprise a substantial portion of an assemblage in undisturbed habitats, as well as in moderately disturbed or polluted habitats. They exhibit physiological or life-history characteristics that enable them to thrive under a broad range of thermal, flow, or oxygen conditions. Many have generalist or facultative feeding strategies enabling utilization of diverse food types. These species have little or no detectable response to moderate stress, and they are often equally abundant in both reference and moderately stressed sites. Some intermediate tolerant taxa may show an "intermediate disturbance" response, where densities and frequency of occurrence are relatively high at intermediate levels of stress, but they are intolerant of excessive pollution loads or habitat alteration.

Attribute V: Tolerant taxa

Tolerant taxa are those that typically comprise a low proportion of natural communities. These taxa are more tolerant of a greater degree of disturbance and stress than other organisms and are, thus, resistant to a variety of pollution or habitat induced stress. They may increase in number (sometimes greatly) under severely altered or stressed conditions. They may possess adaptations in response to organic pollution, hypoxia, or toxic substances. These are the last survivors in severely disturbed systems and can prevail in great numbers due to lack of competition or predation by less tolerant organisms, and they are key community components of level 5 and 6 conditions.

Attribute VI: Non-native or Intentionally Introduced Taxa

With respect to a particular ecosystem, species fitting attribute VI are any species not native to that ecosystem. Species introduced or spread from one region of the U.S. to another outside their normal ranges are non-native, or non-indigenous. This category also includes species introduced from other continents and referred to as "alien" species. Attribute VI can also include introduced disease or parasitic organisms. This attribute represents both an effect of human activities and a stressor in the form of biological pollution. Although some intentionally introduced species are valued by large segments of society (e.g., gamefish), these species might be as disruptive to native species as undesirable opportunistic invaders (e.g., zebra mussels). Many rivers in the U.S. are dominated by non-native fish and invertebrates (Moyle 1986), and the introduction of non-native species is the second most important factor contributing to fish extinctions in North America (Miller et al. 1989). The BCG identifies the presence of native taxa expected under undisturbed or minimally disturbed conditions as an essential characteristic of BCG level 1 and 2 conditions. The BCG only allows for the occurrence of non-native taxa in these levels if those taxa do not displace native taxa and do not have a detrimental effect on native structure and function. Condition levels 3 and 4 depict increasing occurrence of non-native taxa. Extensive replacement of native taxa by tolerant or invasive, non-native taxa can occur in levels 5 and 6. Attribute VI may rely on either sample-based or knowledge-based sources.

Attribute VII: Organism Condition

Organism condition is an element of ecosystem function, expressed at the level of anatomical or physiological characteristics of individual organisms. Organism condition includes direct and indirect indicators such as fecundity, morbidity, mortality, growth rates, and anomalies (e.g., lesions, tumors, and deformities). Some of these indicators are readily observed in the field and laboratory, whereas the assessment of others requires specialized expertise and much greater effort. Organism condition can also change with season or life stage, or occur as short-term events making assessment difficult. The most common approach for state programs is to forego complex and demanding direct measures of organism condition (e.g., fecundity, morbidity, mortality, disease, growth rates) in favor of indirect or surrogate measures (e.g., percent of organisms with anomalies, age or size class distributions) (Simon 2003). Organism anomalies in the BCG vary from naturally occurring incidence in levels 1 and 2 to higher than expected incidence in levels 3 and 4. In levels 5 and 6, biomass is reduced, the age structure of populations indicates premature mortality or unsuccessful reproduction, and the incidence of serious anomalies is high. This attribute has been successfully used in stream indices based on the fish assemblage (Sanders et al. 1999; Yoder and Rankin 1995a). Incidence of disease is being evaluated as an indicator of organism condition for the coral reef BCG (see Appendix B-3).

Attribute VIII: Ecosystem Function

Ecosystem function refers to any processes required for the performance of a biological system expected under naturally occurring conditions. Naturally occurring conditions have been typically interpreted as those conditions found in undisturbed to minimally disturbed conditions but some processes can be sustained under moderate levels of disturbance. Examples of ecosystem functional processes are primary and secondary production, respiration, nutrient cycling, and decomposition. Assessing ecosystem function includes consideration of the aggregate performance of dynamic interactions within an ecosystem, such as the interactions among taxa (e.g., food web dynamics) and energy and nutrient processing rates (e.g., energy and nutrient dynamics) (Cairns 1977).

Additionally, ecosystem function includes aspects of all levels of biological organization (e.g., individual, population, and community condition). Altered interactions between individual organisms and their abiotic and biotic environments might generate changes in growth rates, reproductive success, movement, or mortality. These altered interactions are ultimately expressed at ecosystem-levels of organization (e.g., shifts from heterotrophy to autotrophy, onset of eutrophic conditions) and as changes in ecosystem process rates (e.g., photosynthesis, respiration, production, decomposition).

At this time, the level of effort required to directly assess ecosystem function is beyond the means of most state monitoring programs. Instead, in streams and wadeable rivers, most programs rely on taxonomic and structural indicators to make inferences about functional status (Karr et al. 1986). For example, shifts in the primary source of food might cause changes in trophic guild indices or indicator species. Although direct measures of ecosystem function are currently difficult or time consuming, they might become practical in the future (Gessner and Chauvet 2002). The BCG conceptual model includes ecosystem function for future application.

Attribute IX: Spatial and Temporal Extent of Detrimental Effects

The spatial and temporal extent of stressor effects includes the near-field to far-field range of observable effects of the stressors on a water body. Such information can be conveyed by biological assessments provided the spatial density of sampling sites is sufficient to convey changes along a pollution continuum (USEPA 2013a). Use of a continuum provides a method for determining the severity (i.e., departure from the desired state) and extent (i.e., distance over which adverse effects are observed) of an impairment from one or more sources. Yoder et al. (2005) detailed this approach in their historical assessment of large rivers in Ohio. As with attribute VIII above, attribute IX has not yet been developed and applied in BCG models for specific streams and wadeable rivers. It is included for future development and application. State scientists involved in the development of the BCG conceptual model stated that this attribute was important to include for future testing and development. Some state biological monitoring and assessment programs document the spatial and temporal extent of stressor effects and use the information to predict the recovery potential of a degraded stream, as well as the risk of degradation in high quality streams. This information informs water quality management decisions on prioritization of actions. The National Hydrography Dataset (NHD) (USGS 2014), together with biological assessment information from attributes I–VIII can be an important tool to help evaluate position and extent of condition and stressors in a water body or watershed by mapping the locations (i.e., spatial distribution) of the biological samples.

Attribute X: Ecosystem Connectance

Attribute X refers to the access or linkage (in space/time) to materials, locations, and conditions required for maintenance of interacting populations of aquatic life. It is the opposite of fragmentation and is necessary for persistence of metapopulations and natural flows of energy and nutrients across ecosystem boundaries. Ecosystem connectance can be indirectly expressed by certain species that depend on the connectance, or lack of connectance, within an aquatic ecosystem to fully complete their life cycles and thus maintain their populations. Diadromous fish species are one such example—their absence or presence can provide information on the presence or absence of critical habitats to support different life stages. However, the inverse of connectance, isolation, is important for some species (e.g., amphibians, which are negatively impacted by fish that gain access to amphibian habitat via artificial or natural connections). This difference dependence upon connectance underscores the importance of well-defined BCG levels 1 and 2 as the benchmark for interpreting change in the BCG attributes. The NHD can be an important tool to evaluate the extent of connections (or occurrence of barriers or habitat disconnects) in a water body or watershed. A habitat mosaic measure is being evaluated as an indicator of ecosystem connectance in the estuarine BCG (see Appendix B-2).

2.3 The Biological Condition Gradient Levels of Biological Condition

The BCG has been divided into six levels along a generalized stressor-response continuum to provide discrimination of different levels of condition that are detectable, given current assessment methods and well-designed monitoring protocols. Since the BCG is a continuum, in principle it is possible to determine more or fewer levels depending upon the discriminatory power of a state water quality management program (USEPA 2013a). The six levels are proposed as a hypothetical framework for which the practical concerns of the state would determine the number of levels that can be implemented. For example, in most forested perennial stream ecosystems it may be technically possible to discriminate six classes in the condition gradient, ranging from undisturbed to highly disturbed conditions (Davies and Jackson 2006). However, some states or regions may only be capable of discriminating two or three levels, given current technical program capabilities, while others might be capable of discerning six or more levels based on highly proficient programs and robust data sets (USEPA

2013a). In addition, some regions of the country may not currently support level 1 water conditions. *Regardless of the number of levels a state can detect, the BCG framework is to be a starting point for a state to think about how to use biological information to better determine existing conditions and potential for improvement and how to use the information to better communicate biological condition and to set water quality objectives*.

The six levels of the BCG are described as follows (modified from Davies and Jackson 2006).

- **Level 1, Natural or native condition**—*Native structural, functional, and taxonomic integrity is preserved; ecosystem function is preserved within the range of natural variability.* Level 1 represents biological conditions as they existed (or still exist) in the absence of measurable effects of stressors and provides the basis for comparison to the next five levels. The level 1 biological assemblages that occur in a given biogeophysical setting are the result of adaptive evolutionary processes and biogeography. For this reason, the expected level 1 assemblage of a stream from the arid southwest will be very different from that of a stream in the northern temperate forest. The maintenance of native species populations and the expected natural diversity of species are essential for levels 1 and 2. Non-native taxa (attribute VI) might be present in level 1 if they cause no displacement of native taxa, although the practical uncertainties of this provision are acknowledged (see section 2.2). Attributes I and II (i.e., historically documented and sensitive taxa) can be used to help assess the status of native taxa when classifying a site or assessing its condition.
- **Level 2, Minimal changes in structure of the biotic community and minimal changes in ecosystem function**—*Most native taxa are maintained with some changes in biomass and/or abundance; ecosystem functions are fully maintained within the range of natural variability.* Level 2 represents the earliest changes in densities, species composition, and biomass that occur as a result of slight elevation in stressors (e.g., increased temperature regime or nutrient pollution). There might be some reduction of a small fraction of highly sensitive or specialized taxa (attribute II) or loss of some endemic or rare taxa as a result. The occurrence of non-native taxa should not measurably alter the natural structure and function and should not replace any native taxa. Level 2 can be characterized as the first change in condition from natural, and it is most often manifested in nutrient-polluted waters as slightly increased richness and density of either intermediate sensitive and intermediate tolerant taxa (attributes III and IV) or both. These early response signals have been observed in many state programs as illustrated in Figure 5, which shows slight to moderate increases of mayfly density in response to increases in conductivity in Maine streams. Mayfly taxa typically have been identified in Maine as sensitive ubiquitous taxa and show an increase to initial levels of some stress (e.g., an increase in conductivity or nutrient pollution), followed by a decrease in abundance as stress levels continue to rise.

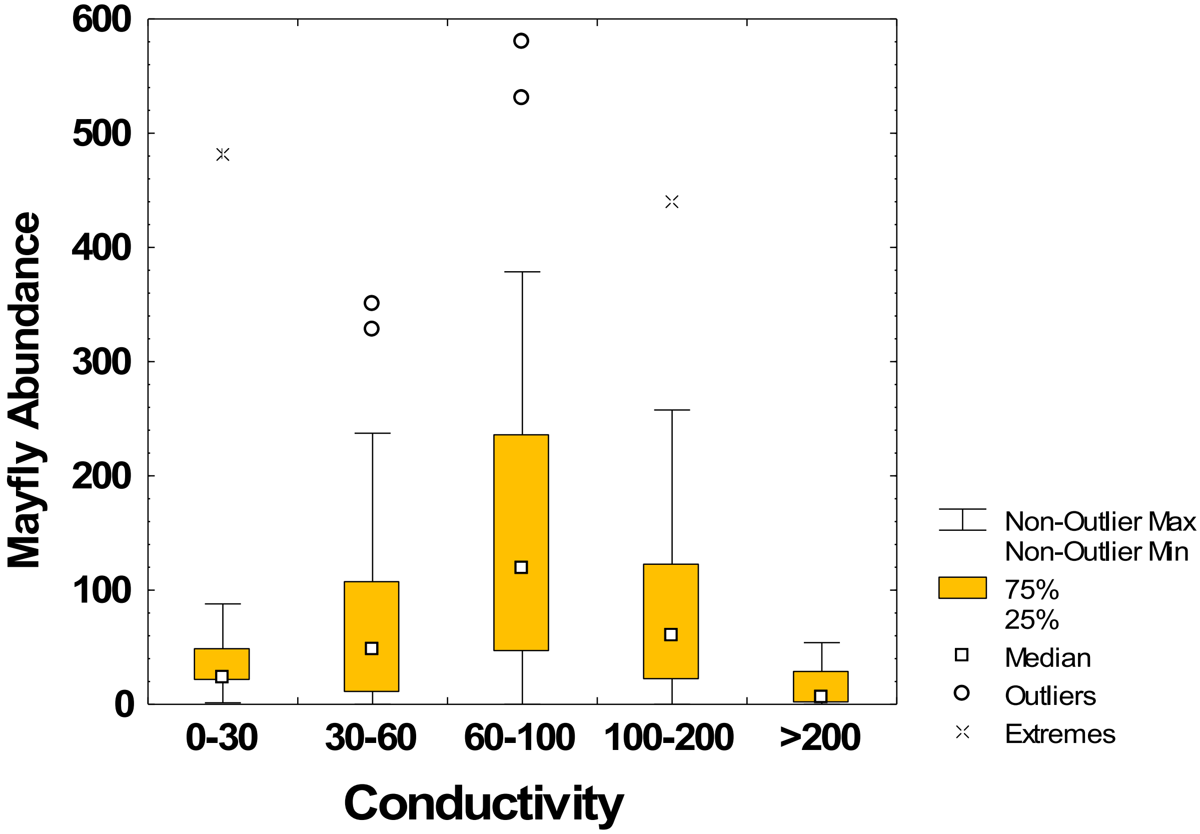

Figure 5. Response of mayfly density to stress in Maine streams as indicated by a gradient of increasing conductivity.

- **Level 3, Evident changes in structure of the biotic community and minimal changes in ecosystem function**—*Evident changes in structure due to loss of some highly sensitive native taxa; shifts in relative abundance of taxa, but sensitive-ubiquitous taxa are common and relatively abundant; ecosystem functions are fully maintained through redundant attributes of the system.* Level 3 represents readily observable changes that, for example, can occur in response to organic pollution or increased temperature. The "evident" change in structure for level 3 is interpreted to be perceptible and detectable decreases in highly sensitive taxa (attribute II), and increases in sensitive-ubiquitous taxa or intermediate organisms (attributes III and IV). Attribute IV taxa (intermediate intolerance) might increase in abundance as an opportunistic response to nutrient or organic inputs.
- **Level 4, Moderate changes in structure of the biotic community with minimal changes in ecosystem function**—*Moderate changes in structure due to replacement of some intermediate sensitive taxa by more tolerant taxa, but reproducing populations of some sensitive taxa are maintained; overall balanced distribution of all expected major groups; ecosystem functions largely maintained through redundant attributes.* Moderate changes of structure occur as stressor effects increase in level 4. A substantial reduction of the two sensitive attribute groups (attributes II and III) and replacement by more tolerant taxa (attributes IV and V) might be observed. A key consideration is that some attribute III sensitive taxa are maintained at a reduced level, but they are still an important functional part of the system (i.e., function is

maintained). While total abundance (density) of organisms might increase, no single taxa or functional group should be overly dominant.

- **Level 5, Major changes in structure of the biotic community and moderate changes in ecosystem function**—*Sensitive taxa are markedly diminished or missing; conspicuously unbalanced distribution of major groups from those expected; organism condition shows signs of physiological stress; ecosystem function shows reduced complexity and redundancy; increased build-up or export of unused materials.* Changes in ecosystem function (as indicated by marked changes in food-web structure and guilds) are critical in distinguishing between levels 4 and 5. This could include the loss of functionally important sensitive taxa and keystone taxa (attribute I, II, and III taxa), such that they are no longer important players in the system, though a few individuals may be present. Keystone taxa control species composition and trophic interactions, and are often, but not always, top predators. As an example, removal of keystone taxa by overfishing has greatly altered the structure and function of many coastal ocean ecosystems (Jackson et al. 2001). Additionally, tolerant non-native taxa (attribute VI) may dominate some assemblages, and changes in organism condition (attribute VII) may include significantly increased mortality, depressed fecundity, and/or increased frequency of lesions, tumors, and deformities.
- **Level 6, Severe changes in structure of the biotic community and major loss of ecosystem function**—*Extreme changes in structure; wholesale changes in taxonomic composition; extreme alterations from normal densities and distributions; organism condition is often poor; ecosystem functions are severely altered.* Level 6 systems are taxonomically depauperate (i.e., low diversity and/or reduced number of organisms) compared to the other levels. For example, extremely high or low densities of organisms caused by excessive organic pollution, severe toxicity, and/or severe habitat alteration may characterize level 6 systems. Non-native taxa may predominate.

2.3.1 Bringing the Biological Condition Gradient Levels and Attributes Together

The BCG narrative portrays general patterns of biological and ecological response common across regions, as measured by the BCG attributes. Table 2 organizes the ten BCG attributes into six categories: community structure, non-natives, condition, function, landscape, and connectivity. Attributes I through V have been combined in one category in Table 2—structure and compositional complexity. This category typically includes measures of the number, type, and proportion of individual taxa within an assemblage (e.g., benthic macroinvertebrates, fish, and algal assemblages). These attributes are the foundation of most state biological assessment programs for streams and wadeable rivers. The five taxonomic attributes characterize biological sensitivity to the cumulative impact of stressors (e.g., highly, intermediate, or tolerant taxa). In addition to the sensitivity-based attributes, biologists have also used assemblage richness and balance, assemblage abundance or biomass, and keystone or habitat-structuring species (e.g., reef-building corals) to define attributes and distinguish levels of condition along a stress gradient. Attributes respond to stressors in distinctly different ways so that there are predictive, quantitative measures along the full range of stress levels (Figure 6, Table 3). Defining and quantifying these changes along the full gradient of stress effects is necessary for developing reliable, predictable measures for incremental changes in biological condition. For example, highly sensitive taxa might disappear from a community in early, or low, levels of stress. Tolerant taxa might become more dominant as stress increases, not only because they might thrive, but also because there are fewer sensitive species and the proportion of tolerant taxa in the entire community increases. Intermediate tolerant taxa might not provide a significant signal under most conditions if they are present under a wide range of stress. However, the absence of this group of taxa in highly stressed conditions can help document highly disturbed conditions, and their reappearance may indicate initial response to management actions for restoration. As work proceeds on applying the BCG to other water body types and developing approaches for including additional assemblages (e.g., periphyton, amphibians, birds) and new methods for sampling and analyzing aquatic life (e.g., DNA analysis), it is expected that these attributes will be refined and comparable detailed descriptions for the remaining attributes will emerge.

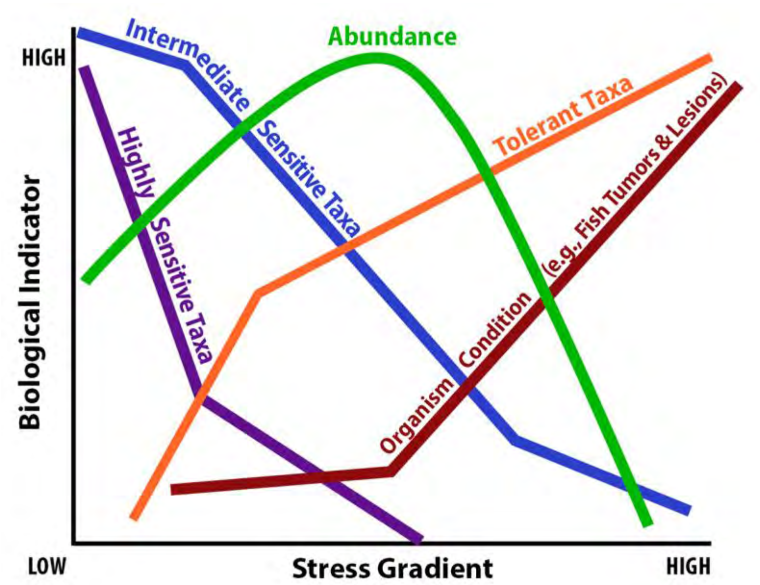

Figure 6. Hypothetical examples of biological response to the cumulative impact of multiple stressors.

Table 2. BCG: Ecological Attributes

	Attribute Grouping	Description	Examples of BCG					
			1	2	3	4	5	6
STRUCTURE	Structure and Compositional Complexity (Attributes I–V) See Table 3 for detailed descriptions for these attributes.	Community or habitat structure and complexity. May also recognize loss of habitats or species due to human activities. Examples include macroinvertebrate or fish indices, phytoplankton or zooplankton community measures, epifaunal measures, biotope mosaics, presence/quantity of sensitive taxa or biotopes, wetland vegetative indices, etc.	Community composition is as naturally occurs, except for global extinctions based on observations from water bodies with similar habitat and ecoregion without measurable human-caused stressors (this includes chlorophyll a levels, biotope mosaics, species composition including large, long-lived, and sensitive species; patterns of vegetation are as naturally occurs)	Minor changes in natural occurrences of biotopes or patterns of vegetation, slight decreases in sensitive species, and slight increases in tolerant species	Evident changes in biological metrics (decreases in sensitive species and increases in more tolerant species, evident changes in vegetation patterns); may be slight decreases in biotope or habitat area; biotope mosaic basically intact	Significant changes in biological metrics (marked decreases in sensitive species [including large or long-lived taxa] and increases in tolerant species, evident changes in vegetation patterns); biotope mosaic slightly altered with replacement of natural habitats/biotopes with tolerant or non-naturally occurring components; detectable loss in some biotope types or habitat area	Most sensitive, large and/or long-lived taxa are absent, with a dominance in abundance of tolerant taxa; significant shifts in species diversity, size, and densities of remaining species; biotope mosaic significantly altered with many natural habitats/biotopes lost with replacement by tolerant or non-naturally occurring components; evident loss in biotope or habitat area	Sensitive, large, and/or long-lived taxa largely absent; possible high or low extremes in abundance of remaining taxa; marked reduction in species diversity and in size spectra of remaining organisms; near complete loss or alteration of natural biotope mosaic with marked loss in biotope or habitat area

	Attribute Grouping	Description	Examples of BCG					
			1	2	3	4	5	6
NON-NATIVES	Non-Native Taxa (Attribute VI)	Status of non-native species. May include measures of the impact of invasive and non-native species. Examples include estimated numbers of species or individuals, relative density or biomass measures of natives and non-natives, or replacement of native species	Non-native taxa, if present, do not significantly reduce native taxa or alter structural or functional integrity	Non-native taxa may be present, but occurrence has a non-detrimental effect on native taxa	Non-native taxa may be prominent in some assemblages (e.g., crustaceans, bivalves, fish) and some sensitive native taxa may be reduced or replaced by equivalent non-native species (e.g., replacement of native trout with introduced salmonids)	Increased abundance of tolerant non-native species (e.g., Common Carp, non-native centrarchids, Common Reed) or native species (e.g., salmonids) only maintained by regular stocking	Some assemblages (e.g., mollusks, fishes, macrophytes) are dominated by invasive non-native taxa (e.g., Silver Carp, Zebra Mussels, Eurasian Watermilfoil); or increasing dominance by tolerant non-native species such as Common Carp	Same as level 5; not distinguishable based on non-native species alone
CONDITION	Organism Condition (Attribute VII)	Measures condition of individual organisms, including anomalies and diseases. Examples include external anomalies, lesions, disease outbreaks (local or widespread), coral bleaching, seagrass condition, fish pathology, and frequency of diseased or affected organisms	Diseases and anomalies are consistent with naturally occurring incidents and characteristics	Diseases and anomalies are consistent with naturally occurring incidents and characteristics	Incidences of diseases and anomalies may be slightly higher than expected conditions	Incidences of diseases and anomalies are slightly higher than expected. For example, coral bleaching events may occur sporadically and result in slightly elevated mortality. Anomalies in fish occur in a small fraction of a population	Disease outbreaks are increasingly common, anomalies are increasingly common, particularly in long-lived taxa where biomass may also be reduced (e.g., bleaching events are frequent enough to cause mortality of corals). Anomalies, such as deformities, erosion, lesions, and tumors in fish, occur in a measurable fraction of a population	Host species in which diseases and anomalies have been observed are now absent, so diseases might be difficult to detect. Anomalies, disease, etc. may occur across multiple species or taxa groups

	Attribute Grouping	Description	Examples of BCG					
			1	2	3	4	5	6
FUNCTION	Function (Attribute VIII)	Measures of energy flow, trophic linkages and material cycling. They may include proxy or snapshot structural metrics that correlate to functional measures. Examples include photosynthesis: respiration ratios, benthic: pelagic production rates, chlorophyll a concentrations, macroalgal biomass, bacterial biomass and activity	Energy flows, material cycling, and other functions are as naturally occur; characterized by complex interactions and long-lived links supporting large, long-lived organisms	Energy flows, material cycling, and other functions are within the natural range of variability; characterized by complex interactions and long-lived links supporting large, long-lived organisms	Virtually all functions are maintained through operationally redundant system attributes, minimal changes to export and other indicative functions. Some functions increased due to pollution or low level disturbance (e.g., production, biomass, respiration)	Most functions are maintained through operationally redundant system attributes, though there is evidence of loss of efficiency (e.g., increased export or decreased import, there may be shifts in benthic: pelagic production rates	Loss of some ecosystem functions are manifested as changed export or import of some resources and changes in energy exchange rates (photosynthesis: respiration ratios, benthic: pelagic production rates, respiration or decomposition rates)	Most functions show extensive and persistent disruption, shifts to primary production, microbial dominance, fewer and shorter-length trophic links and highly simplified trophic structure, marked shifts in benthic: pelagic production rates
LANDSCAPE	Spatial and Temporal Extent of Detrimental Effects (Attribute IX)	Measures of a landscape's capacity, contributing surface water to a single location, to maintain the full range of ecological processes and function that support a resilient, naturally occurring aquatic community. The functions and processes to be measured include hydrologic regulation, regulation of water chemistry and sediments, hydrologic connectivity (see also attribute X), temperature regulation, and habitat provision	N/A—A natural disturbance regime is maintained	Limited to small pockets and short duration	Limited to a local area or within a season	Mild detrimental effects may be detectable beyond the local area and may include more than one season	Detrimental effects extend far beyond the local area leaving only a few islands of adequate conditions; effect extends across multiple seasons	Detrimental effects may eliminate all refugia and colonization sources within a region or catchment and affect multiple seasons

	Attribute Grouping	Description	Examples of BCG					
			1	2	3	4	5	6
CONNECTIVITY	Ecosystem Connectance (Attribute X)	Observations of exchange or migrations of biota between adjacent water bodies or habitats. Important measures within the area being studied may be strongly affected by factors adjacent to or larger than the immediate study area. Metrics may include dams, causeways, fragmentation measures, hydrological measures, or proxies such as characteristic migratory species	System is naturally connected, or disconnected, in space and time, exchanges, migrations, and recruitment from adjacent water bodies or habitats are as naturally occurs	System is naturally connected, or disconnected, in space and time, exchanges, migrations, and recruitment from adjacent water bodies or habitats are as naturally occurs	Slight loss, or increase, in connectivity between adjacent water bodies or habitats (e.g., between upstream and downstream water bodies), but colonization sources, refugia, and other mechanisms mostly compensate. May also be increase in connectivity due to canals, interbasin transfers	Some loss, or increase, in connectivity between adjacent water bodies or habitats (e.g., between upstream and downstream water bodies), but colonization sources, refugia, and other mechanisms prevent complete disconnects or other failures	Significant loss, or increase, in ecosystem connectivity between adjacent water bodies or habitats (e.g., between upstream and downstream water bodies or habitats) is evident; recolonization sources do not exist for some taxa, some near-complete disconnects or connect exist	For many groups, a complete loss in ecosystem connectivity in at least one dimension (either spatially or temporally) lowers reproductive or recruitment success or prevents migration or exchanges with adjacent water bodies or habitats, frequent disconnects or other failures. For other groups, a complete loss in ecosystem disconnect in at least one dimension lowers reproductive or recruitment success (e.g., predation of amphibians by fish in once isolated headwater streams)

Table 3. BCG Matrix: Taxonomic Composition and Structure Attributes I–V

	BCG Levels					
Ecological Attributes	1 Natural or native condition Native structural, functional, and taxonomic integrity is preserved; ecosystem function is preserved within the range of natural variability	2 Minimal changes in the structure of the biotic community and minimal changes in ecosystem function Virtually all native taxa are maintained with some changes in biomass and/or abundance; ecosystem functions are fully maintained within the range of natural variability	3 Evident changes in structure of the biotic community and minimal changes in ecosystem function Some changes in structure due to loss of some rare native taxa; shifts in relative abundance of taxa but sensitive-ubiquitous taxa are common and abundant; ecosystem functions are fully maintained through redundant attributes of the system	4 Moderate changes in structure of the biotic community and minimal changes in ecosystem function Moderate changes in structure due to replacement of some sensitive-ubiquitous taxa by more tolerant taxa, but reproducing populations of some sensitive taxa are maintained; overall balanced distribution of all expected major groups; ecosystem functions largely maintained through redundant attributes	5 Major changes in structure of the biotic community and moderate changes in ecosystem function Sensitive taxa are markedly diminished; conspicuously unbalanced distribution of major groups from that expected; organism condition shows signs of physiological stress; system function shows reduced complexity and redundancy; increased build- up or export of unused materials	6 Severe changes in structure of the biotic community and major loss of ecosystem function Extreme changes in structure; wholesale changes in taxonomic composition; extreme alterations from normal densities and distributions; organism condition is often poor; ecosystem functions are severely altered
I Historically documented, sensitive, long-lived or regionally endemic taxa	As predicted for natural occurrence except for global extinctions	As predicted for natural occurrence except for global extinctions	Some may be marginally present or absent due to global extinction or local extirpation	Some may be marginally present or absent due to global, regional, or local extirpation	Usually absent	Absent
II Highly sensitive taxa	As predicted for natural occurrence, with at most minor changes from natural densities	Most are maintained with some changes in densities	Some loss, with replacement by functionally equivalent sensitive-ubiquitous taxa	May be markedly diminished	Usually absent or only scarce individuals	Absent
III Intermediate sensitive taxa	As predicted for natural occurrence, with at most minor changes from natural densities	Present and may be increasingly abundant	Common and abundant; relative abundance greater than sensitive-rare, taxa	Present with reproducing populations maintained; some replacement by functionally equivalent taxa of intermediate tolerance.	Frequently absent or markedly diminished	Absent
IV Intermediate tolerant taxa	As predicted for natural occurrence, with at most minor changes from natural densities	As naturally present with slight increases in abundance	Often evident increases in abundance	Common and often abundant; relative abundance may be greater than sensitive- ubiquitous taxa	Often exhibit excessive dominance	May occur in extremely high or extremely low densities; richness of all taxa is low
V Tolerant taxa	As naturally occur, with at most minor changes from natural densities	As naturally present with slight increases in abundance	May be increases in abundance of functionally diverse tolerant taxa	May be common but do not exhibit significant dominance	Often occur in high densities and may be dominant	Usually comprise the majority of the assemblage; often extreme departures from normal densities (high or low)

2.4 How the Conceptual Biological Condition Gradient was Developed, Tested, and Evaluated

The conceptual BCG model was developed and tested by an expert workgroup primarily composed of scientists from government and the research community (Davies and Jackson 2006). This section summarizes how the BCG conceptual model was tested to the satisfaction of the expert workgroup and peer reviewers (from Davies and Jackson 2006). For examples on constructing BCG models and quantitative decision rules applied to specific assemblages and habitats, please see Chapters 3 and 4.

A matrix was created that summarized biologists' experience and knowledge about how biological attributes change in response to stress in aquatic ecosystems (Davies and Jackson 2006). In building the model, the workgroup followed an iterative, inductive approach, similar to means-end analysis (Martinez 1998). The workgroup understood that the primary value of the model is as a tool for shared learning and as a framework for communication.

The workgroup began by testing whether biologists from different parts of the country would draw similar conclusions regarding the condition of a water body using simple lists of organisms and their counts. This approach was initially based on Maine's experience, in which expert biologists independently assigned samples of macroinvertebrates to *a priori* defined levels of biological condition defined by differences in assemblage attributes (Davies et al. 1995; Davies et al. In press; Shelton and Blocksom 2004).

To provide a functional framework for practitioners, the workgroup described how each of the 10 attributes varies across six levels of biological condition along a gradient of increasing anthropogenic stress (i.e., human disturbance). The general model was then described in terms of the biota of a specific region (Maine). Based on 20 years of monitoring data, the Maine BCG describes how the relative densities of specific taxa, with varying sensitivities to stress, change across the BCG levels of condition (Davies and Jackson 2006).

To test the general applicability of the BCG to sampling data taken from other stream systems across the country, the workgroup evaluated how consistently individual biologists classified samples of aquatic biota based on the attributes incorporated into the BCG. Government, field, and research biologists participated in the data exercise. The full workgroup was divided into breakout groups according to region (northeast, south-central, northwest, arid southwest/great plains) and assemblage (fish or invertebrates) expertise. Samples were selected from invertebrate and fish data sets to span as many of the BCG levels as possible (i.e., to span the full gradient of conditions). The invertebrate samples and fish samples used in the tests were collected from six different regions within the U.S. (northeast, mid-Atlantic, southeast, northwest, southwest, central) and included only basic descriptors of stream physical characteristics (e.g., substrate, velocity, width, depth), taxonomic names, densities, and in some cases, metric values. These data represent the basic core elements common to nearly all biological monitoring programs. Participants were asked to place each sample into one of the six condition levels, and they were cautioned not to apply a simple relative quality ranking since all six levels did not necessarily occur within the data sets. Biologists relied primarily on differences in relative abundances and sensitivities of taxa (i.e., attributes I–VI) to make level assignments, because this was the information typically collected in state monitoring programs and the data needed to evaluate the status of the other attributes were not available. Percent concurrence among the individuals was calculated to assess the level of agreement among biologists when applying the BCG to raw data. Perfect concurrence was set to equal the product of the number of raters by the number of streams.

In the first stage of the data exercise, between-biologist differences were evaluated by asking all workgroup participants to rate a single data set of 6–8 samples. The breakout groups were then asked to classify samples from larger and more variable data sets. The groups were also instructed to summarize their interpretations and to identify biological responses to changes in conditions not captured by the BCG. Finally, the workgroup participants identified how, from their perspectives, the BCG levels corresponded to the CWA biological integrity objective and interim goal for protection of aquatic life (e.g., protection and propagation of fish, shellfish, and wildlife).

Overall, workgroup members independently agreed on placement of sites in the same BCG levels for 82% of the benthic macroinvertebrate samples and 74% of the fish samples. When assignments differed, the range of variation among workgroup members was within one level in either direction for all samples with a few exceptions. BCG levels were revised following full workgroup discussion so that transitions were more distinct.

Each of the breakout groups independently reported that the ecological characteristics corresponding to BCG levels 1, 2, 3 and either some or all of BCG level 4 characteristics were generally compatible with how they assess the CWA's interim goal for protection of aquatic life. The experts unanimously agreed that BCG levels 1, 2, and 3 attained the CWA goal and BCG levels 5 and 6 did not. Opinions differed among the experts on whether all or some aspects of BCG level 4 characteristics were compatible with attaining this goal. For example, the workgroup extensively discussed what constituted an acceptable degree of replacement of sensitive taxa by tolerant taxa. However, experts united in a clear consensus that the BCG process provided detailed, readily transparent documentation of the expert logic and underlying science for establishing BCG levels. Additionally, expert discussion on implementation of the BCG framework to interpretation of condition included the following programmatic considerations:

- *The technical rigor of the monitoring program that produced the condition assessments*—Conceptually, a less rigorous monitoring program produces assessments with a greater degree of uncertainty, or precision, and potentially lower accuracy. In lieu of improving the program's technical rigor, or to compensate for uncertainty associated with monitoring programs of lower technical rigor, some experts recommended that a more protective, e.g., conservative, BCG level be used to measure attainment of the CWA ALU goal.
- *Protection of high quality conditions*—The experts identified the characteristics described by BCG levels 1 and 2 as consistent with their understanding of the CWA "biological integrity" objective. Concern was expressed that a single threshold comparable to BCG level 4 is not protective of high ecological quality and that water bodies comparable to BCG levels 1, 2, or 3 would likely decline significantly before action would be triggered to address sources of degradation. Experts noted that restoration and remediation costs are typically much higher than costs for prevention. Experts recommended that multiple thresholds protective of existing ALU conditions be established (e.g., thresholds comparable to BCG levels 2, 3, or 4). Alternatively, if only a single threshold is established, some experts recommended that the threshold should be protective of higher level conditions comparable to BCG level 3.

Workgroup members reported that key concepts were important with respect to classifying samples into levels and identifying the boundaries in between. For levels 1 and 2, biologists identified the maintenance of native species populations as essential to their understanding of biological integrity. Although many participants noted that methods for distinguishing differences between levels in attribute VIII (ecosystem function) were poorly defined, most nevertheless identified ecosystem function changes (as inferred by marked changes in food-web structure and guilds) as critical in distinguishing between levels 4 and 5.

Discussion following the data exercise revealed that participants readily agreed on some of the BCG attributes, but not others. For example, participants indicated they mostly used attributes I–V (taxonomic composition, pollution sensitivity), attribute VI (non-native taxa, for levels 2–6 only), and attribute VII (organism condition) to evaluate biological conditions in streams and wadeable rivers. In contrast, because attributes VIII–X (ecosystem function and scale-dependent features) are rarely directly assessed by biologists, the evaluation of these attributes was accompanied by relatively high uncertainty. Even so, workgroup members strongly advocated retaining these attributes in the BCG because of the importance of this information in making restoration decisions. There was considerable discussion regarding to which axis, the biological or stress axis, the attributes for ecosystem connectance and spatial and temporal extent of detrimental effect should be assigned. As an interim measure, the workgroup members recommended including these attributes as components of the biological axis primarily because of the importance state biologists placed on this information in predicting restoration or protection success. The BCG, thus, serves as a guide to interpret condition and is expected to be further refined as development and application continues.

The presence of non-native taxa in level 1 was also the subject of considerable discussion. Knowledge of the extensive occurrence of some non-native taxa in otherwise near-pristine systems conflicted with the desire by many to maintain a conceptually pure and natural level. Further discussion resulted in agreement that the presence of non-native taxa in level 1 is permissible only if they cause no displacement of native taxa, although the practical uncertainties of this provision were acknowledged. The resulting level descriptions, which allow for non-native species in the highest levels as long as there is no detrimental effect on the native populations, has practical management implications. For example, introduced European brown trout (*Salmo trutta*) have replaced native brook trout (*Salvelinus fontinalis*) in many eastern U.S. streams. In some catchments, brook trout only persist in stream reaches above waterfalls that are barriers to brown trout. The downstream reaches can be nearly pristine except for the presence of brown trout. In these places, if society decided to remove the introduced brown trout, and if stream habitat is preserved throughout the catchment, brook trout can potentially repopulate downstream reaches. In the use designation process, recognizing that the entire catchment has the *potential* to attain level 1 condition will inform the public that a very high quality resource exists.

Critical gaps in knowledge and scientific literature were uncovered during the development of the BCG. For example, the workgroup identified the need for regional evaluations of species tolerance to stressors. Tolerance information presented in the current version of the BCG tends to be based on generalized taxa responses to a non-specific stressor gradient. At that time, tolerance information was not available for most taxa and for many common stressors (temperature, nutrients, and sediments). In some cases, tolerance values are based on data collected in other geographic regions or for other purposes (e.g., van Dam's European diatom tolerances are used for North American taxa) (van Dam et al. 1994). In the future, availability of improved tolerance value information can be used to refine the BCG and improve its precision (e.g., Cormier et al. 2013; Whittier and Van Sickle 2010).

Additionally, taxa that are considered tolerant to stressors in one region of the country may not be similarly classified in another region. For example, long-lived taxa have generally been characterized as sensitive to increasing pressure and tend to be replaced by short-lived taxa in stressed systems. As such, the presence of long-lived taxa in a water body has been used to indicate high quality conditions, whereas the predominance of short-lived taxa may indicate degradation. However, in streams in the arid western U.S., extreme changes in hydrology might define the natural regime and an opposite trend might be observed: short-lived taxa can dominate the biological community in natural settings. In these systems, a shift to long-lived taxa may be an indicator of altered, less variable flow regimes due to flow management.

When the expert workgroup was initially developing the conceptual BCG framework (2000–2004), attributes VIII–X were not routinely measured as part of a state biological monitoring and assessment program. However, the state scientists participating in the workgroup deemed these attributes as ecologically important because the extent of ecosystem alteration has important environmental implications in terms of an individual water body's vulnerability to further effects from stressors, as well as potential for mitigation (Davies and Jackson 2006). The state scientists explained that they informally estimated ecosystem function, connectance, and extent of detrimental effects using different surrogate measures (e.g., shift in functional feeding groups) and/or measures of watershed condition (e.g., presence and connection of wetlands and streams, intact forests). This information was used to inform decisions on recovery potential for a water body and prioritize actions to protect high quality conditions.

Additionally, attributes IX and X might play an important role in evaluating longer term impacts, restoration potential, and recoveries. For example, ecosystem connectivity is fundamental to the successful recruitment into and maintenance of organisms in any environment. A single impacted stream reach in an otherwise intact watershed has far more restoration potential than a similar site in a basin that has undergone extensive landscape alteration.

A critical gap that was not discussed in 2005, but is now an area of intensive work, is predicting the impacts of climate change on aquatic systems. Gaining an understanding of how the BCG attributes (I–X) will behave under future climate scenarios, and developing approaches and indicators to measure these impacts, will be important future work for improving the BCG.

2.5 Conclusion

The conceptual BCG framework is a tool to help state water quality management programs better describe their ALU goals and measure increments of change in biological condition along a full gradient of stress—and to use that information to interpret existing conditions, identify high quality waters, and track progress towards achieving desired improvements. The BCG provides a common interpretative framework to assist in comparability of results across jurisdictional (e.g., county, state, national) and program (e.g., water quality and natural resource agencies) boundaries and to communicate this information to the public. In order to use the BCG, states will need to calibrate it to their own habitats and monitoring data and develop a numeric model. Although the BCG is a universal conceptual framework, quantitative calibrations are regionally data set-specific. Additionally, as an added benefit, state water quality management programs have reported that using expert consensus in developing BCGs has proven to be a valuable training tool for their technical staff and field crews. The panel interactions and development of consensus in interpreting data directly contribute to a more uniform approach and shared understanding of the aquatic ecosystems for which the state is responsible. Chapters 3 and 4 describe how a quantitative BCG model can be developed using expert panels and different approaches for quantification of the conceptual framework.

Chapter 3. Calibration of Biological Condition Gradient Models

The purpose of calibrating the BCG is to populate the conceptual model with quantitative data, develop quantitative decision rules to assign sites to BCG levels, and build a bridge from that model to management goals and endpoints. A calibrated BCG has both a narrative and a quantitative scientific description applicable to specific ecological regions or subregions. The BCG level descriptions can be used to describe the biological conditions associated with specific management goals and to support biological criteria development. The scientific description of the BCG can help make the management goals transparent to both decision makers and stakeholders. It can be used to assess baseline conditions and track incremental changes in condition.

This chapter proposes an approach to develop detailed narrative descriptions of BCG levels and attributes. Description and calibration of the BCG are achieved through consensus of expert opinion (Figure 7). The experts define the attributes, and the changes in those attributes, that characterize BCG levels and signal shifts to a different level. The outcome is a multiple attribute decision model that simulates the consensus expert decisions based on a set of quantitative rules. The next chapter provides three approaches to quantify the narrative BCG and develop numeric thresholds for site assignments.

Figure 7. Benthic macroinvertebrate and fish experts developing decision rules for freshwater streams in Alabama.

Use of professional expert consensus has a long pedigree in the medical field, including the National Institutes of Health (NIH) Consensus Development Conferences to recommend best practices for diagnosis and treatment of diseases.[5] In addition to the NIH consensus conferences, other researchers, institutes, and countries develop medical consensus statements, using both the NIH methods and others (Nair et al. 2011).

Recent environmental assessments developed using professional judgment have shown that experts are highly concordant in their ratings of sites, including marine benthic invertebrate communities in California bays (Weisberg et al. 2008). Another example is in nearshore marine environments assessed by an international panel covering European Atlantic, Mediterranean, American Atlantic, and American

[5] The program ran from 1977 to 2013. For more information, see: http://consensus.nih.gov/. Accessed February 2016.

Pacific habitats and experts (Teixeira et al. 2010). The approach has also been demonstrated effective for developing assessments of sediment quality (Bay et al. 2007; Bay and Weisberg 2010) and a decision model for fecal contamination of beaches (Cao et al. 2013). Likewise, in BCG development, aquatic biologists have come to very tight consensus on the descriptions of individual levels of the BCG, as well as very close agreement on the BCG level assigned to individual sites (e.g., Danielson et al. 2012; Davies and Jackson 2006; Gerritsen and Jessup 2007a; Gerritsen and Leppo 2005; Gerritsen and Stamp 2012; Gerritsen et al. 2013; Jessup and Gerritsen 2014; Kashuba et al. 2012; Snook et al. 2007).

All scientific and technical products, including biological indices used for assessment, include results of professional judgment and assumptions throughout (Scardi et al. 2008; Steedman 1994). The BCG expert consensus approach asks the experts to make judgments on the biological significance of changes in the attributes identified in Chapter 2. For this approach to be credible and valid, the panel should be comprised of experts with a wide and deep breadth of knowledge and expertise and not be constrained to a single agency in order to minimize internal bias. Additionally, it is essential that the expert logic in developing the decisions be fully documented so the rules will be transparent and understandable to those that were not engaged in the expert panel. The objective is to develop a set of decision rules that can be implemented by others not engaged in the expert panel.

3.1 Overview

The first step in calibration of the BCG is to develop detailed narrative descriptions of BCG levels and attributes specific to the water body type and region. Experts are given assemblage species composition and abundance data sets from the region for which they are developing the BCG. In order to minimize pre-conceived judgments, they are also given physical information about the sites (e.g., catchment area, slope, elevation, ecoregion, habitat type) but not the precise locations, land uses, sources, and stressor information. Following discussion of the conceptual model of the BCG, including detailed presentation on the description of the BCG levels and attributes, the experts are asked to put each sample site into one of the BCG levels. Each sample is discussed by the group, and facilitators elicit the reasoning used by the experts in their ratings. The median of the expert ratings is taken as the final BCG level for a sample (Gerritsen and Jessup 2007; Gerritsen and Leppo 2005; Gerritsen and Stamp 2012; Gerritsen et al. 2013; Jessup and Gerritsen 2014; Snook et al. 2007).

After an initial rating of at least 30 samples, the experts are asked to begin to articulate rules or guidelines that they use to make their decisions, starting with the highest level (BCG level 1) and working through level 6. Data evaluations and site assignments continue as rules are articulated and then revisited and further tested. In some situations, it may be necessary for the experts to use historical data and information to develop rules for the highest levels of the BCG when there are no or few samples in the data set that are representative of undisturbed or minimally disturbed conditions. Following the expert meetings, organizers and analysts examine the distributions of the quantitative data with respect to the initial proposed guidelines stated by the experts and the experts' actual BCG decisions. The distribution analysis forms the basis of quantitative boundaries around the experts' proposed rules, and analysts in turn develop quantitative rule-based models. Quantitative rules and performance are in turn reviewed by the expert panels to adjust rules or thresholds as necessary. Reviews and iterative recalibration are typically carried out by webinar and conference call. The panels also rate an independent set of test samples that were excluded from the calibration process.

The outcome of a full BCG calibration, including development of a quantitative model, includes:

- A current state-of-knowledge description of the biological assemblage of water bodies under pre-development, undisturbed condition to serve as a fixed, historic baseline (the level 1 prototype). If there are no BCG level 1 sites available, then this description may be based on historical observations, records, and/or data.
- Descriptions of each identified level of the BCG.
- A set of transparent rules for assigning sample sites to levels of the BCG.
- A quantitative model of the rules, or other technical approach, to assign new samples to levels of the BCG, without reconvening an expert panel.
- A set of BCG condition levels that can serve as management goals for classes of water bodies and as thresholds for biological criteria, if the state so chooses.

There are several key steps to the calibration process (Figure 8):

- **Assemble and organize data—**The BCG is developed using information and data from the state's existing biological monitoring program and/or other data sources (e.g., different data sets or regional pooled data from other states and federal agencies). The data should cover the entire range of conditions and stress within at least one ecological region. The data set should be sufficiently large with a well-defined approach for classification, identification of natural conditions, and criteria for reference site selection. Usually, the BCG cannot be calibrated within small jurisdictions or within urban or agricultural regions only—it requires data from outside the jurisdiction to ensure that the least stressed reference, as well as the full range of other stressors, are represented.
- **Conduct preliminary data analysis/data preparation**—Prior to the calibration workshop, the data must be put in a format that can be readily used by workshop participants. In addition, stressor-response relationships are examined to describe the responses of the assemblages and of individual taxa to the stress gradients represented in the data.
- **Convene expert panel**—The key component of BCG calibration is expert consensus of aquatic biologists on qualitative and quantitative descriptions of the BCG levels. Experts selected should be familiar with the water bodies, identities of species, and species and assemblage responses to stress in the regions of concern. The panel should include experts from not only the state biological assessment program but other state and federal natural resource agencies and research scientists from the academic community. Additionally, experts who regularly work with the regulated community can offer a level of assurance and interpretive assistance about the purpose and value of using the BCG in water quality assessments.
- **Develop quantitative BCG model**—Following the development of decision rules, one of several approaches can be applied to automate assigning water bodies to condition levels in the state database. Approaches discussed in Chapter 4 of this document include multiple attribute decision models, multivariate discriminant models, and development of thresholds for commonly used biological indices (e.g., multimetric indices (MMIs) or predictive model indices (e.g., observed over expected taxa [O/E])).
- **Test models, adjust, and recalibrate**—The development process is iterative and may require several passes through the process to converge on a consistent, locally calibrated BCG that is scientifically defensible.

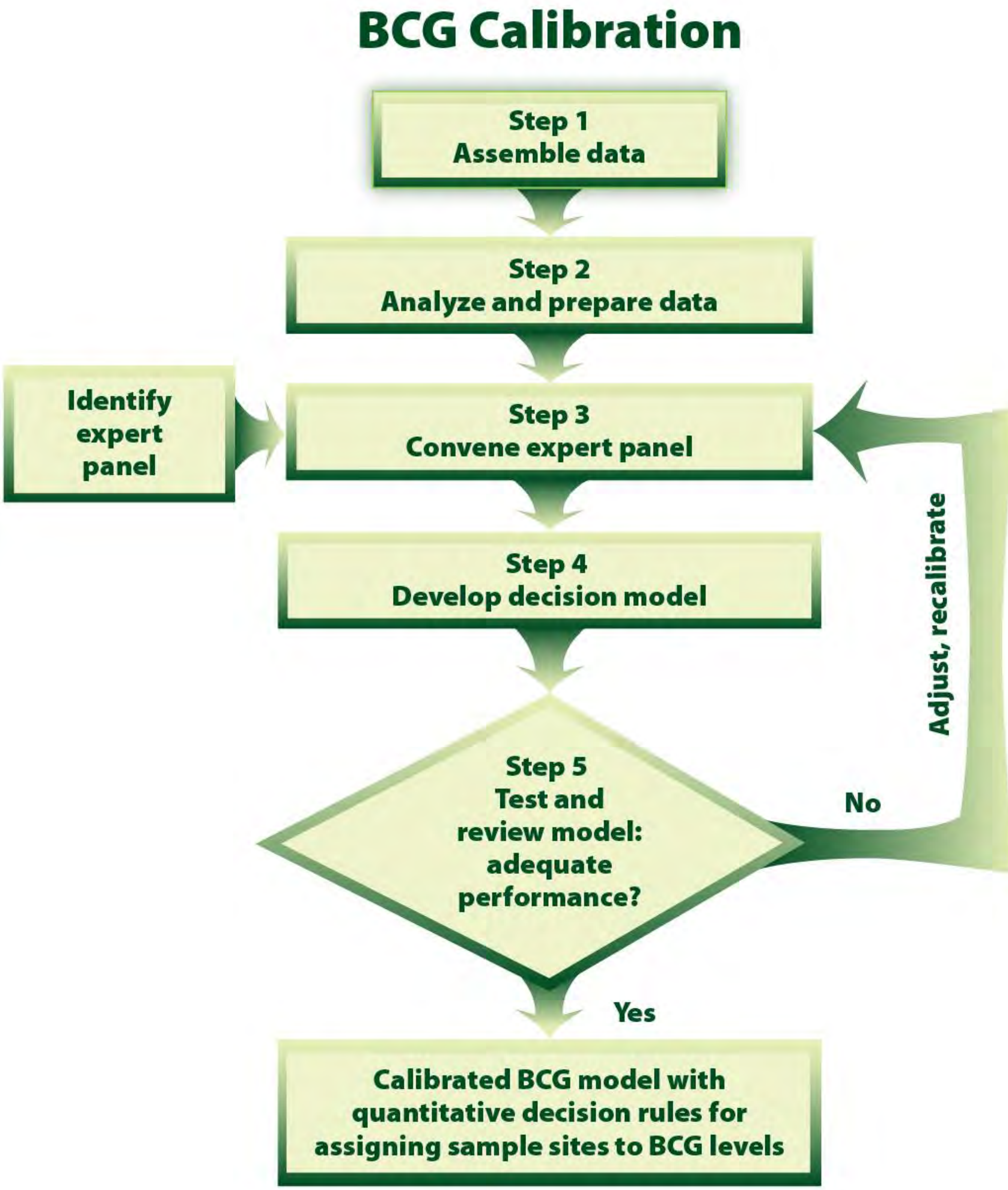

Figure 8. Steps in a BCG calibration.

3.1.1 Case Studies and Applications

Since 2005, several states or other entities (e.g., river basin associations, counties) have either calibrated, or are in the process of calibrating, the BCG (Table 4). Most of the BCG models that have been calibrated to date apply to perennial streams that are exposed to increases in temperature, nutrients, toxic substances, and fine sediments. This is the stream-type and stressor regime originally described by the conceptual model. Nevertheless, the model has been extended and calibrated to large rivers (Appendices B1 and B4; Bradley et al. 2014), estuaries (Appendix B2), coral reefs (Appendix B3; Shumchenia et al. 2015), and lakes (Gerritsen and Stamp 2014). Refinement of the model attributes to accommodate regional and water body type differences for water bodies other than streams and wadeable rivers has occurred without loss of model integrity. Thus, the BCG can be applicable to other aquatic ecosystems and stressors with appropriate modifications.

Section 3.2 below provides a detailed description of the step-by-step process that has been used to calibrate BCG models. Chapter 4 provides approaches to quantify the expert-derived BCG model, and case studies drawn from Table 4 illustrate different components of the process.

Table 4. BCG calibration and testing projects

State/Region	Water body type (if applicable)	Biological Assemblages	Objective	Status (Citation)
Alabama	Highland streams and wadeable rivers	Benthic macroinvertebrates and fish in high gradient streams	Calibrated BCG model and automated decision model for invertebrates (all streams) and fish (3 regions)	Complete (Jessup and Gerritsen 2014)
	Coastal plains streams	Benthic macroinvertebrates and fish in low gradient streams	Calibrated BCG model and automated decision model for invertebrates and fish	In progress
California	Streams	Algae	Calibrated BCG model and decision model for stream algae	In progress
Connecticut	High gradient streams and wadeable rivers	Benthic macroinvertebrates	Calibrated BCG model and automated decision model; also calibrated to Connecticut's macroinvertebrate MMI	Complete. (Gerritsen and Jessup 2007b)
		Fish	Calibrated BCG model and automated decision model; also calibrated to Connecticut's fish MMI	Complete (Stamp and Gerritsen 2011)
Illinois	Streams	Benthic macroinvertebrates and fish	Calibrated BCG model and automated decision model	In progress
Indiana	Streams and rivers	Fish	Calibrated BCG model and automated decision model	In progress
Maine	Streams and wadeable rivers	Algae	Calibrated BCG model to assign ALUs per Maine's 3 designated use classes and technical approach for benthic macroinvertebrates	Complete (Davies and Tsomides 2002; Davies et al. In press; Danielson et al. 2012)
	Wetlands	Benthic macroinvertebrates	Calibrating automated decision model to assess tiered designated ALU classes	In progress
Maryland, Montgomery County	Streams	Benthic macroinvertebrates and fish (quantitative), salamanders (qualitative)	Calibrated BCG model to communicate monitoring information on condition	Stamp et al. 2014

State/Region	Water body type (if applicable)	Biological Assemblages	Objective	Status (Citation)
Minnesota	Streams and wadeable rivers	Benthic macroinvertebrates and fish	Calibrated BCG model and automated decision model for nine stream types; also incorporates Region 5 coldwater results	Complete (Gerritsen et al. 2012)
	Lakes	Fish	Calibrated BCG model and automated decision model for four lake types	Complete (Gerritsen and Stamp 2014)
New England	High gradient streams and wadeable rivers	Benthic macroinvertebrates	Cross-calibrated BCG model and automated decision model for multiple sampling methodologies	Complete (Snook et al. 2007)
New England	Large rivers	Fish	Calibrated BCG model and automated decision model	In progress
New Jersey	High and low gradient streams and wadeable rivers	Benthic macroinvertebrates	Calibrated BCG model and automated decision model	Complete (Gerritsen and Leppo 2005)
	Streams and wadeable rivers	Diatoms	Calibrated BCG model and automated decision model	In progress
Pennsylvania	High gradient streams and wadeable rivers	Benthic macroinvertebrates	Conceptual model and verbal description of BCG levels, calibrated to Pennsylvania's MMI	Complete (Gerritsen and Jessup 2007a)
Puerto Rico and U.S. Virgin Islands	Stony coral reefs	Stony corals and resident reef fish	Calibrated BCG model and automated decision model	In progress (Bradley et al. 2014)
Rhode Island	Estuaries	Seagrass extent, benthic community, shellfish production, primary productivity in Greenwich Bay, Rhode Island	Conceptual BCG model anchored in natural conditions prior to 1850 and showing changes	Complete (Shumchenia et al. 2015)
		Habitat mosaic indicator as measure of whole system condition for Narragansett Bay	In progress	In progress preparation, Shumchenia et al. in review)
Upper Mississippi River Basin	Large rivers	Fish	Calibrated BCG model and automated decision model	In progress
Vermont	Streams and wadeable rivers	Benthic macroinvertebrates	Calibrated BCG model and biological criteria	VT DEC 2004

3.2 Step One: Assemble and Organize Data

Evaluating data quality and preparing it for rule development is critical for an efficient and effective expert panel meeting. The data should cover the entire range of conditions and stress within at least one ecological region. Typically state databases have been used in the stream BCGs developed to date, but large regional databases, either a single data set or pooled data sets, have also been used (e.g., Upper Mississippi Basin BCG and New England River BCG (see Appendices B1 and B4)). Combining data sets presents a unique set of challenges for experts in interpreting site data and detecting consistent patterns of biological change in response to increasing stress. If different data sets are combined, decisions on how the data sets are reconciled must be well documented for the experts to successfully use the data in rule development. When BCG rules are developed for more than one assemblage, typically different data sets are used for each assemblage and the rules are developed and applied independently. The rules for the different assemblages are tested jointly as a later step in the BCG model development.

There are three tasks required for assembling and organizing data prior to convening an expert panel:

1. **Obtain Data**—In preparation for the calibration process, relevant data are extracted from the database. Data should include the biological survey (taxonomic identification and counts) and all related data on the geo-referenced sampling site: locations and characteristics; catchment data including area, slope, land use characteristics, and physical habitat; chemical water quality data; and field observations by sampling personnel. Evaluation and documentation of the quality of the data set is an essential component of the BCG approach, including documentation of technical issues and concerns that should be further addressed through additional data collection and analysis. Section 3.2.1 discusses elements of a data set and monitoring program that should be evaluated and documented.
2. **Determine Natural Classification**—In order to prevent natural variability from confounding responses to stress, it is necessary to determine a natural classification system for the water bodies under consideration (if not already complete) (USEPA 2013a). If there is only a collection of data, and no agreed-upon classification system, substantial analytical effort might be needed to develop it. Classification is beyond the scope of this document; see Barbour et al. (1999), Hawkins et al. (2000a), USEPA (2013a), Olivero and Anderson (2008), and Olivero Sheldon et al. (2015) for references to classification approaches for freshwater streams. Selection of a classification method was one of the first tasks the coral reef expert panel undertook prior to successful rule development (see Appendix B3). The classification decision has implications for statistical sampling design and monitoring protocols.
3. **Organize Data Tables**—A comprehensive and relational database is a requirement for a high quality monitoring program (USEPA 2013a). Data can be organized in spreadsheets for the panel workshops (see Figure 12 for an example of datasheet used in BCG development to date). For permanent storage, retrieval, archiving, and to maintain a quality record, a relational database will be necessary (e.g., Oracle®, MS-Access®, Sequel Server®).

Quantitative assessment within the BCG framework requires consistent, high quality biological, physical, chemical, and geographic monitoring information. The technical foundation of monitoring determines the degree of confidence with which the information can be used to support water quality management decision making, including calibration of the BCG. This section describes data requirements consistent with EPA's recommended program review of biological assessment programs (USEPA 2013a).

All BCG developments to date have used existing state or federal agency monitoring data. There have been no monitoring programs specifically designed for BCG development. However, recommendations on the technical elements of a monitoring program that would produce good data for BCG development are not different from the requirements for a high-quality program specified by EPA (2013a) and are discussed below. This document is not guidance for monitoring design, optimal effort, or sampling methods. Instead, it focuses on minimum requirements for BCG development, including consistently sampled aquatic biota; water quality and habitat observations adequately matching the biological sampling; and land use/land cover information (e.g., from the NHD coverage). Consistency and adequacy of a data set are evaluated by the expert panel, analysts, and facilitators, and documentation of BCG development includes recommendations on specific technical areas where further development would strengthen or refine the quantitative BCG model and underlying decision rules.

3.2.1 Data Requirements: Understanding the Quality of the Data Set

EPA described 13 technical elements contributing to quality of biological assessment programs (USEPA 2013a). These elements are listed below and constitute the technical underpinnings important for a biological assessment program to be able to discriminate levels of condition along a gradient of disturbance (Table 5). Selected elements of biological assessment program design and data collection, compilation, and interpretation important for BCG development are discussed below. For a more complete description, see EPA's *Biological Assessment Program Review: Assessing Level of Technical Rigor to Support Water Quality Management* (USEPA 2013a). It is recommended that these elements be considered when assembling a data set for BCG calibration. Understanding the technical strengths and limitations of the data sets to be used in the calibration will help guide development of the BCG and its application.

Table 5. Definitions of the technical elements (USEPA 2013a)

	Technical Element	Definition
Biological Assessment Design	Index Period	A consistent time frame for sampling the assemblage to characterize and account for temporal variability.
	Spatial Sampling Design	Representativeness of the spatial array of sampling sites to support statistically valid inference of information over larger areas (e.g., watersheds, river and stream segments, geographic region) and for supporting WQS and multiple programs.
	Natural Variability	Characterizing and accounting for variation in biological assemblages in response to natural factors.
	Reference Site Selection	Abiotic factors to select sites that are least impacted, or ideally, minimally affected by anthropogenic stressors.
	Reference Conditions	Characterization of benchmark conditions among reference sites, to which test sites are compared.
Data Collection and Compilation	Taxa and Taxonomic Resolution	Type and number of assemblages assessed and resolution (e.g., family, genus, or species) to which organisms are identified.
	Sample Collection	Protocols used to collect representative samples in a water body including procedures used to collect and preserve the samples (e.g., equipment, effort).
	Sample Processing	Methods used to identify and count the organisms collected from a water body, including the specific protocols used to identify organisms and subsample, the training of personnel who count and identify the organisms, and the methods used to perform quality assurance/quality control checks of the data.
	Data Management	Systems used by a monitoring program to store, access, and analyze collected data.
Analysis and Interpretation	Ecological Attributes	Measurable attributes of a biological community representative of biological integrity and that provide the basis for developing biological indices.
	Discriminatory Capacity	Capability of the biological indices to distinguish different increments, or levels, of biological condition along a gradient of increasing stress.
	Stressor Association	Relationship between measures of stressors, sources, and biological assemblage response sufficient to support causal analysis and to develop quantitative stressor-response relationships.
	Professional Review	Level to which agency data, methods, and procedures are reviewed by others.

3.2.1.1 Biological Assessment Design Elements

The first four technical elements are particularly critical aspects of sampling design to consider when evaluating data for BCG calibration, and they involve selection of sites and times for sampling to obtain representative and statistically valid information (USEPA 2013a). The fifth element, reference condition, is also discussed below but in relation to its role relative to the BCG benchmark, BCG level 1 (e.g., anthropogenically undisturbed reference condition).

Index Period

Sampling index periods are selected based on known ecology to minimize or account for natural variability, maximize sampling gear efficiency, and maximize the information gained on the assemblage (Barbour et al. 1999; USEPA 2013a). For temperate fresh water bodies, index periods are typically a span of 3–6 months during the growing season.

Spatial Sampling Design: Representative of Stress Gradient

The objective of BCG calibration is to characterize the biological response across a generalized stress gradient from undisturbed to highly disturbed conditions. The BCG should be developed for specific natural classes, such as ecoregions or physiographic provinces. Sample coverage must be representative of the ecoregion(s), as well as the stress gradients that can occur. Case examples of characterizing stress gradients are given later in this chapter (section 3.3.1) and discussed more generally in Chapter 5. Achieving representativeness might require using data from outside of the jurisdictional boundaries of a state so that ecoregional expectations are as fully sampled and defined as possible. In addition to representativeness, the data should have sufficient sample size to support the calibration. As a rule-of-thumb, 30 or more samples for each water body class (at a minimum for levels 2–5, and levels 1 and 6, if regionally available) are generally required (see natural classification below). If samples are not sufficient, then BCG development should be delayed until enough data are acquired.

Calibration of the BCG model requires data points (samples) along the stress gradient from low to high levels of stress. An expert panel examines the sites and assigns the sites to BCG level based solely on the biological information. Having the stress information ensures that the expert panel sees sites that are representative of the stress gradient. Ideally, the data set needs to include the full gradient of conditions and complement of stressors (e.g., pollution sources, invasive species, habitat disturbances) that are common to a state or region, such that the full gradient of assemblage response is included in the model development.

Natural Variability: Classification

Biological assessment based on knowledge of the biota under undisturbed or minimally disturbed reference sites forms expectations for natural conditions. Many natural regional and habitat characteristics (e.g., stream size, slope, dominant natural substrate) also affect the species composition of undisturbed water bodies. Accordingly, a critical step in developing a biological assessment program is to classify the natural conditions to the extent that they affect the biological indicators (e.g., Barbour et al. 1999; Gibson et al. 1996; Hawkins et al. 2000a). The term classification includes development of continuous models that explain natural variability of biological assemblages. For example, fish species richness is strongly dependent on catchment area or average flow. Modeling approaches that combine both discrete and continuous variables (e.g., general linear models) may be especially powerful if the data support them. Failure to properly classify sites can cause the BCG calibration to fail, yielding assessment errors that can undermine confidence in results. Classification of natural conditions should be complete and satisfactory to experts. If not, time and resources will be necessary to develop the classification system.

Reference Site Selection

Obtaining a representative stress gradient requires that the data set is large enough to include the full range of disturbance, from undisturbed to highly disturbed conditions. Data owners and field personnel should document the comprehensiveness of the data set with respect to coverage of the full range, or not, of disturbance. It might be necessary to obtain data from neighboring states or regions to ensure that the gradient is represented in the data set. A minimum of 30 to 40 sites might be sufficient to calibrate the BCG depending upon both the characteristics of the natural system and the quality of the data set. Characterization of the quality of reference sites is essential to defining the range of conditions in the data set the experts will be using to develop decision rules. The criteria used by states to select their reference sites inform this determination.

Reference Condition

In this document, the terms "undisturbed," "minimally disturbed," and "least disturbed" conditions are used when referring to the level of anthropogenic stress to which a water body and its surrounding watershed may be subject. These terms are well defined by Stoddard et al. (2006). The level of stress associated with the reference sites used by the state to define reference condition is the critical information needed for BCG calibration. In many cases, the state's reference condition is not comparable to the BCG benchmark for undisturbed or minimally disturbed conditions. This is important information, not only for the BCG calibration but also for water quality program managers and the public.

BCG calibration is not based on least disturbed reference sites, because least disturbed sites are typically the "best of what is left" and may mistakenly be perceived by the public as the best that can be because undisturbed conditions no longer exist (e.g., Dayton et al. 1998; Papworth et al. 2008; Pauly 1995). In this case, expectations for improvements might be set lower than the potential for a water body to improve. Part of the BCG process can include developing a description of undisturbed conditions that may include consideration of contemporary, empirically least stressed sites and historical descriptions; paleolimnological investigations; and museum records. The description of an undisturbed condition may be narrative and perhaps incomplete, but its documentation helps provide a transparent and clear framework for the public to understand what biologically may have already been lost from their waters as well as potential for what could be restored. In many of the BCGs that have been developed, undisturbed and minimally disturbed conditions have been combined for practical purposes and categorized as representing BCG levels 1 and 2.

3.2.1.2 Methodological Elements

The second set of technical elements are aspects of quality in sampling, processing, and data management. Data used for calibration must be consistent, or be made consistent in post-processing. It is especially important to examine methods when biological assessment data from multiple sources are to be pooled. For information on combining data derived from multiple sources, see Gerritsen et al. (2015). Elements of sampling methodology include:

Taxa and Taxonomic Resolution

The biological response data should be the taxonomic composition and related information from one or more biological assemblages in water bodies: benthic macroinvertebrates, fish, periphyton, aquatic macrophytes, phytoplankton (lakes and estuaries), and zooplankton (lakes and estuaries). To develop the model, a knowledgeable panel of experts is required for each assemblage.

Experience has shown that "lowest practical" identification, to species when possible, is superior for BCG calibration, because species differ in their characteristics within genera. Species identification is necessary for fish assemblages, but genus-level identifications are adequate for BCG calibration using benthic macroinvertebrates. When pooling data, the taxonomic resolution must be standardized to the lowest common level among the data sets.

Sample Collection

Field methods should be consistent and well-documented. The objective of the sampling methods should be to obtain consistent samples that are representative of the target biological assemblage (see Barbour et al. (1999) and USEPA (2013a) for discussions of sample collection methods). The BCG has been cross-calibrated for several sampling methods used in New England and in the Upper Midwest (Gerritsen and Stamp 2012; Snook et al. 2007). Where possible, initial BCG development in a new region is done with data from a single sampling methodology and then can be calibrated and tested with data generated using different sampling methods. Level of effort is a key consideration in sample design. Many of the BCG attributes (attributes I, II, VI, VII, IX, and X) are particularly sensitive to level of effort. Certain key taxa may be sparse, seasonal, or patchy in their distribution and easily missed by a standardized field collection method. In making a site assessment, other supplemental information (e.g., natural history surveys, fishery agency reports and observations, academic studies), beyond just the collected samples, should be included in making a level determination. This will lend an additional layer of confidence and improve the result.

Sample Processing

Laboratory processing of samples (except fish) is recommended (USEPA 2013a; Yoder and Barbour 2009). Macroinvertebrate and diatom samples are typically processed to a standardized count representing a constant sampling effort. In some cases, if subsampling efforts are mixed, it is possible to randomly subsample larger efforts to smaller efforts (e.g., 300-count subsamples randomly subsampled further to match 100-count subsamples).

Data Management

Identification of reference and stressed sites requires that the monitoring database be comprehensive, including watershed and site characteristics, habitat measurement, and physical and chemical water quality measurements. Physical and chemical measurements should be made at the same time and place that the biological community information is collected. Non-biological data, including catchment area, slope, land use, site, habitat, and physical and chemical water quality data are used to determine a site's natural classification and stressor status, such as whether it is a reference site or a stressed site, and where it is located along the stress gradient.

Data should be stored in a relational database so that queries can retrieve relevant information (e.g., biological data, chemical data, physical measurements) on site, geo-referenced location, multiple measurements from multiple sampling times, and catchment data. Data stored in spreadsheets or warehoused in such a way that physical, chemical, and accurate geo-reference cannot be located are of limited use and might require substantial costs to fill in missing information and for quality assurance (Gerritsen et al. 2015). Exceptions should be made for historic information and data that may not be amenable to spreadsheets. These data may not be suitable for a relational database but should be retained because they may provide important qualitative information and context that can be used to inform BCG development.

3.2.1.3 Analysis and Interpretation Elements

Ecological Attributes

These are the measurable attributes of a biological community that are representative of biological integrity and which provide the basis for developing a BCG model. The BCG attributes (Table 1) are the basis for this technical element. The selection of attributes might depend on the spatial scale and specific water body being assessed. Each attribute provides some information about the biological condition of a water body. Combined into a conceptual model comparable to the BCG, the attributes can offer a more complete picture about current water body conditions and also provide a basis for comparison with naturally expected water body conditions. All states that have applied a BCG for streams, rivers, and wetlands have used the first seven attributes that describe the composition and structure of the biotic community on the basis of the tolerance of species to stressors. Where available, they have included information on the presence or absence of native and nonnative species, and, for fish and amphibians, used measures of overall condition (e.g., size, weight, abnormalities, and tumors). Though not measured directly in state or tribal stream biological assessment programs, the last three BCG attributes of ecosystem function and connectedness and spatial and temporal extent of stressors can provide valuable information when evaluating the potential for a stream, river, or wetland to be protected or restored.

Discriminatory Capacity

This technical element addresses the degree of sensitivity of the BCG model in distinguishing incremental change along a continuous gradient of stress. Detailed descriptions of biological change along a gradient of stress can provide the conceptual basis for refined ALUs for specific ecotypes and regions leading to biological criteria development. Additionally, depending on the sensitivity, or discriminatory capacity, of the BCG model, the information can be used to help identify high quality waters and establish incremental goals for improving degraded waters. Six general increments of change can be described for each of the BCG's ecological attributes (for example, see Table 3). These incremental changes can serve as a template for developing biological criteria that represent aspects of biological integrity and which show a predictable, measurable response to increasing levels of stress.

The number of increments that can realistically be distinguished in a BCG model is dependent not only on the water body ecotype and natural classification factors that define biological assemblage characteristics, but also on the effect of anthropogenic stressors. For example, the sensitivity of an index developed for a forested, high-gradient stream might support distinguishing five or even six increments of quality along a continuous stressor gradient, while an intermittent, seasonal, or desert stream may yield fewer increments. Some of this difference is due to inherent natural characteristics of the assemblages, and some might be due to current limitations of science and practice.

Stressor Associations

Stressor association refers to the use of biological assessment data at appropriate levels of taxonomy to develop relationships between measures of biological response and anthropogenic stressors, including both stressors and their sources (Huff et al. 2006; Miller et al. 2012; Yuan 2010; Yuan and Norton 2003). This element includes examination of biological assessment data for patterns of response to categorical stressors (Riva-Murray et al. 2002; Yoder and DeShon 2003; Yoder and Rankin 1995a). A capability for developing these relationships extends the use of biological assessments from assessing condition to informing identification of possible causes and sources of a biological impairment at multiple scales.

Stressor association is directly dependent on a high level of technical development of other elements, particularly the elements for spatial sampling design, taxa and level of taxonomic resolution, database management, and discriminatory capacity. These elements are important building blocks for the data collection and analysis needed to more confidently identify stressors and their sources and to estimate stressor-response relationships. For example, the ability to estimate these relationships relies on paired stressor and response sampling at appropriate spatial and temporal scales and a level of taxonomic resolution and index sensitivity sufficient to detect incremental biological changes along a stress gradient. Also, a relational database that supports complex queries enables efficient and full utilization of data. A high level of technical development for each of these elements and others provides the foundation for stressor association.

Professional Review

Professional review and testing of the BCG quantitative decision rules should be conducted by experts outside of the panel to evaluate and improve model objectivity and scientific defensibility and to refine and improve the model. Review by outside experts can be used to refine and improve the model. Because of the specific knowledge of the expert panel for any given BCG, discussion with the outside peer reviewers is essential. Technical expert review across expert panels has not yet been conducted for the BCGs developed to date, but it is planned as a pilot.

3.3 Step Two: Preliminary Data Analysis and Data Preparation

Before an expert panel is convened to describe the BCG levels, it is necessary to reduce and prepare the data for the panel's use during the workshops and webinars. In addition, it is useful to conduct exploratory data analyses to visualize empirical relationships of the biotic assemblages. Analysis and data preparation include:

1. **Characterizing Stress Gradients—**Identifying stress gradients to select sites for BCG calibration that are representative of stress gradients in the region, from undisturbed to highly disturbed levels of condition. If undisturbed conditions do not exist, the level of disturbance should be recorded and efforts made to collect historical data and records that may help the panel develop a conceptual, descriptive condition level absent of anthropogenic influence (BCG level 1). See Chapter 5 for further discussion.
2. **Analyzing Taxon Response Relationships—**Using the stress gradient(s) to examine stressor-response of individual taxa to augment known or surmised species tolerances and traits with empirical information on responses observed in the field, as well as to develop species distribution maps of species observed in the data set. This step also ensures that all panelists have the same information available to them, as some panelists may be more familiar with the monitoring data set than others. See Chapter 5 for further discussion.
3. **Preparing Data Work Sheets—**Identifying and formatting a calibration data set for the workgroup's calibration exercise.

This section discusses the preliminary analysis and data manipulation prior to calibration workshops.

3.3.1 Data Preparation: Characterize Stress Gradients

Water bodies are subject to a wide variety of anthropogenic stressors, and multiple stressor situations are common. However, few state data sets are sufficiently large and complete to be able to analytically separate the effects of individual stressors. To help select sites for the calibration exercises, a practical approach is to consider all stressors together without regard for interactions among them (Smith et al. 2001), or to use aggregate land cover as a summation of sources of potential stressors to streams (e.g., Landscape Development Intensity Index [LDI]; Brown and Vivas 2005). Stressor-response analysis with multiple, independent stressor gradients is currently an area of active research (e.g., Baker and King 2010; Norton et al. 2015), but it is beyond the scope of this document.

Quantitative Gradients

Identifying stress gradients relevant to the data sets at hand will be facilitated by some exploratory data analysis to identify biological responses to the stressors. Scatter plots are generally the most useful and efficient, but more detailed analysis can be done if desired, including regression analyses, quantile regression, and classification and regression tree (CART) analysis (Death and Fabricius 2000), and other models. The purpose of these analyses is not diagnostic, as BCG calibration does not include identifying the most likely causes for biological impairment. The purpose is to develop a database suitable for discerning patterns of biological response to increasing levels of stress.

Scatter plots can be examined for every stressor that will be included in a stress gradient, as well as for aggregated sources of stress such as land use/land cover. For this purpose, scatter plots are simple graphical displays of a response variable on the y-axis, against a presumed correlated parameter on the x-axis (e.g., Figure 9). Examples of stress variables examined for some of the BCG applications are shown in Table 6.

Table 6. Examples of quantitative stressor variables that have been used for BCG projects

Project	Quantitative Disturbance gradient
Minnesota streams	Human Disturbance Score (HDS)
Connecticut streams (fish)	% Developed area
Minnesota lakes	% Urban + Agricultural + Mining land use
	Trophic State Index
Maine stream algae	Total phosphorus
Maine stream benthic macroinvertebrates	% Impervious surface
Northern Piedmont region of Maryland	% Impervious surface
	Habitat index
Alabama	Human Disturbance Gradient (HDG)
Illinois	Habitat index
	% Impervious surface
	Total nitrogen
Indiana	% Impervious surface

3.3.1.1 Example—Using Land Use/Land Cover Indicators to Develop a Quantitative Stress Gradient (Minnesota, Alabama, Maryland Piedmont)

Measures of land use and land cover have been used as surrogate indicators of stressor effects. Table 6 contains a list of these type of indicators that have been used for GSA development (For more information on the GSA, see Chapter 5). In the Northern Piedmont of Maryland, the workgroup selected imperviousness as a primary stress indicator (Stamp et al. 2014, see Chapter 6). The percent imperviousness in a watershed or a catchment was available for all sites in the data set. Based on scatterplots like the one shown in Figure 9, the level of imperviousness has a clear impact on biological assemblages. Imperviousness was considered during the sample selection process to ensure that the full stress gradient was represented in the BCG model calibration data set. Imperviousness was also used to generate the taxon-response plots that helped inform BCG attribute assignments (see section 3.3.2).

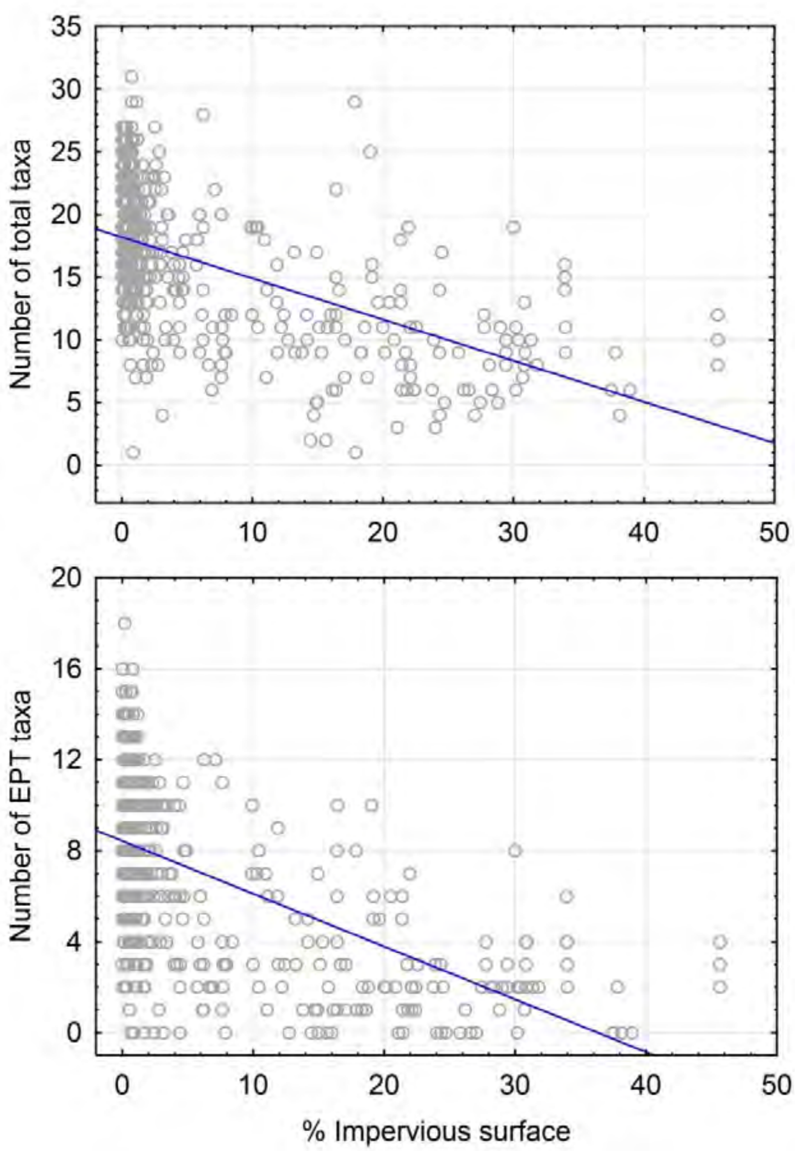

Figure 9. Scatterplots of number of total taxa (upper) and number of EPT taxa (lower) versus % impervious surface in the macroinvertebrate data set for streams in the Northern Piedmont of Maryland. Plots are fit with a linear trend line.

In some instances, quantitative stress gradients have been developed to capture multiple stressors in one integrated score. Examples include Minnesota's Human Disturbance Score (HDS) and Alabama's Human Disturbance Gradient (HDG). Input variables for the Minnesota HDS and the Alabama HDG are listed in Table 7 and Table 8, respectively. The Alabama HDG utilizes the LDI (developed by Brown and Vivas (2005)), which associates land uses with a scale of disturbance intensity and weights the index score based on land uses in the upstream catchment. Alabama Department of Environmental Management (ADEM) has used the HDG to assign its stream reaches to one of eight HDG categories based on the percentile of its overall HDG score, with categories 1–3 representing the top 25th percentile of watershed condition.

Table 7. Input variables for Minnesota Pollution Control Agency's (MPCA's) HDS (MPCA 2014a)

HDS Metric	Scale	Score
Animal unit density	watershed	10
Feedlot density	watershed	adjust
Feedlot proximity	local	adjust
Point source density	watershed	10
Point source proximity	local	adjust
Percent disturbed riparian habitat	watershed	10
Riparian condition rating	local	10
Percent agricultural land use	watershed	10
Percent agricultural land use within 100-m riparian buffer	watershed	adjust
Percent agricultural land use on ≥ 3% slope	watershed	adjust
Percent impervious surface	watershed	10
Urban land use proximity	local	adjust
Percent of stream distance modified by channelization	watershed	10
Site channelization rating	local	10
Road/stream intersection (road crossing) density	watershed	adjust

Table 8. Input variables for Alabama's HDG (Source: Lisa Huff, ADEM, personal communication)

The LDI associates land uses with a scale of disturbance intensity and weights the index score based on land uses in the upstream catchment, such that land uses that produce higher levels of disturbance receive higher LDI coefficients (Brown and Vivas 2005).

Variable	LDI coefficient	Source
Population density/km^2	1	2000 U.S. Census
% Urban	8	2006 National Land Cover Database
% Barren	8.6	
% Pasture	3.1	
% Cropland	4.7	
Road density	8.3	2010 Census TIGER/Line Shapefiles
# Stream/road crossings	8.3	

Ordinal Stress Gradient(s)

Where there are many measured stressors, it is possible to develop an ordinal, generalized stress gradient by summing and ranking the number of different stressors observed at distinct sites. A site is given a score of 1 for each stressor observed there (e.g., copper above a chronic screening threshold, excess nutrients, poor habitat score, upstream discharge), and the site score is the sum of all stressor scores. Sites with scores of 0 are candidates for "least stressed" within the context of the region. Categories of stress can be defined using measured stressors (e.g., contaminants and habitat condition) from the monitoring data, with watershed information that identifies sources of stress. The categories are a mixture of both sources and measured stressors and will inevitably be correlated to some extent. The categorization can identify a gradient of stress levels comparable to levels of disturbance (e.g., undisturbed, minimally disturbed, highly disturbed conditions (Stoddard et al. 2006)).

Stressors, whether individual or categories, can be screened by examining the response of individual taxa to the stressor or source (Figure 10)—if there is no response, the stressor should not be used in developing the ordinal gradient.

After relevant stressors and sources have been categorized, sites can be identified according to the number of stressors and sources in low, medium, or high categories. Sites where all stressors and sources are "low" qualify as least stressed, and sites where many stressors are "high" qualify as most stressed. Depending on the number of sites and stressors, intermediate categories can also be identified. Depending on the level of stressors detected in the "least stressed" category, undisturbed or minimally disturbed conditions may not be included in the data set. If this is the case, expert judgment on undisturbed or minimally disturbed conditions can be elicited based on historical observations, records, and data. Although a qualitative assessment, this information provides context for the quantitative information (e.g., "least stressed" conditions do not present undisturbed or minimally disturbed conditions).

3.3.1.1 Example: Connecticut Ordinal Stress Gradient

To identify sites to use in a BCG calibration exercise for Connecticut, analysts developed an ordinal stress gradient to apply to sample sites. The approach was to screen measured stressors for association with biological measurements and identify thresholds (stressor concentrations) below which no effects or association could be detected and screening thresholds above which association was strong. This was not an attempt to do a causal analysis (Norton et al. 2015), but simply a screening based on pairwise associations.

Connecticut DEP had sampled dissolved metals and several other water quality parameters simultaneously with each stream biological sample. For example, Figure 10 shows the number of Plecoptera (stonefly) taxa and dissolved copper concentration in Connecticut stream sites. High numbers of stonefly taxa (> 4) only occur when copper is less than 0.008 mg/L, and nearly all samples where copper was greater than 0.008 mg/L had fewer than 4 stonefly taxa (Figure 10). For the stressor gradient, the threshold for low copper stress was set at < 0.008 mg/L, and the threshold for high copper stress was set at > 0.008 mg/L. Note that there is not inference of causality, only screening of associations.

Stress categories were identified for Connecticut monitoring sites based on land use and water chemistry parameters in the database. Urban land use, natural land cover, population density, and chloride concentration were all good predictors of biological condition. Connecticut Department of Energy and Environmental Protection (CT DEEP) defined six stress categories for streams, based on the distribution of stressor parameters in the database.

CT DEEP's thresholds for the "least stressed" category (Table 9) were determined from stressor-response scatterplots of sensitive taxa in the samples versus the stressor parameters (dashed line in Figure 10). Screening thresholds for metals (Table 9) were determined from stress-response scatterplots of number of mayfly or stonefly taxa in the samples vs. metal concentrations (Figure 10). These two orders are generally considered highly sensitive to metal contamination (e.g., Buchwalter and Luoma 2005). Metals not included in Table 7 (aluminum, cadmium, mercury, lead, selenium) were either not associated with biological responses (no observable stress-response), or they were not detected in most observations in the data set. Using the criteria of Table 9, least disturbed sites were identified as sites with all eight stressor values in the "least stressed" category, and highly disturbed sites were identified as sites with four or more stress values in the "high" category. The screening allowed selection of sites for calibration to cover the range from "least disturbed" to putative "highly disturbed."

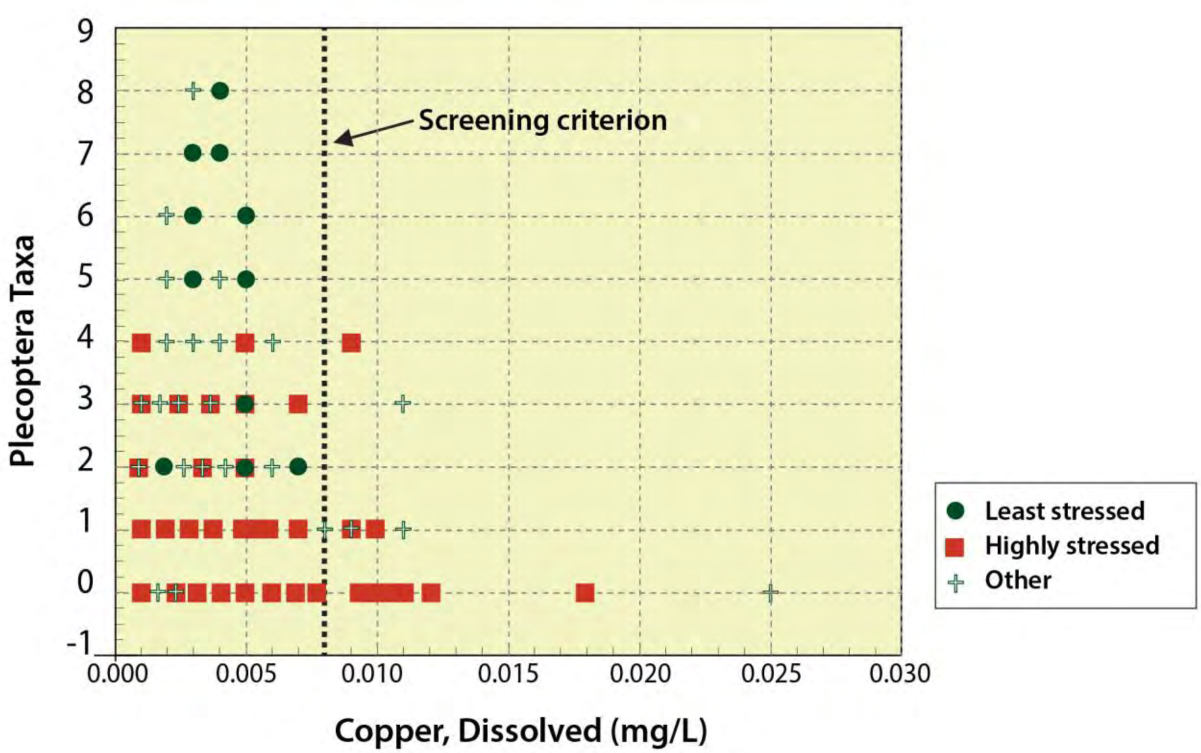

Figure 10. Number of Plecoptera (stonefly) taxa and dissolved copper (Cu) concentration, Connecticut sites. The screening criterion, (0.008 mg/L Cu) was estimated by eye from the presence of stoneflies at low Cu concentrations, and their near absence above 0.008 mg/L Cu. In the calibration, least stressed sites were required to have Cu < 0.008 mg/L (among other criteria). The screening criterion separates sites with no detectable influence of copper from those where copper may be a factor (among others) in loss of Plecoptera.

Table 9. Example screening thresholds for stressor gradient (Connecticut)

Parameter	Stress Category				
	Least Stress	Slight Stress	Moderate Stress	High Stress	Severe Stress
Catchment parameters					
Natural land cover*	> 80%	70%–80%	60%–70%	< 60%	
Developed land	< 10%		10%–25%	> 25%	
Impervious surface	< 4%		4%–10%	> 10%	
Water quality, non-metals					
Chloride	<15 mg/L	15–20 mg/L	20–30 mg/L	> 30 mg/L	
Water quality, metals					
Copper	< 0.008 mg/L			≥ 0.008 mg/L	
Iron	< 0.4 mg/L			≥ 0.4 mg/L	
Nickel	< 0.01 mg/L			≥ 0.01 mg/L	
Zinc	< 0.02 mg/L			≥ 0.02 mg/L	
Decision criteria for stress level	All parameters lowest stress category	Land cover or chloride Slight category; All others lowest category	Any one nonmetal allowed High category; All others Moderate or lower	Up to three non-metals High; Any metals High	All non-metals High-Severe; Any metals High

*defined as the sum of deciduous, conifer, open water, and all wetland categories

3.3.2 Data Preparation: Analyze Taxon Stressor-Response

An early task of the expert panel is to assign taxa to the attributes I through VI for development of stream and river BCGs. These are the primary attributes that are used to assess sites among BCG levels 2 through 6 for streams and rivers. Attribute VII, which provides information on organism condition (especially of long-lived organisms), is a general indicator of organism health, such as deformities, anomalies, lesions, tumors, or excess parasitism. This attribute has been used with great success in indices based on the fish assemblage. To date, attributes VIII through X have not been consistently applied to biological assessment and BCG development for streams and rivers. These attributes are also being explored for application in larger, more complex systems such as large rivers, estuaries, and coral reefs (see Appendix B). Additionally, these attributes may be more easily assessed, quantifiable, and amenable to rule development using spatial analysis.

Attribute assignment uses both empirical data analysis and expert judgment. Typically, tolerances of many genera or species are available from well-known compendia on macroinvertebrates (e.g., Barbour et al. 1999; Hilsenhoff 1982; Merritt et al. 2008). The published tolerances are broad and might not apply to species or genera in the data set at hand, but they provide a convenient initial value for the panel to consider. To augment the published tolerances and traits information, local data are also evaluated empirically to determine whether the published values, or the expert's opinions, are supported by the local data.

While it is tempting to rely only on the empirical analysis and "let the data tell the story," in practice, many data sets are not sufficient to determine tolerance of all taxa. For example, a taxon that occurs in five samples is too infrequent in the data set to estimate its tolerance. Nevertheless, it may be a taxon where the tolerance is well-established; for example, *Limnodrilus hoffmeisteri* is a worm characteristic of severe organic enrichment associated with untreated sewage discharge, and Brook Trout is a highly sensitive fish species in streams of northeastern North America. Both of these organisms are relatively uncommon in regions of the country with a high degree of development and with regulated discharges.

However, their biology and tolerance are well-known. Similarly, there are likely to be other taxa for which the assembled experts have substantial experience, but that might be insufficiently represented in the data set. Presentation of the stress-response analysis ensures that all experts in the workgroup are aware of, and familiar with, the data set at hand and associations that exist in that data set.

Empirical analysis of the data set being used in the calibration can greatly assist the attribute assignment. After developing a stressor gradient, it becomes possible to support assignment of taxa to attributes based on biological responses to the stressor gradient. This is similar to the analysis often used to identify tolerance groups (e.g., Yuan 2004, 2006).

Several different statistical approaches can be applied to examine individual species' response to stressors: (1) correlation tables and simple scatter plots, (2) central tendencies, (3) environmental limits, (4) optima, and (5) curve shapes (Yuan 2006). Correlations and scatter plots show the strength and shape of a stress-response. Tolerance values expressed in terms of central tendencies attempt to describe the average environmental conditions under which a species is likely to occur; tolerance expressed in terms of environmental limits attempt to capture the maximum or the minimum level of an environmental variable under which a species can persist; and tolerance expressed in terms of optima define the environmental conditions that are most preferred by a given species. These types of tolerances are expressed in terms of locations on a continuous numerical scale that represent the environmental gradient of interest. Both abundance-based and presence/absence-based models can be built using these statistical approaches. See Yuan (2006) for analytical methods.

3.3.2.1 Example: Stressor-response of Macroinvertebrates (Maryland Piedmont) and Fish (Minnesota Lakes)

When panelists assign taxa to attribute groups I–VI, they rely on a combination of empirical examination of taxon occurrences at sites that span a human disturbance, or stress, gradient, as well as professional experience as field biologists who have sampled water bodies in the areas of interest. During the attribute assignment process, panelists are provided with taxon-response plots in which the frequency and abundance of the taxa are plotted over the range of the disturbance gradient (Yuan 2006). Several different statistical models can be used to generate these plots, including:

- Weighted averaging to estimate optima and tolerance values (abundance based).
- Cumulative distribution function median and extreme limits (presence/absence).
- Logistic regression (linear, nonlinear, generalized additive model) median and extreme limits (presence/absence).

Taxon-response plots can be used to infer central tendencies (average environmental conditions under which a species is likely to occur), tolerance limits (maximum or minimum levels of an environmental variable under which a species can persist), and optima (environmental conditions that are most preferred by a given species).

The panelists use these plots to help inform BCG attribute assignments, particularly for attributes II (highly sensitive), III (intermediate sensitive), IV (intermediate tolerant), and V (tolerant). Taxa in these attribute categories are expected to follow the response patterns shown in Figure 11.

Prior to generating the plots, stressor variables are selected based on considerations such as availability of quantitative field-collected data and responsiveness of the biological assemblage to the stressor, or a stressor index such as Minnesota's HDS (Table 6). In one example, taxon-response plots were generated for two stressor variables—imperviousness and habitat index scores—based on data from the Northern Piedmont of Maryland (Stamp et al. 2014). For Minnesota lakes, the group examined taxon-response plots for urban/agricultural/mining land use in the contributing watershed and the trophic state index (Gerritsen and Stamp 2014). Examples of taxon-response plots from these two projects can be found in Figure 12. In these examples, there was good agreement between the taxon-response plots and attribute assignments, but this does not always happen. In cases of disagreement, the group relies on consensus professional opinion, unless contradicted by an overwhelming response in the data analysis. To interpret the graphs in Figure 12, the points are actual data of relative abundance, the curve represents the capture probability (logistic regression generalized additive model fit and confidence interval following Yuan 2006), and the red vertical dashed lines represent the optimum (50%) and tolerance (95%) values. Curves are smoothed to facilitate comparison to the "ideal" plots of Figure 11.

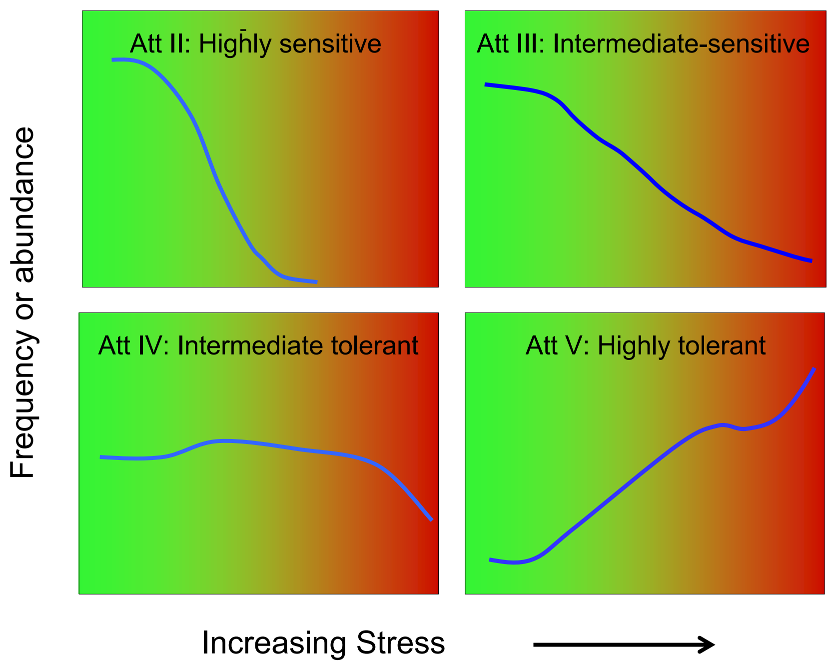

Figure 11. The frequency of occurrence and abundances of attribute II, III, IV, and V taxa are expected to follow these patterns in relation to the stressor gradient. Attribute II taxa have a high relative abundance and high probability of occurrence in minimally-disturbed sites. Attribute III taxa occur throughout the disturbance gradient, but with higher probability in better sites. Attribute IV taxa also occur throughout the disturbance gradient, but with roughly equal probability throughout, or with a peak in the middle of the disturbance range. Attribute V taxa occur throughout the disturbance gradient, but with higher probability of occurrence, and higher abundances, in more stressed sites.

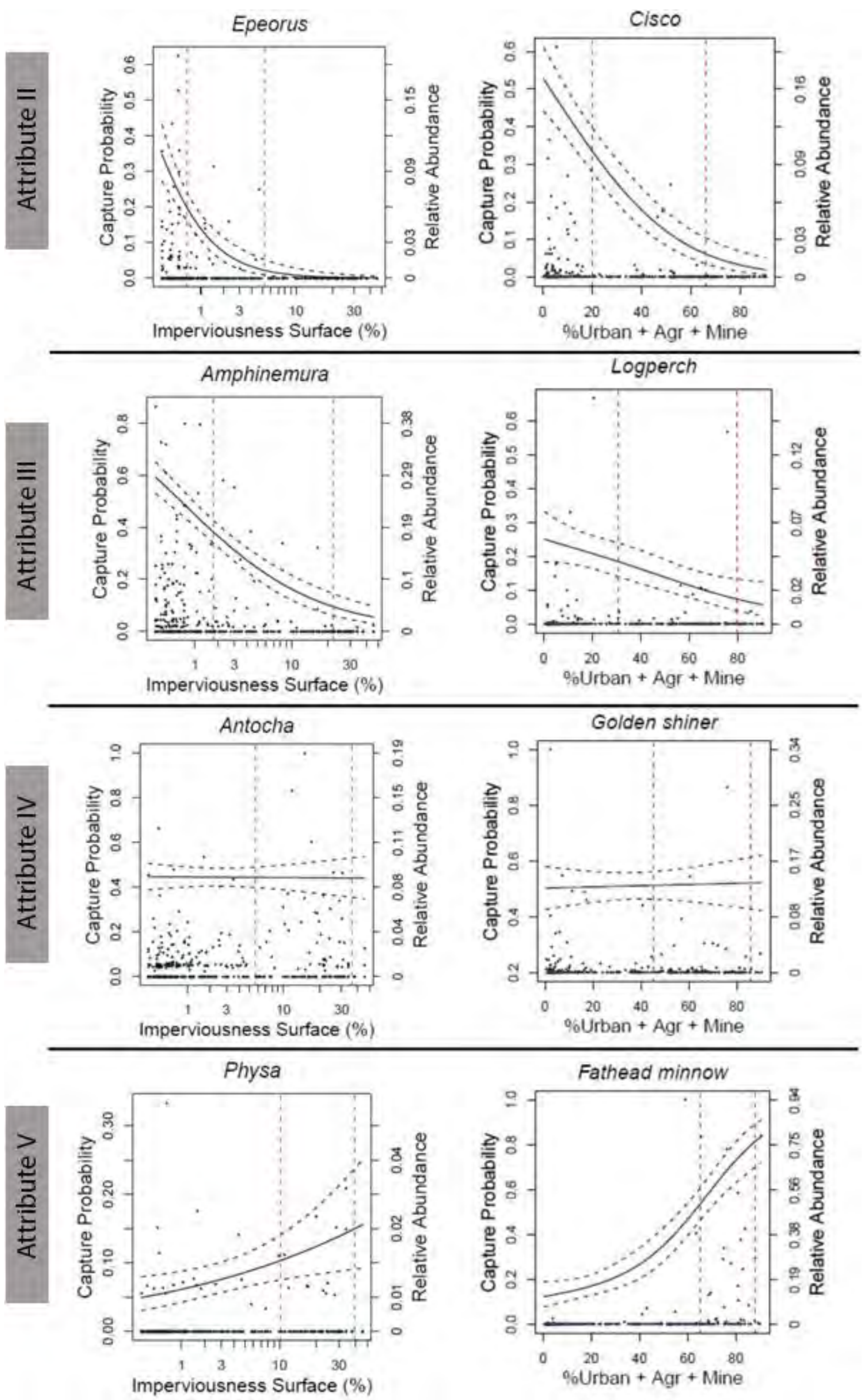

Figure 12. Examples of attribute II (highly sensitive), III (intermediate sensitive), IV (intermediate tolerant), and V (tolerant) taxon-response plots for the Northern Piedmont of Maryland and Minnesota lakes. The plots on the left show responses of four macroinvertebrate taxa from the Northern Piedmont of Maryland to impervious surface (the x-axis is log-transformed). The plots on the right show responses of five fish taxa from Minnesota lakes to urban/agricultural/mining land use.

3.3.3 Data Preparation: Organize Data for Expert Panel

The expert panel will need to work with a taxon list for the database and with sample data. The taxon list should include the taxonomic hierarchy for each genus or species in the database, and it should be sorted taxonomically for ease of use. Information to be included for each species should include known tolerance/sensitivity from other sources (e.g., published Hilsenhoff tolerances, trophic guild, spawning guild, habit, habitat preference). For lists of taxa that include some of these characteristics, see Barbour et al. (1999) and Merritt and Cummins (1996).

The panel will also need to work with data sheets from individual sites. Figure 13 is an example of a data sheet that has been used in stream BCG development. These sheets should include all taxa, counts, and the panel-assigned attribute for each taxon, sorted taxonomically. Attribute assignments (left-hand column, Figure 13) are finalized during the expert panel meeting, and they are entered into the tables at that time.

In a typical workshop, the expert panel should have data available from approximately 20 to 40 sites from a single water body class, which are selected (by data analysts, not panelists) from the entire range of the stressor gradient. There should be good representation of least stressed sites, as well as most stressed sites, and all categories of stress in between. The sites selected are typically a subset of sites used to develop the stress-response curves (Figure 12).

Although the data analysts have selected cover the range of disturbance, stress information on individual sites is not provided to the expert panel. In BCG development, the rating should be done "blind" without knowledge of stressors or levels of disturbance to minimize preconceived perceptions and bias.

BCG_SampID	HA11	Assigned Level	Area (km²)	7.68
StationID			Pct Urban	
Station Name			Pct Agr	
WMA			Pct Forest	
Gradient	High		Pct Wetlands	
CollDate	05-05-1994		Habitat Score	
BCG Attribute	**FinalID**	**Individuals**	**Order**	**Family**
4	*Psephenus herricki*	1	Coleoptera	Psephenidae
2	*Diamesa nivoriunda*	2	Diptera	Chironomidae
5	*Dicrotendipes neomodestus*	1	Diptera	Chironomidae
5	*Orthocladius dorenus*	6	Diptera	Chironomidae
5	*Orthocladius obumbratus*	1	Diptera	Chironomidae
5	*Orthocladius rivulorum*	2	Diptera	Chironomidae
5	*Micropsectra*	1	Diptera	Chironomidae
5	*Tanytarsus*	1	Diptera	Chironomidae
2	*Acentrella turbida*	2	Ephemeroptera	Baetidae
2	*Drunella cornutella*	12	Ephemeroptera	Ephemerellidae
3	*Ephemerella dorothea*	21	Ephemeroptera	Ephemerellidae
3	*Ephemerella rotunda*	3	Ephemeroptera	Ephemerellidae
3	*Eurylophella temporalis*	12	Ephemeroptera	Ephemerellidae
2	*Epeorus*	2	Ephemeroptera	Heptageniidae
2	*Ameletus*	3	Ephemeroptera	Siphlonuridae
3	*Amphinemura delosa*	25	Plecoptera	Nemouridae
2	*Isoperla transmarina*	6	Plecoptera	Perlodidae
4	*Ceratopsyche slossonae*	1	Trichoptera	Hydropsychidae
4	*Cheumatopsyche*	1	Trichoptera	Hydropsychidae
5	*Hydropsyche betteni*	1	Trichoptera	Hydropsychidae
3	*Pycnopsyche*	4	Trichoptera	Limnephilidae
4	*Polycentropus*	1	Trichoptera	Polycentropodidae

Summary

BCG Attribute	Taxa	Individuals
1	0	0
2	6	27
3	5	65
4	4	4
5	7	13
6	0	0
x	0	0
Total	*22*	*109*

Figure 13. Example data table for site assessment, showing how site data may be arranged for a panel's assessment. Attribute summary information is included at the bottom. Note that stressor information is blank—the panel rates sites without knowledge of stressors.

3.4 Step Three: Convene an Expert Panel

The expert workshop to calibrate the BCG is central to BCG development. Calibrating a BCG requires refining the generalized conceptual model to reflect regional conditions (Davies and Jackson 2006). The process has several steps:

- An expert panel of ecologists and field biologists is assembled.
- The panel assigns taxa to attributes I–VI. This step makes use of the taxon-response analysis described in section 3.3, combined with the experience and judgment of panel members.
- The panel assigns a set of sites to levels of the BCG. In this step, the panel also develops a general description of the native aquatic assemblages under natural, undisturbed conditions. The description of natural conditions requires biological knowledge of the region, a natural classification of the assemblages, and, if available, historical descriptions of habitats and assemblages.
- The panel develops narrative and quantitative decision rules to assign sites to BCG levels.

3.4.1 Expert Panel

An expert panel provides specific technical descriptions of each BCG level through the process of assigning sites to the levels. The panel should consist of (1) ecologists with strong field and identification experience with organisms represented in the monitoring data; (2) ecologists with knowledge of the natural history of the organisms and organism tolerances; (3) water quality experts; and, if possible, (4) one or more persons familiar with the historical background and context of water bodies of the region. This expertise could include knowledge of historic vegetation cover of the region and changes to the present or past distributions from museum records and old accounts of the taxa in the species list. Past experience with panels suggests that an ideal number of participants for each assemblage group is between 8 and 12; fewer than 8 results in a narrow diversity of expertise and viewpoints represented, yet a panel with more than 12 participants can become unwieldy and slow in identifying individual opinions. Panel meetings should also include a facilitator familiar with the BCG calibration process; staff familiar with the data and analysis already done (section 3.3); and recorder(s) to record decisions, expert logic, and important discussion points.

In the introductory session of the workshop, the panel is introduced to the BCG concept and ground rules for assessing sites and developing decision rules. Panel members must have sufficient time to digest and discuss the process and feel comfortable with it. This requires one or more introductory sessions to familiarize them with the conceptual BCG model, applications, calibration, and the data and procedures to be used. These sessions may be done as webinars to save time in the face-to-face panel meetings. For several of the BCG development efforts, two to three webinars have been conducted with the expert panel and have proven to be very effective in educating the panelists about the BCG. These webinars have also been useful in addressing questions and issues ahead of the workshop that would otherwise have sidetracked the work of the panel during the face to face meeting. Additionally, a dry run with the panelist in use of data spreadsheets and evaluating the data can result in new information and insight from the panelists that can be incorporated into developing the BCG. A very useful initial exercise is a "practice run" to rate approximately three sites that the facilitation team has reason to believe might be relatively good condition, mediocre condition, and poor condition, respectively. This allows panelists to experience the process on which they will be spending considerable time. Upon completion of the introductory session, the panel begins work, as explained in the following sections.

3.4.2 Assign Taxa to Attributes

Prior to calibrating BCG levels, the panel assigns taxa in the database to the taxonomic attributes (attributes I to VI). Assignments of taxa to attributes rely on examination of empirical stress-response relations, as well as professional experience of field biologists who have sampled the water bodies of the region. In this way, the professional opinions of the workgroup can be tested with the empirical data (Figure 12). Several taxa may have insufficient data within the statewide data set. The wider collective experience of the workgroup can enhance the empirical database with experience with under-represented taxa, and knowledge of natural history.

In cases of disagreement between empirical analyses and professional opinion, the group can employ a weight of evidence approach, including consensus professional opinion and strong and consistent response shown in the data analysis (Figure 12). To save time in the face-to-face panel workshop, attributes and assignment of taxa to the (taxonomic) attributes can be introduced in the pre-workshop webinars, and each expert is asked to assign taxa to attributes as homework. Experts are also given results of the stressor-response analyses of individual taxa. The facilitation team compiles the experts' taxon assignments prior to the workshop, and participants discuss each taxon to develop consensus assignments.

After the taxa are assigned to the attributes, the attribute numbers should be entered into the site-specific data sheets (Figure 12).

3.4.2.1 Example: Alabama Taxon Assignments

Prior to the face-to-face BCG workshop for northern Alabama streams, panelists received taxa lists from the facilitation team and were asked to make preliminary attribute assignments based on (1) relevant literature and (2) taxon-response plots showing relationships between the frequency and abundance of the taxa over the range of the Alabama HDG. The facilitation team compiled the results and used them as a starting point for the attribute assignment component of the workshop, during which panelists made assessments based on consensus professional opinion. Once the attribute assignments were made, the facilitator entered them into a master taxa worksheet, which automatically updated the attribute assignments in the sample worksheets (Figure 13). Table 10 shows the distribution of macroinvertebrate and fish taxa across attribute categories for northern Alabama streams.

Table 10. Distribution of macroinvertebrate and fish taxa across the BCG attributes in northern Alabama

BCG Attribute		Macroinvertebrates			Fish		
		# of taxa	% of individuals	Examples	# of taxa	% of individuals	Examples
I	Historically documented, sensitive, long-lived, or regionally endemic taxa	1	0.2	Gastropods: *Fontigens*	6	2.7	Bankhead Darter, Crown Darter, Holiday Darter, Sipsey Darter
II	Highly sensitive taxa	110	16.7	Beetles: *Optioservus*, Mayflies: *Heptagenia*, *Leucrocuta*, Caddisflies: *Brachycentrus, Glossosoma*, Stoneflies: *Leuctra, Tallaperla*	15	6.8	Burrhead Shiner, Cahaba Shiner, Bigeye Shiner, Goldline Darter, Warpaint Shiner, Blenny Darter
III	Intermediate sensitive taxa	136	20.6	Beetles: *Macronychus*, Mayflies: *Stenonema*, *Isonychia*, Midges: *Tvetnia, Brillia*, Caddisflies: *Chimarra*, Odonata: *Macromia*	38	17.4	Shadow Bass, Black Redhorse, Rock Bass, Northern Studfish, Southern Studfish, Bigeye Chub, Tuskaloosa Darter, Rainbow Shiner
IV	Taxa of intermediate tolerance	173	26.2	Midges: *Polypedilum, Tanytarsus, Rheotanytarsus, Thienemannimyia*, Beetles: *Stenelmis*, Dragonflies: *Boyeria*, Mayflies: *Baetidae*	76	34.7	Longear Sunfish, Alabama Hog Sucker, Banded Sculpin, Alabama Shiner, Silverstripe Shiner
V	Tolerant native taxa	67	10.2	Caddisflies: *Cheumatopsyche*, Worms: *Oligochaeta*, Midges: *Ablabesmyia, Dicrotendipes*, Dragonflies: *Argia*, Flies: *Simulium*, Gastropods: *Physella*	29	13.2	Bluegill, Blackbanded Darter, Largemouth Bass, Striped Shiner, Spotted Bass, Blacktail Shiner, Blackspotted Topminnow
Va	Opportunistic tolerant taxa	—	—	—	9	4.1	Creek Chub, Bluntnose Minnow, Redbreast Sunfish, Western Mosquitofish, Eastern Mosquitofish, Green Sunfish, Largescale Stoneroller, Yellow Bullhead
VI	Non-native taxa	2	0.3	*Corbicula* and Astacidae	5	2.3	Common Carp, Fathead Minnow, Goldfish, Grass Carp, Red Shiner
X	Migrating fish (surrogate for ecosystem connectance)	—	—	—	2	0.9	American Eel, Atlantic Needlefish
—	No attribute assignment (insufficient information)	171	25.9	Coarse identifications and uncommon occurrences	39	17.8	Uncommon occurrences
Totals		***660***	***100***		***219***	***100***	

3.4.3 Assign Sites to Condition Levels

Working from a description of undisturbed communities and the species composition data from example sites, the panel assigns sites to the levels of the BCG. These site assignments are used to describe changes in the aquatic communities for lower levels of biological condition, leading to a complete descriptive model of the BCG for the region. Throughout this process, the panel makes use of the prepared data (Figure 12 and Figure 13) to examine species composition and abundance data from sites with different levels of cumulative stress, from least stressed to severely stressed.

3.4.3.1 Description of Natural, Undisturbed Conditions

First, the panel attempts to reconstruct the native aquatic assemblages under natural, undisturbed conditions. This is an application of historical ecology (McClenachan et al. 2015), and if resources are available, a formal effort should be made to describe the historical conditions. The description of natural conditions requires biological knowledge of the region, a natural classification of the assemblages, and, if available, historical descriptions of the habitats and assemblages. A useful exercise is to ask each panelist to describe the community of an undisturbed, natural system. This develops a best professional judgment description of undisturbed communities for the region that is, at best, qualitative.

Descriptive studies of historic and prehistoric distributions of species can be useful in developing a description of pre-settlement or pre-industrial conditions. For example, most classic fish distribution monographs draw heavily on early descriptions and collections by 19th century naturalists (e.g., descriptions in *The Fishes of Ohio*; Trautman 1981) to develop estimates of pre-settlement distributions for as many species as possible. Fish and mollusks have also been investigated from native and early settler middens to derive distributions of harvested species, and these can be combined with other studies to develop more comprehensive descriptions (e.g., Angelo et al. 2002, 2009).

For example, in Kansas, few streams have completely escaped the effects of large-scale agricultural and livestock practices implemented over the past 150 years (Angelo et al. 2009). Although many of the biological surveys from the mid-1800s were performed after the start of intensive agriculture, they still provide valuable documentation of the occurrence of several freshwater species that soon disappeared from specific watersheds or the region as a whole. Museum collections and other historical records indicate that many creeks and smaller rivers in the Great Plains supported a variety of predominately eastern fish and shellfish species, most requiring clear water and relatively stable stream bottoms. In fact, Kansas was once home to more than 50 Unionid mussel species. Today, several mollusk species are no longer found in most of their original habitats (Figure 14). Over the past 150 years, at least 11 aquatic molluscan taxa have become extinct in Kansas, and an additional 23 species are currently designated as endangered, threatened, or vulnerable.

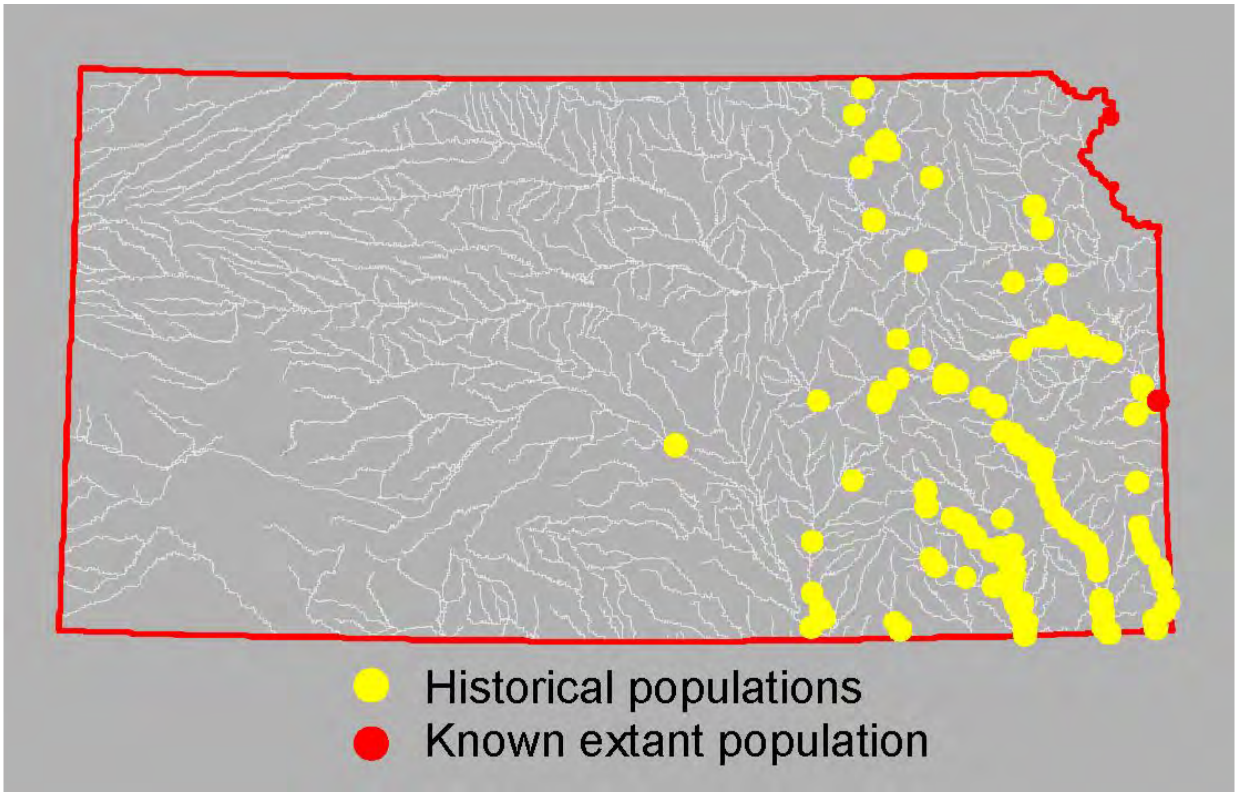

Figure 14. Decline in geographical distribution of black sandshell mussel in Kansas (after Angelo et al. 2009).

A description of undisturbed conditions may also be developed more quantitatively if databases, expertise, and resources are available. With the growth of biological monitoring, there have been several recent attempts to develop predictive statistical models of biological composition (typically metrics, but also taxa) using multiple regression (e.g., Waite et al. 2010) or other modeling approaches (e.g., random forests [DeWalt et al. 2009]; Threshold Indicator Taxa ANalysis (TITAN) [Baker and King 2010]). These model approaches can be used to extrapolate to undisturbed conditions and predict relevant metrics (Waite et al. 2010), composition, or individual species ranges (DeWalt et al. 2009) under undisturbed conditions. They are especially useful if museum records, paleolimnological investigations, or historical descriptions do not apply (e.g., invertebrates were typically of less interest than fish to early explorers and many naturalists).

There are challenges and drawbacks when using historical data to reconstruct natural stream conditions. It takes a great deal of time and commitment to piece together numerous bits of information, especially considering the limitations and inconsistencies inherent in historical data. Much of the information is not directly comparable to modern assessment data, largely because results from previous studies and observations are often based on different sampling methodologies. Sometimes the data are not applicable because they were obtained after settlers significantly impacted the land, but often such physical habitat data are missing or incomplete. Finally, some regions settled early in the history of the nation may simply lack definitive historical data on the baseline biological condition.

As an example, Shumchenia et al. (2015) constructed the first estuarine BCG framework that examines changes in habitat structure through time. Using historical data and descriptions, including maps, navigational charts, land use descriptions, sediment cores, and shellfish landings, they described a minimally disturbed range of conditions for the ecosystem, anchored by observations before 1850. Like many estuaries in the U.S., the relative importance of environmental stressors changed over time, but even qualitative descriptions of the biological indicators' status provided useful information for defining condition levels. In addition to helping conceptually define the biotic community expected in an undisturbed or minimally disturbed environment, the BCG was used to show that stressors rarely acted alone and that declines in one biological indicator influenced the increase or decline of others.

3.4.3.2 Assignment of Current Sites

The panel works with data tables showing the species and attributes for each site (Figure 13). In developing assessments, the panel works "blind," that is, no stressor information is included in the data table. Only non-anthropogenic classification variables are shown (in Figure 13, watershed area and gradient). Sites are selected by the facilitation team to span the range of stress that occurs in the region, from the least stressed to the most stressed. Panel members discuss the species composition and what they expect to see for each level of the BCG.

A typical site assignment proceeds as follows: The facilitator projects the data onto a screen (Figure 13) and calls out some salient data on the site, including area, gradient, total taxa, and possibly some summary metrics. Panelists take several minutes to look at the data, and each panelist proposes a BCG level for the site, along with principal reasons for the decision. The site and decision reasons are discussed by the panel, and panelists are allowed to change their decisions, if desired.

Following assignment of 20 or more sites to levels of the BCG, the panel develops a description of each level, along with rules that are expected to be met by each level, starting from the highest quality condition observed in the data set (e.g., level 1) and working down to the most severely altered condition (e.g., level 6). The description and rules can be as quantitative as the panel cares to make them. Examples of water bodies that might have low resolution include intermittent and ephemeral streams, wetlands, and tidal fresh portions of estuaries. Also, BCG levels might be absent from the data set. In most developed states, there is general recognition that BCG level 1 is exceedingly rare or absent. BCG level 6 is often absent from data sets because the most egregious pollution has been remediated, leaving level 5 as the poorest quality observed. Level 6 may sometimes be observed in older data (pre-1985). If a panel determines that two or more levels cannot be discriminated, then they are typically combined into one; for example "levels 3–4" or "levels 5–6." This should only be done when the panel determines that the levels cannot be discriminated, not simply because one or more levels happen to be absent from the given data set.

Assessing biological condition and assigning sites to a level of the BCG are based on the detailed attribute descriptions developed earlier for the water body and region for which the model is being developed, plus other taxonomic attributes the panel agrees are important. It is entirely possible to determine biological condition with a subset of the attributes. For example, biological assessment in streams and rivers is currently carried out with indicators very similar to taxonomic and condition attributes I through VII of the BCG, all derived from species composition. However, a measure of the spatial distribution of estuarine habitats for assessing whole estuary condition is under development in Narragansett Bay based on a spatial habitat measure and on the "historic balance" of critical estuarine habitats in Tampa Bay (Cicchetti and Greening 2011; Shumchenia et al. 2015). This indicator is under development as a surrogate for attribute X (ecosystem connectivity), and would provide information on the presence and spatial relationship of habitats critical to a functioning estuarine system. The importance of individual attributes depends on the system being assessed, and information or indicators for all attributes may not be necessary.

As an example, a panel of aquatic biologists from three states (Michigan, Wisconsin, and Minnesota) and four tribal water quality agencies calibrated BCG models for coolwater wadeable streams of the Upper Midwest (Gerritsen and Stamp 2012). Prior to performing site assessments, the group discussed their expectations for sites spanning the different BCG levels. Table 11 contains the narrative descriptions of each of the BCG levels (modified after Davies and Jackson (2006)), as well as lists of fish and macroinvertebrate taxa that the group expected to commonly find in samples from each BCG level. The overall relationship between BCG level and Minnesota's disturbance score is shown in Figure 15.

Table 11. Description of transitional cold-cool assemblages (benthic macroinvertebrate and fish taxa) in each assessed BCG level, Upper Midwest coldwater streams. Definitions are modified after Davies and Jackson (2006) (Source: Gerritsen and Stamp (2012)).

BCG level 1	**Definition:** Natural or native condition—*native structural, functional, and taxonomic integrity is preserved; ecosystem function is preserved within the range of natural variability*
	Fish: If the stream is in a location where brook trout are native, *native brook trout* must be present. Non-native salmonids must be absent. Up to twelve additional taxa, including highly sensitive (attribute I, II, & III) species such as *slimy sculpin* and *brook lamprey*, are also be present. If tolerant taxa are present, they occur in very low numbers.
	Macroinvertebrates: There is a lack of sufficient information to know what the historical undisturbed macroinvertebrate assemblage looked like.
BCG level 2	**Definition:** Minimal changes in structure of the biotic community and minimal changes in ecosystem function—*virtually all native taxa are maintained with some changes in biomass and/or abundance; ecosystem functions are fully maintained within the range of natural variability*
	Fish: Overall taxa richness and density is as naturally occurs. Non-native salmonids may be present. If the stream is in a location where brook trout are native, *native brook trout* must be present and must not be negatively impacted by non-native salmonids such as *brown trout*. Other highly sensitive (attribute II) and intermediate sensitive (attribute III) taxa such as *sculpins (mottled or slimy), dace (pearl, finescale, northern red belly, longnose)* and *brook lamprey* are also present. Tolerant taxa may be present but in low numbers.
	Macroinvertebrates: Overall taxa richness and density is as naturally occurs. Most sensitive (attribute II) taxa (e.g., *Trichoptera*: *Glossosoma, Rhyacophila, Lepidostoma, Dolophilodes; Ephemeroptera*: *Ephemerella, Epeorus; Plecoptera: Leuctridae*) and other taxa must be present. These plus intermediate sensitive (attribute III) taxa (e.g., *Ephemeroptera*: *Paraleptophlebia*; *Plecoptera*: *Acroneuria, Isoperla, Paragnetina*; *Trichoptera*: *Brachycentrus, Chimarra*) occur in higher relative abundances than in BCG level 3 samples. Tolerant taxa occur in low numbers.
BCG level 3	**Definition:** Evident changes in structure of the biotic community and minimal changes in ecosystem function—*Some changes in structure due to loss of some rare native taxa; shifts in relative abundance of taxa but intermediate sensitive taxa are common and abundant; ecosystem functions are fully maintained through redundant attributes of the system*
	Fish: Overall taxa richness and density is as naturally occurs. Sensitive taxa such as *dace (pearl, finescale, northern red belly, longnose)* and *northern hog suckers* must outnumber tolerant taxa such as *central stonerollers* and *bluegill.* Taxa of intermediate tolerance (attribute IV) such as *white suckers*, *blacknose dace, common shiners, darters (johnny, fantail),* and *creek chub* are common, and some tolerant (attribute V) taxa such as *northern pike, yellow perch,* and *stonerollers* may be present. If extra tolerant taxa such as *green sunfish* and *bluntnose* and *fathead minnows* are present, they occur in very low numbers.
	Macroinvertebrates: Overall taxa richness and density is as naturally occurs. Similar to BCG level 2 assemblage except sensitive taxa (e.g., Ephemeroptera: Paraleptophlebia; Plecoptera: Acroneuria, Isoperla, Paragnetina; Trichoptera: Brachycentrus, Chimarra; Diptera: Diamesa, Eukiefferiella, Tvetenia) occur in lower relative abundance and the most sensitive (attribute II) taxa may be absent. Taxa of intermediate tolerance (attribute IV) (e.g., *Gammarus, Oligochaeta, Simulium; Coleoptera: Optioservus, Stenelmis; Ephemeroptera: Baetis, Stenonema; Trichoptera: Hydropsyche, Cheumatopsyche*) are common, and some tolerant taxa (attribute V) occur in low numbers.

BCG level 4	**Definition:** Moderate changes in structure of the biotic community and minimal changes in ecosystem function—*Moderate changes in structure due to replacement of some intermediate sensitive taxa by more tolerant taxa, but reproducing populations of some sensitive taxa are maintained; overall balanced distribution of all expected major groups; ecosystem functions largely maintained through redundant attributes*
	Fish: Sensitive taxa such as *dace (pearl, finescale, northern red belly, longnose)* and *northern hog suckers* are present but occur in very low numbers. Taxa of intermediate tolerance (attribute IV) such as *white suckers, blacknose dace, common shiners, darters (johnny, fantail)* and *creek chub* are common, and some tolerant (attribute V) taxa such as *northern pike, yellow perch* and *stonerollers* are present. When compared to BCG level 3 samples, highly tolerant taxa such as *green sunfish* and *bluntnose* and *fathead minnows* are present in greater numbers.
	Macroinvertebrates: Overall taxa richness is slightly reduced. Sensitive taxa (including EPT taxa) are present but occur in low numbers. Taxa of intermediate tolerance (attribute IV) (e.g., *Gammarus, Oligochaeta, Simulium; Coleoptera: Optioservus, Stenelmis; Ephemeroptera: Baetis, Stenonema; Trichoptera: Hydropsyche, Cheumatopsyche*) are common, as are tolerant (attribute V) taxa (e.g., *Diptera: Cricotopus, Dicrotendipes, Paratanytarsus; Hyalella; Physa; Turbellaria*).
BCG level 5	**Definition:** Major changes in structure of the biotic community and moderate changes in ecosystem function—*Sensitive taxa are markedly diminished; conspicuously unbalanced distribution of major groups from that expected; organism condition shows signs of physiological stress; system function shows reduced complexity and redundancy; increased build-up or export of unused materials.*
	Fish: Overall taxa richness may be reduced. Sensitive taxa drop out. Taxa of intermediate tolerance (attribute IV) such as *white suckers, blacknose dace, common shiners, darters (johnny, fantail),* and *creek chub* are common. There is an influx of tolerant and highly tolerant taxa such as *bluegill*, *yellow perch, largemouth bass, northern pike, central stonerollers, bluntnose minnows, fathead minnows,* and *green sunfish*.
	Macroinvertebrates: Overall taxa richness is slightly reduced. Sensitive taxa may be absent. Taxa of intermediate tolerance (attribute IV) (e.g., *Gammarus, Oligochaeta, Simulium; Coleoptera: Optioservus, Stenelmis; Ephemeroptera: Baetis, Stenonema; Trichoptera: Hydropsyche, Cheumatopsyche*) and tolerant (attribute V) taxa (e.g., *Diptera: Cricotopus, Dicrotendipes, Paratanytarsus; Hyalella; Physa; Turbellaria*) are common. Tolerant taxa occur in higher abundances than in BCG level 4 samples.

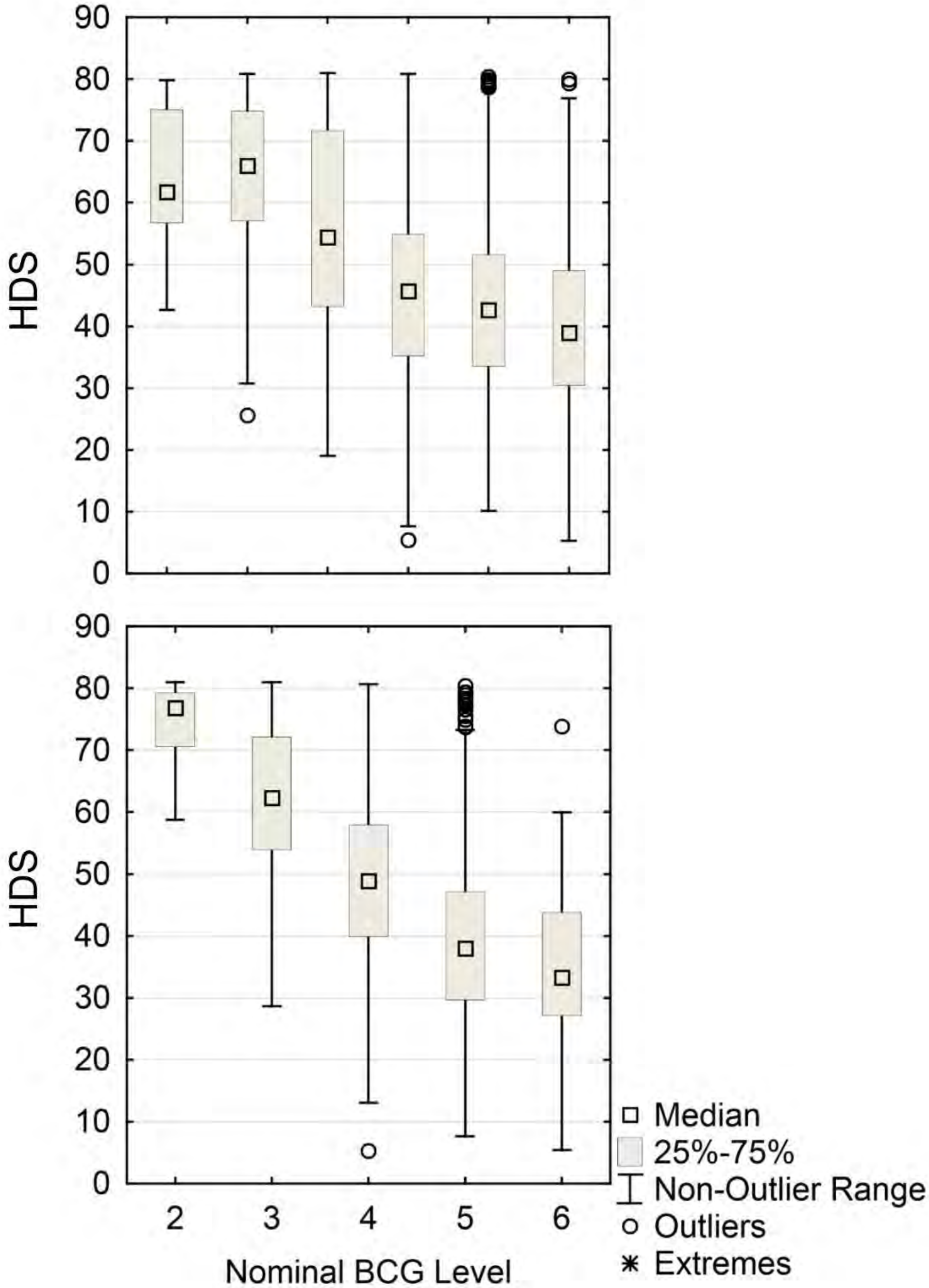

Figure 15. Box plots of HDS for Minnesota streams, grouped by nominal BCG level (panel majority choice) for fish (upper) and macroinvertebrate (lower) samples. HDS scores range from 0 (most disturbed) to 81 (least disturbed) (Gerritsen et al. 2013).

3.4.3.3 Variability in Panelist Biological Condition Gradient Calls

Consistency among panelists is important. In addition to integer BCG levels (e.g., levels 2, 3, 4), panelists also aim to identify sites somewhat better or somewhat worse than the integer levels, up to and including samples that are borderline between adjacent BCG levels. In calibration exercises, intermediate levels have been assigned (+) and (-). This information has been used to help define the threshold where an expert would assign a site to a different BCG level. An expert assigning a site to a BCG level with a (+) or (-) caveat would be asked what additional change in the site data would lead to a different level assignment, and why.

For the BCG project in the Northern Piedmont of Maryland, the macroinvertebrate workgroup assessed 46 calibration samples. Panelists rated samples in the six BCG levels, and modified those with (+) and (-) as desired. Median BCG level assignments were calculated for each sample as the group nominal level.

Deviations of each panelist's assignments from the group median call were estimated, where deviations were assumed to be in quantities of ⅓ BCG level. Deviations are shown in Figure 16. On average, 62% of BCG level assignments matched exactly with the median, 32% were within ±⅓ BCG level, 5% were within ±⅔ BCG level, and 1% differed by one BCG level (Figure 16).

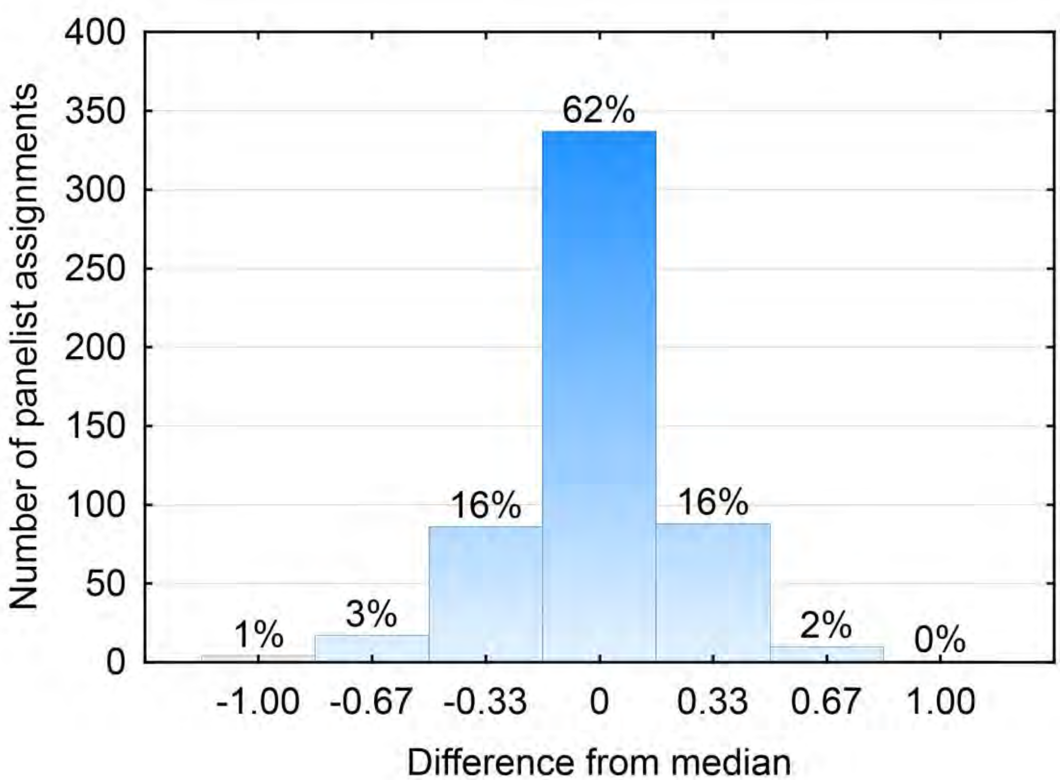

Figure 16. Distribution of individual panelists BCG assignments, as deviations from group sample median, Maryland Piedmont BCG workshop. Percentages above each bar. Data from Stamp et al. 2014.

3.5 Biological Condition Gradient Decision Rules

This chapter described steps to develop narrative descriptions and rules for assigning sites to BCG levels. The core objective of the panel process is to elicit expert judgment on what the experts consider ecologically significant change in the biotic community—and to document the underlying rationale. Through development of expert consensus, first narrative and then quantitative rules emerge, and they are tested and refined based on the current state of the science. Additionally, where gaps in information are identified, the development of decision rules is comparable to formulating a hypothesis, thereby setting up opportunities for applied research that clearly articulate water quality management information needs for goal setting and condition assessments.

The chapter concludes with development of narrative descriptions of BCG levels for specific water bodies within a region or basin. Chapter 4 addresses how to convert these narrative descriptions into narrative then quantitative decision rules for a numeric BCG model. There is no bright line between development of the narrative description and numeric decision rules. In all BCG development efforts to date, preliminary quantitative decision rules have emerged early as part of developing the narrative description and rules. In the first round of data analysis and interpretation, the experts typically formulate their reasoning in the following manner: "I expect more (or fewer) species because …." or "the presence of two or more taxa of attribute III signifies this condition level to me because …." By the second or third round of the data exercise assigning sites to BCG levels, increasingly quantitative statements are provided when experts are asked to explain their logic for assigning sites to BCG levels. These preliminary quantitative statements provide a template for building quantitative decision rules through an iterative, interactive process with the expert panel. Encapsulation of expert judgment provides the transparency and clarity for decision makers and stakeholders to understand the logic and science underpinning ALU goal descriptions and assessments.

Chapter 4. Quantitative Rules and Decision Systems

Routine use of a quantitative BCG model requires a way to automate application of the decision rules so that assessments can be made for newly sampled water bodies without reconvening the expert panel. This chapter discusses approaches to quantify the narrative BCG model and to test and validate the numeric model, corresponding to Steps 4 and 5 of the BCG Calibration process (Figure 8). Quantitative rules rely on sample data using standardized protocols (i.e., most applicable to attributes II–VI). This chapter presents:

- An approach to quantify the conceptual BCG framework and develop a numeric model. This approach is based on elicitation of the experts' decision criteria and incorporation into a numeric decision model using a mathematical set theory approach (e.g., fuzzy logic) (See section 4.1). This approach has been tested and refined in most of the BCG projects to date.
- Considerations and approaches for relating the BCG with the state's existing biological assessment methods and tools (e.g., biological indices such as MMIs and O/E models) (See section 4.2). To date, most states have developed biological indices.
- An additional approach to quantify the BCG narrative decision rules that has been implemented by a state, multivariate linear discriminant modeling. This approach involves development of statistical models that "predict" (or imitate) the expert decisions and may or may not use elicited expert reasoning or rules (See section 4.3). As BCG development and calibration continues, it is expected that the BCG process will be refined and expanded and alternate methods identified and tested.

4.1 Quantitative Rule Development and Application

This approach assumes that because the expert panelists largely agree on BCG ratings for water bodies, they use a common set of decision criteria to achieve the ratings. The approach consists of deriving narrative and numeric decision rules based on expert logic and consensus, including testing of the rules with the expert panel and then with experts outside of the panel. Application of the decision criteria—a set of quantitative rules—can then be applied to any relevant data set or sample.

Quantitative rule and direct decision model development is comprised of the following steps:

- **Elicitation of numeric decision criteria**—During the expert panel meeting, experts are asked for their reasoning behind the decisions. The reasoning is the basis for the BCG level descriptions (Table 11), and also for decision criteria (narrative rules) that the experts use. The narrative rules are elicited from the panel and then quantified.
- **Quantification and testing**—Quantitative rules in turn form the basis of a decision model. A methodology to apply the elicited rules is through a mathematical set theory approach, fuzzy logic (Zadeh 1965, 2008), which mimics human thinking and decision making. Results of the quantitative decision model are compared to the panel's decision, and mismatches are further discussed by the panel to resolve ambiguous or incomplete rules. Ideally, the final model should be tested with an independent data set that was assessed by the panel but not used to calibrate the model. Other approaches to rule elicitation and development include reproducing the expert panel results (but not necessarily their reasoning) with an empirical discriminant analysis model (section 4.2; Davies et al. In press; Shelton and Blocksom 2004), or developing a Bayesian predictive model from the elicitation of reasoning (e.g., Kashuba et al. 2012).

4.1.1 Elicitation of Numeric Decision Criteria

Level descriptions in the BCG conceptual model are intentionally general (e.g., reduced richness, increased dominance, loss or replacement of specific assemblages), which allows for different methods, sources of information, and interpretations to be used in rule development. To allow for consistent assignments of sites to levels, it is necessary to formalize the expert knowledge by codifying level descriptions into a set of rules (e.g., Droesen 1996). If formalized properly, water quality management program scientists with adequate data can follow the rules to obtain the same level assignments as the group of experts. This replicability makes the actual decision criteria transparent to stakeholders.

Rules are logic statements that experts use to make their decisions (e.g., "If plecoptera richness is high, then biological condition is high."). Rules on attributes can also be combined (e.g., "If the proportion of highly sensitive taxa (attribute II) is high, the proportion of tolerant individuals (attribute V) is low, and so on, then assignment is BCG level 2.").

Numeric rule development requires discussion and documentation of level assignment decisions and the reasoning behind the decisions. During this discussion, it is necessary to record each participant's level decision (i.e., vote) for the site, the critical or most important information for the decision (e.g., the number of taxa of a certain attribute, the abundance of an attribute, the presence of indicator taxa), and any confounding or conflicting information and how this information was reconciled for the eventual decision.

As the panel assigns example sites to BCG levels, the panel members are polled on the critical information and criteria they used to make their decisions. These form preliminary, narrative rules that explain how panel members make decisions. For example, "For BCG level 2, sensitive taxa must make up at least half of all taxa in a sample." The decision rule for a single level of the BCG does not always rest on a single attribute (e.g., highly sensitive taxa) but may include other attributes as well (intermediate sensitive taxa, tolerant taxa, indicator species, organism condition), so these are termed "Multiple Attribute Decision Rules." With data from the sites, the rules can be checked and quantified. For mathematical fuzzy set modeling, quantification of rules will allow the agency to consistently assess sites according to the same rules used by the expert panel, and it will allow a computer algorithm, or other persons, to obtain the same level assignments as the panel.

Rule development requires discussion and documentation of BCG level assignment decisions and the reasoning behind the decisions. During this discussion, the facilitators record:

- Each participant's decision for the site:
  - The critical or most important information for the decision—for example, the number or abundance of taxa of a certain attribute, the presence of indicator taxa, the absence of certain taxa, and explanation why this information is ecologically important.
  - Any confounding or conflicting information and how this was resolved for the eventual decision.
- Iteration
  - Rule development is iterative, and it usually requires at least two panel sessions.
  - Building from the initial site assignments, preliminary narrative rules are developed. Descriptive statistics of the attributes and other biological indicators for each BCG level

determined by the panel are then developed for testing. These statistical descriptions will be used for testing and refinement as numeric decision rules are developed and vetted.

- Following the initial development phase, the draft rules are tested by the panel with new data to ensure that new sites are assessed in the same way. The new test sites should not have been used in the initial rule development and also should span the range of anthropogenic stress. Any remaining ambiguities and inconsistencies from the first iterations are also resolved at this stage.

4.1.2 Codification of Decision Criteria: Multiple Attribute Decision Criteria Approach

The expert rules can be automated in Multiple Attribute Decision Models. These models replicate the decision criteria of the expert panel by assembling the decision rules using logic and set theory, in the same way the experts used the rules. In the case studies presented later in this chapter, the models replicated expert panel's decisions at greater than 90% accuracy, including tied or intermediate decisions between adjacent BCG levels (e.g., between level 3 and level 4).

Instead of a statistical prediction of expert judgment, this approach directly and transparently converts the expert consensus to automated site assessment. The method uses modern mathematical set theory and logic (called "fuzzy set theory") applied to rules developed by the group of experts. Mathematical fuzzy set theory is directly applicable to environmental assessment, it has been used extensively in engineering applications worldwide (e.g., Demicco and Klir 2004), and environmental applications have been explored in Europe and Asia (e.g., Castella and Speight 1996; Ibelings et al. 2003).

Mathematical fuzzy set theory allows degrees of membership in sets, and degrees of truth in logic, compared to all-or-nothing in classical set theory and logic. Membership of an object in a set is defined by its membership function, a function that varies between 0 and 1. One can compare how classical set theory and fuzzy set theory treat the common classification of sediment, where sand is defined as particles less than or equal to 2.0 mm diameter, and gravel is greater than 2.0 mm (Demicco and Klir 2004). In classical "crisp" set theory, a particle with diameter of 2.00 mm is classified as "sand," and one with 2.01 mm diameter is classified as "gravel." In fuzzy set theory, both particles have nearly equal membership in both classes (Demicco 2004). Measurement error of 0.005 mm in particle diameter greatly increases the uncertainty of classification in classical set theory, but in fuzzy set theory a particle near the boundary would have nearly equal membership in both sets "sand" and "gravel." Fuzzy sets, thus, retain the understanding and knowledge of measurements close to a set boundary, which is lost in classical sets.

Demicco and Klir (2004) proposed four reasons why mathematical fuzzy sets and logic enhance scientific methodology, and these are applicable to BCG development:

- Fuzzy set theory has greater capability to deal with "irreducible measurement uncertainty," as in the sand/gravel example above.
- Fuzzy set theory captures vagueness of linguistic terms, such as "many," "large," or "few."
- Fuzzy set theory and logic can be used to manage complexity and computational costs of control and decision systems.
- Fuzzy set theory enhances the ability to model human reasoning and decision making, which is critically important for defining thresholds and decision levels for environmental management.

4.1.2.1 Rule-based Inference Model

People tend to use strength of evidence in defining decision criteria, and in allowing some deviation from their ideal for any individual attributes, as long as most attributes are in or near the desired range. For example, the definitions of "high," "moderate," "low," etc. are quantitative and can be interpreted and measured to mean different things. An important step in the BCG process is development of expert consensus defining these, or other, general terms and documenting the expert logic that is the basis for the decisions. The decision rules preserve the collective professional judgment of the expert group and set the stage for the development of models that can reliably assign sites to levels without having to reconvene the same group. In essence, the rules and the models capture the panel's collective decision criteria.

An inference model is developed to replicate the panel decision process, and this section describes an inference model that uses mathematical fuzzy logic to mimic human reasoning. Each linguistic variable (e.g., "high taxon richness") must be defined quantitatively as a fuzzy set (e.g., Klir 2004). A fuzzy set has a membership function, and example membership functions of different classes of taxon richness are shown in Figure 17. In this example (Figure 17), piecewise linear functions (functions consisting of line segments) are used to assign membership of a sample to the fuzzy sets. Fuzzy membership functions were assumed to be adequately defined by piecewise linear functions. Metric values below a lower threshold have membership of 0; values above an upper threshold have membership of 1, and membership is a straight line between the lower and upper thresholds. For example, in Figure 17 (top), a sample with 20 taxa would have a membership of approximately 0.5 in the set "Low to Moderate Taxa" and a membership of 0.5 in the set "Moderate Taxa."

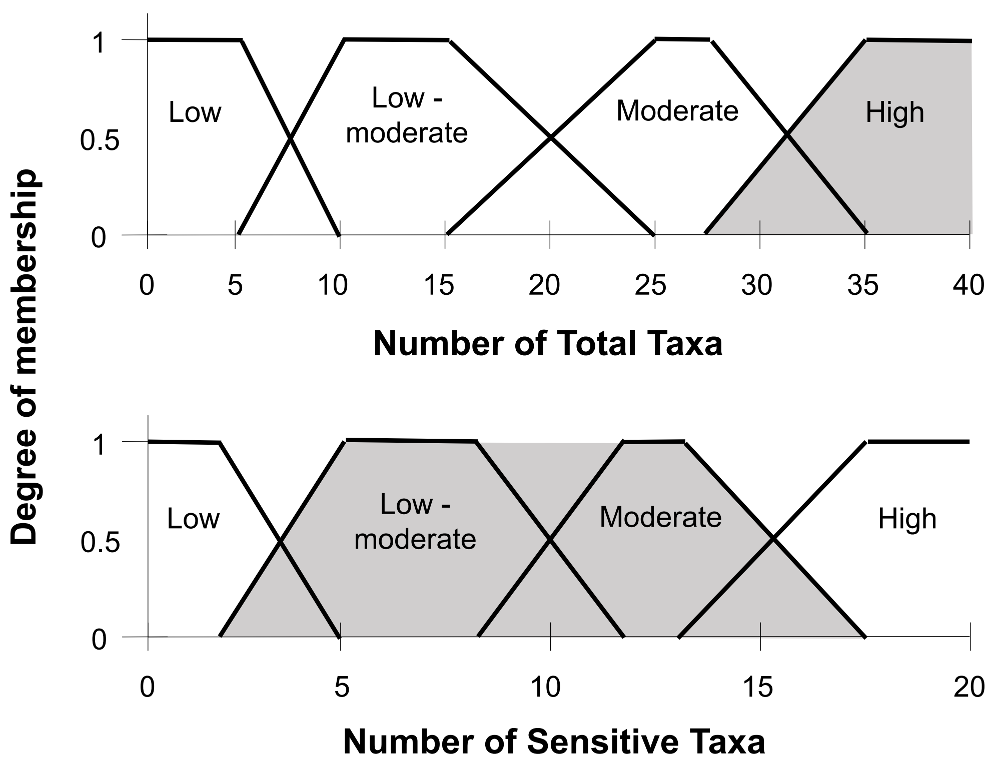

Figure 17. Fuzzy set membership functions assigning linguistic values to defined ranges for Total Taxa (top) and Sensitive Taxa (bottom). Shaded regions correspond to example rules for BCG level 3: "Number of total taxa is high," and "number of sensitive taxa is low-moderate to moderate."

How are inferences made? Suppose there are two rules for determining whether a water body is BCG level 3 (using definitions of Figure 17):

- The number of total taxa is high.
- The number of sensitive taxa is low-moderate to moderate.

In classical set theory, the boundaries between the categories would be vertical lines at the intersections of the membership functions in Figure 17. The rules would then be:

- Total taxa > 30
- Sensitive taxa > 4 and sensitive taxa < 15

If the two rules are combined with an "AND" operator, that is, both must be true, then under classical set theory, if total taxa = 30 and sensitive taxa = 5, the sample would be judged not to be in the set of BCG level 3, because the rule specifies total taxa must be greater than 30. Finding a single additional taxon would result in assessment of BCG level 3. In fuzzy set theory, an AND statement is equivalent to the minimum membership given by each rule:

Level 3 = MIN (total taxa is high, sensitive taxa is low to moderate)

For 30 total taxa, fuzzy membership in "total taxa is high" = 0.5 (Figure 17), and fuzzy membership in "Sensitive taxa is low-moderate to moderate" = 1.0 (Figure 17). Membership of level 3 is then 0.5. In the fuzzy set case, a single additional taxon raises the membership in BCG level 3 from 0.5 to 0.6.

If the two rules are combined with an "OR" operator, then either can be true for a site to meet BCG level 3, and both conditions are not necessary. Crisp set theory now yields a value of "true" if total taxa = 32 and sensitive taxa = 4 (total taxa > 27, therefore it is true). Fuzzy set theory yields a membership of 1 (maximum of 0.5 and 1). Using the fuzzy set theory model, finding a single additional taxon in a sample does not cause the assessment to flip to another level, unlike crisp decision criteria.

Output of the inference model may include membership of a sample in a single level only, ties between levels, and varying memberships among two or more levels. The level with the highest membership value is taken as the nominal level.

4.1.2.2 Quantitative Model Development

Rules identified by the panel, whether quantitative or qualitative, are compared to data summaries of the panel decisions. In particular, if the panel identified a moderate number of sensitive taxa for BCG level 3, then the analyst (i.e., the individual who develops the quantitative decision model) examines the number of sensitive taxa in samples the panel assigned to BCG level 3. The analyst selects a reasonable minimum of the distribution of sensitive taxa in BCG level 3, say the minimum or a 10^{th} quantile, as the decision threshold. This is repeated for all rules and attributes identified by the panel members as being important to their decisions. As a starting point, a plot of the attribute or metric values as box plots by the panel-designated BCG level can be helpful (see section 4.1.2.3 for an example). This type of graphic shows minimum, maximum, median, and selected quantiles for each metric and BCG level. Sample sizes for each BCG level might be small, especially for the highest and lowest levels (BCG levels 1 and 2, and 6, respectively), and might require more professional judgment from the panel to develop rules.

For a particular attribute or metric, the threshold identified by the panel will typically be the 50% membership value in a fuzzy membership function. For example, if the panel identifies "5 or more" sensitive taxa as a requirement for BCG level 3, then 5 taxa would correspond to 50% membership; 3 taxa may correspond to 0% membership, and 7 taxa to 100%. Because number of taxa are always whole numbers, the membership function is not continuous. Some rules are non-fuzzy: if a rule requires "at least 1" or "presence," then presence receives a membership of 100% and absence receives 0%.

A spreadsheet is convenient for developing the rule-based model. Membership functions and rules for each level and each relevant attribute or metric are laid out in the top row, and data for each sample are arrayed in rows. Sample data are called by the rule formulas and the final decision logic is applied to determine membership in each BCG level for each sample.

In models developed up to now, rules work as a logical cascade from BCG level 1 to level 6. A sample is first tested against the level 1 rules; if a required rule fails, then the level fails, and the assessment moves down to level 2, and so on (Figure 18). Depending on how the expert panel makes decisions and rates samples, component rules for a single level may be (1) all-or-nothing (i.e., all rules must be met); (2) some rules have alternate rules (e.g., a very low percentage of tolerant individuals may substitute for a high percentage of sensitive individuals); or (3) any number n of, say, n + 1 rules must be met. Required rules must be true for a site to be assigned to a level. BCG levels 1 and 2 represent minimally-disturbed, natural conditions, hence the rules tend to be the most restrictive. As assemblages change with increasing anthropogenic influence, the changes may manifest in different effects (decline of sensitive species; and/or increases in abundance or dominance of tolerant individuals), and the rules for the middle levels may have more alternative situations. In the more degraded levels (especially BCG level 5), the rules tend to be simple, reflecting a degraded and simplified assemblage. In the cascading logic from BCG level 1 to 6 (Figure 18), there are no rules for level 6 because it is the bottom "bin" that catches sites that fail rules from levels 1 to 5. Examples of these are shown in the case studies that follow.

Two examples on development of numeric decision rules for streams and wadeable rivers follow. The first example shows development of numeric decision rules for benthic macroinvertebrates and fish for cold- and cool-water streams in the Upper Midwest. The second example highlights use of diatom assemblage data from Northern New Jersey in developing a numeric BCG. Both examples illustrate the BCG development process. Macroinvertebrates follow the classic paradigm that overall species richness is higher in the higher BCG levels (levels 1 and 2), but coldwater fish and diatoms are nearly opposite: overall richness is low in pristine coldwater streams, and diatom richness is low in undisturbed oligotrophic streams. Both are dominated by a small number of highly sensitive taxa. As streams become more disturbed, richness and abundance of intermediate and tolerant taxa increase for both fish and diatoms. In the fish assemblage, sensitive taxa disappear in the most disturbed sites, but sensitive taxa may hang on in highly-disturbed diatom assemblages.

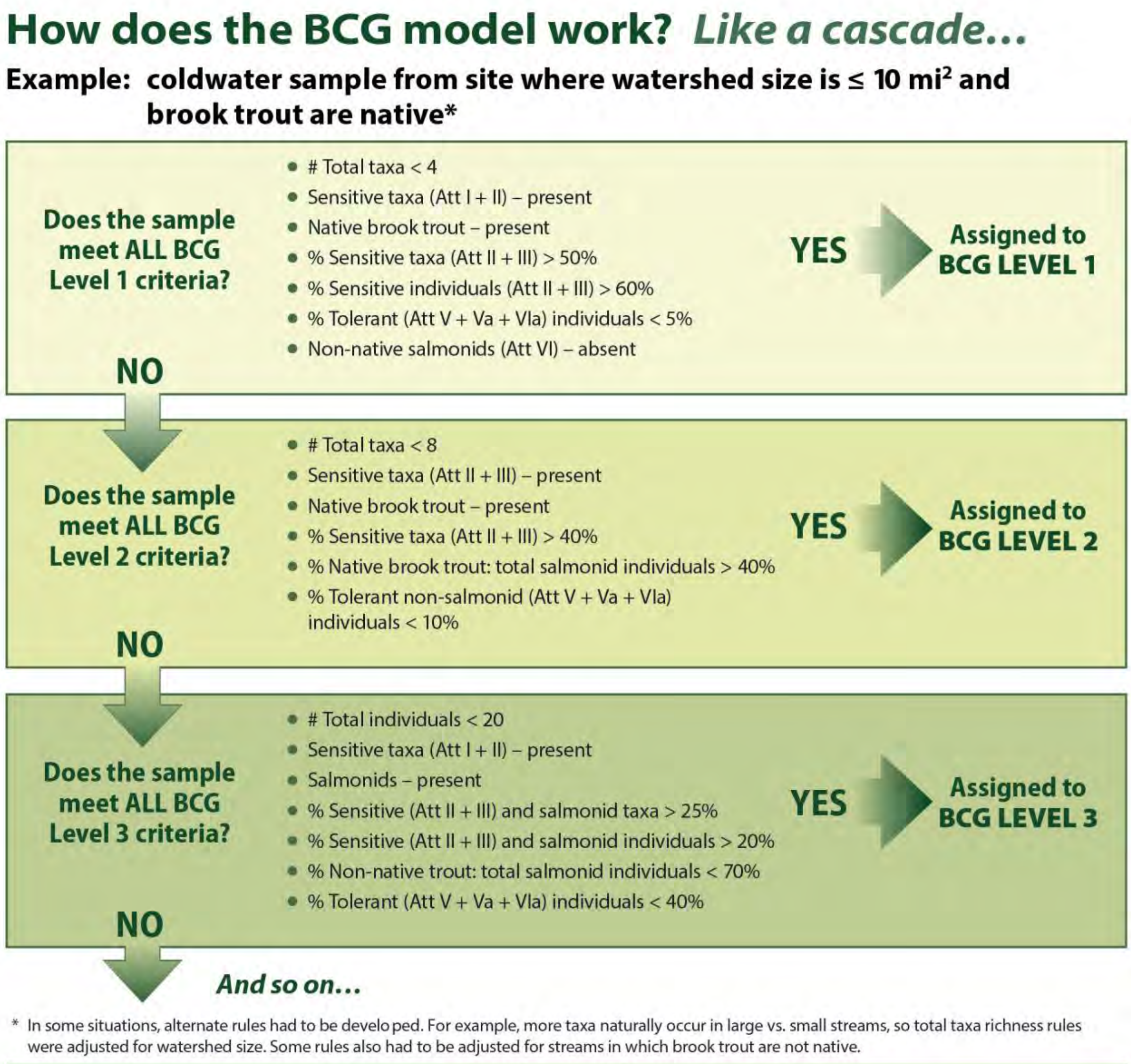

Figure 18. Flow chart depicting how rules work as a logical cascade in the BCG model, from Upper Midwest cold and coolwater example (Source: Modified from Gerritsen and Stamp 2012). For convenience, midpoints of membership functions (50% value) only are shown. For complete rules, see Table 15 and Table 16.

4.1.2.3 Example #1: Quantitative Rules and Decision System for Benthic Macroinvertebrates and Fish, Upper Midwest

Panelists from Indian Nations and the states of Michigan, Wisconsin, and Minnesota calibrated BCG models for fish and macroinvertebrate assemblages in cold and cold-cool transitional wadeable streams of the Upper Midwest (Gerritsen and Stamp 2012). The cool-transitional water macroinvertebrate BCG model was calibrated based on assessments of 37 samples. Panelists made the site assessments using worksheets that contained lists of taxa, taxa abundances, BCG attribute levels assigned to the taxa, BCG attribute metrics, and limited site information, such as watershed area, stream size, average July temperature, and percent forest.

Study Sites

Panelists assigned fish and macroinvertebrate samples from cool-transitional streams to four BCG levels (BCG levels 2–5). Samples were not assigned to BCG level 1 because panelists did not feel that there was enough information to know what the historical undisturbed macroinvertebrate assemblage in this region looked like. Only two of the 37 calibration samples were assigned to BCG level 5 (many of the coolwater sites in this region are in the Northern Lakes and Forests ecoregion). A detailed verbal description of each level is given above in Table 11 (Chapter 3).

Decision rules were initially derived from discussions with the panelists on why individual sites were assessed at a certain level. Panelists made statements such as "BCG level 2 samples should have both a moderate abundance and richness of sensitive taxa (attributes I, II, and III)." These statements were compiled into a set of narrative rules (Table 12).

Table 12. Example of Narrative rules for transitional cold-cool assemblages in Upper Midwest streams (Source: Gerritsen and Stamp (2012))

BCG level 2	**Definition:** Minimal changes in structure of the biotic community and minimal changes in ecosystem function—*virtually all native taxa are maintained with some changes in biomass and/or abundance; ecosystem functions are fully maintained within the range of natural variability*
	Fish Taxa richness is low to moderate Brook Trout, if native, are present Total sensitive taxa are one third of taxa richness Abundance of sensitive individuals is low to moderate Brook Trout (if native) are nearly half of all Salmonidae individuals Tolerant individuals may be a small fraction of total
	Macroinvertebrates Taxa richness is moderate to high Highly sensitive (attribute I and II) taxa make up a very small fraction (or more) of total richness and total abundance All sensitive taxa (attributes I + II + III) make up moderate fraction of richness and abundance Sensitive EPT taxa make up at least a small fraction of total richness
BCG level 3	**Definition:** Evident changes in structure of the biotic community and minimal changes in ecosystem function—*Some changes in structure due to loss of some rare native taxa; shifts in relative abundance of taxa, but intermediate sensitive taxa are common and abundant; ecosystem functions are fully maintained through redundant attributes of the system*
	Fish Taxa richness is moderate but not high Total number of sensitive taxa is greater than tolerant taxa, OR number of sensitive individuals is twice greater than number of tolerant individuals Single most dominant intermediate taxon (attribute III) is less than half of all individuals Extremely tolerant individuals are a very small fraction of total
	Macroinvertebrates Taxa richness is moderate to high Highly sensitive (attribute I and II) taxa are present Total sensitive taxa (attributes I + II + III) make up small fraction of richness and abundance Most dominant tolerant taxon is less than a small fraction of abundance Sensitive EPT taxa make up at least a small fraction of total richness

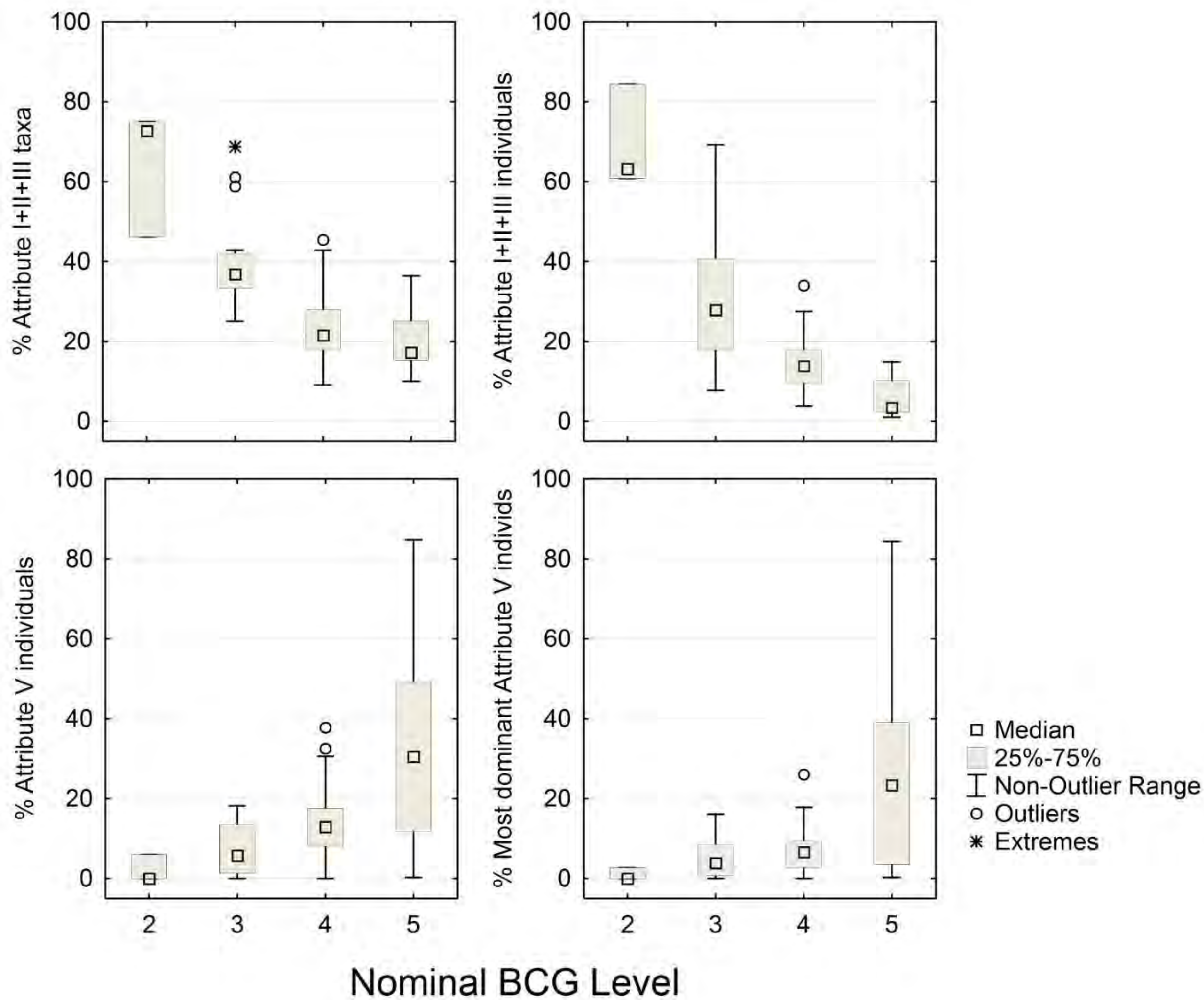

Figure 19. Benthic Macroinvertebrate Taxa: Box plots of sensitive (attribute I+II+III) and tolerant (attribute V) BCG attribute metrics, grouped by nominal BCG level (panel majority choice). These metrics were used in the macroinvertebrate BCG model for coldwater streams in the Upper Midwest.

Using the narrative rules, data were examined for numerical ranges and relationships. For example, examination of the data ranges of attribute I, II, and III taxa for macroinvertebrates (Table 13; Figure 19) showed that the median percent abundance of attribute I, II, and III taxa from BCG level 2 was 75%. The decision rules were adjusted by the empirical distributions of the attribute metrics shown in Table 13 and Figure 19, so that the model would replicate the panel's actual decisions as closely as possible. For the macroinvertebrates, the most important considerations expressed by the experts were percent individuals and percent taxa metrics for attribute II, II+III, IV, and V taxa, and metrics pertaining to three sensitive orders of aquatic insect taxa (e.g., Ephemeroptera, Plecoptera, and Trichoptera (EPT)). Panelists expected BCG level 2 samples to have a moderate presence of highly sensitive (attribute II) taxa, moderate to high total taxon richness, and a low proportion of tolerant (attribute V) taxa. BCG level 3 samples had similar numbers of total taxa but slightly reduced numbers of highly sensitive (attribute II) taxa. Total sensitive taxa (attribute II+III) were still required to be present in BCG level 4 samples, but with reduced richness and abundance. Higher proportions of tolerant (attribute V) individuals occurred in BCG level 4 samples, but could not comprise more than 60% of the assemblage.

BCG level 5 samples were discriminated from BCG level 4 samples by complete loss of sensitive taxa and a further increase in the percent tolerant (attribute V) individuals.

Table 13. Benthic macroinvertebrate taxa: Ranges of attribute metrics in cold-cool transitional macroinvertebrate samples. BCG levels by panel consensus, in the Upper Midwest BCG data set (Gerritsen and Stamp 2012).

Attributes	Metric	BCG Level (Panel Consensus)				
		2 (n=19)	3 (n=13)	4 (n=7)	5 (n=2)	6 (n=1)
0 General	Total Taxa	20–63	20–64	13–58	31–56	31
	Total Individuals	91–359	134–407	138–336	294–321	192
II Highly sensitive taxa	# Taxa	3–11	0–7	0–1	0	4
	% Taxa	8–28	0–15	0–3	0	13
	% Individuals	6–42	0–7	0–1	0	34
III Intermediate sensitive taxa	# Taxa	6–19	7–19	4–17	2–6	16
	% Taxa	19–61	18–49	9–31	6–11	52
	% Individuals	13–55	17–54	3–83	1–9	44
II + III All sensitive taxa	# Taxa	10–26	10–24	4–17	2–6	20
	% Taxa	30–71	22–57	11–31	6–11	65
	% Individuals	31–76	20–56	3–83	1–9	78
	SensEPT # Taxa	6–20	6–14	1–6	2–4	13
	SensEPT_% Individuals	18–71	14–47	2–17	1–2	60
IV Intermediate tolerant taxa	# Taxa	7–28	7–29	8–32	16–29	9
	% Taxa	26–49	35–53	50–65	52	29
	% Individuals	23–53	43–71	17–87	26–30	21
	% Most Dom Individuals	6–31	8–34	5–27	5–15	7
V Tolerant taxa	# Taxa	0–10	1–11	0–9	9–11	0
	% Taxa	0–17	3–22	0–16	20–29	0
	% Individuals	0–22	0–12	0–59	40–72	0
	% Most Dom Individuals	0–17	0–6	0–57	17–59	0

Observations of the attribute metrics from the fish assemblage are shown in Table 14. No attribute I species were identified in the coldwater fish assemblage. The fish assemblage in undisturbed or minimally disturbed coldwater streams typically has few species: native trout, sculpins, and possibly a minnow species. Increases in fish taxa richness in true coldwater is an indicator of degradation. BCG levels 1 and 2 required native trout (Brook Trout), but the native trout could be replaced by non-native salmonids in BCG levels 3 and 4. As with the invertebrates, there was increasing abundance and dominance of tolerant species, both native and non-native, in the poorer condition levels (BCG levels 4 and 5). No BCG level 6 sites were observed in the cold and cool data set. Panelists identified level 5 rules (governing the transition from level 5 to level 6) from their experience with BCG level 6 in warmwater streams.

Table 14. Fish taxa: Ranges of attribute metrics in cold-cool transitional fish samples. BCG levels by panel consensus.

Attributes	Metric	BCG Level (Panel Consensus)				
		1 (n=1)	2 (n=13)	3 (n=14)	4 (n=9)	5 (n=7)
0 General	Total Taxa	9	1–15	4–18	10–24	10–17
	Total Individuals	470	11–207	8–598	109–534	102–1483
II Highly sensitive taxa	# Taxa	2	0–2	0–2	0–1	0
	% Taxa	22	0–100	0–25	0–7	0
	% Individuals	7	0–100	0–20	0–1	0
III Intermediate sensitive taxa	# Taxa	3	0–5	0–5	1–4	0–1
	% Taxa	33	0–67	0–36	4–22	0–10
	% Individuals	68	0–72	0–60	0–44	0–4
II + III All sensitive taxa	# Taxa	5	1–5	0–6	1–4	0–1
	% Taxa	56	33–100	0–50	4–22	0–10
	% Individuals	75	14–100	0–60	0–44	0–4
IV Intermediate tolerant taxa	# Taxa	4	0–9	1–10	4–12	3–8
	% Taxa	44	0–60	18–63	40–60	29–55
	% Individuals	25	0–83	14–88	39–83	13–93
	% Most Dom Individuals	14	0–39	8–63	18–68	7–48
V Tolerant taxa	# Taxa	0	0–1	0–5	3–8	3–7
	% Taxa	0	0–17	0–36	20–40	19–70
	% Individuals	0	0–13	0–20	4–30	1–43
	% Most Dom Individuals	0	0–13	0–16	2–18	1–19
Va Highly tolerant native taxa	# Taxa	0	0–1	0–2	0–3	0–5
	% Taxa	0	0–11	0–13	0–13	0–36
	% Individuals	0	0–1	0–1	0–18	0–85
	% Most Dom Individuals	0	0–1	0–1	0–18	0–56
VI Non-native or intentionally introduced taxa	# Taxa	0	0–1	0–3	0–1	0–1
	% Taxa	0	0–20	0–43	0–6	0–9
	% Individuals	0	0–25	0–41	0–7	0–2
	% Most Dom Individuals	0	0–25	0–41	0–7	0–2
VIa Highly tolerant non-native taxa	# Taxa	0	0	0	0–1	0–1
	% Taxa	0	0	0	0–4	0–6
	% Individuals	0	0	0	0	0–3
	% Most Dom Individuals	0	0	0	0	0–3

<u>BCG Rule Development</u>

For the Upper Midwest, BCG quantitative rule development can be followed by comparing Table 12 (narrative rules), Table 13 (metric distributions), and Table 15 (quantitative rules). In Table 12, the narrative rule for BCG level 2, macroinvertebrate taxa richness is: "Taxa richness is moderate to high" (Table 12). In Table 13, total taxa in BCG level 2 sites ranged from 20 to 63 invertebrate taxa (Table 13), so 20–63 is "moderate to high." The rule for total taxa (Figure 17, BCG level 2, Coolwater) was set at a midpoint of ≥ 20 taxa, with the fuzzy boundaries defined as 16 to 24. The fuzzy boundary of 16–24 defines the lower end of the "moderate" membership function for total taxa in Figure 17; membership functions were assumed to be described by straight-line segments (Figure 17). For the total taxa rule, a site with 20 invertebrate taxa would then have a membership of 50% in BCG level 2; a site with 16 taxa would have a membership of 0 (zero), and a site with 18 taxa would have a membership of 25%. A site with 24 or more taxa would have full (100%) membership in BCG level 2 for the total taxa rule. Note that the total taxa rule is the same for BCG levels 2 and 3; these BCG levels cannot be distinguished based on total taxa. Other rules must be used.

The panel's discrimination between levels 2 and 3 was primarily from richness and abundance of sensitive taxa. Attribute II taxa were always present in BCG level 2, but they were allowed to be absent in BCG level 3 (Table 13). The rules for level 2 required highly sensitive taxa (attribute II) to make up more than 5% of taxon richness and 8% of the individuals, while in level 3 the attribute II taxa were only required to be present (e.g., one taxon, one individual; Table 15). Similarly, total sensitive taxa (sum of attributes II and III) were required to comprise 30% or more of both richness and abundance in BCG level 2, but only 20% of richness, and 10% of abundance in BCG level 3. Here the panel also allowed an exception or alternative in the rules: if sensitive attribute III individuals were particularly abundant (> 40% of the community), then attribute II taxa were allowed to be absent (Alternate rule in Table 15).

The quantitative rules of Table 15 and Table 16 were developed in the same way: panel members expressed why decisions were made, with statements of what they would require to rate a higher BCG level, or what would be lost for them to rate the sample lower. These statements were later compared to the distributions of the metrics in the panel's assessed sites to yield first-iteration quantitative rules and model. The panel would then review the quantitative rules and their assessments and make adjustments to the rules (or assessments) as needed. The final quantitative rules typically emerge after two or three iterations.

Decision rules follow the patterns observed in the distributions of the metrics among BCG levels assigned by the panel. BCG level 2 requires a strong presence of sensitive (attribute II and III) taxa and, for invertebrates, sensitive EPT taxa. Other level 2 rules include minimum numbers of total taxa for invertebrates, maximum number of total taxa for fish, and low dominance of tolerant taxa in both assemblages. It is important here to emphasize that whenever absolute values are used, the sampling effort should be specified.

BCG level 3 decision rules allow slight reductions in sensitive taxa and individuals and increases in tolerant taxa. Total number of taxa requirements are the same as BCG level 2. Since metrics do not decline in lockstep with each other, the panels occasionally allowed alternative rules where an exceptionally good value in one metric could be balanced by a poor value of another. Typically, these were tradeoffs of number of sensitive taxa for number of sensitive individuals. For example, in the invertebrate rules (Table 15), the percent sensitive (attributes I, II, and III) taxa and individuals—were subject to alternate rules: If the value of the percent sensitive taxa metric is > 20%, then the percent sensitive individuals must be > 10%. Alternatively, if the value of the percent sensitive taxa metric is > 40%, then the percent sensitive individuals metric need only be > 5%.

BCG level 4 is characterized by decreased richness and abundance of sensitive taxa. However, sensitive taxa must still be present above a minimum floor. The disappearance of sensitive taxa is what typically discriminates level 5 from level 4, as well as an increase in the percent tolerant (attribute V) individuals (Table 12, Table 16, Table 17).

Table 15. Benthic macroinvertebrate taxa: Decision rules for macroinvertebrate assemblages in coldwater and coolwater (transitional cold-cool) streams; samples with > 200 organisms. Rules show the midpoints of fuzzy decision levels, followed by the range of the membership function. The midpoint is where membership in the given BCG level is 50% for that metric.

BCG Level	Metrics	Coldwater		Coolwater	
		Rule		Rule	
2	# Total taxa	≥ 14 (11–16)		≥ 20 (16–24)	
2	% Most sensitive taxa (Att I + II)	> 10% (7%–13%)		> 5% (3%–7%)	
2	% Most sensitive individuals (Att I & II)	—		> 8% (6%–10%)	
2	% Sensitive taxa (Att II + III)	> 30% (25%–35%)		> 30% (25%–35%	
2	% Sensitive individuals (Att II + III)	> 30% (25%–35%)		> 30% (25%–35%)	
2	% Most dominant tolerant taxa (Att V)	< 5% (3%–7%)		—	
2	% Sensitive EPT taxa (Att I + II + III)	> 10% (7%–13%)		> 10% (7%–13%)	
		Rule	Alt Rule	Rule	Alt Rule
3	# Total taxa	≥ 14 (11–16)		≥ 20 (16–24)	
3	# Most sensitive (Att I + II) taxa	—	present	NA	
3	% Sensitive taxa (Att II + III)	> 20% (15%–25%)	> 40% (35%–45%)	> 20% (15%–25%)	
3	% Sensitive individuals (Att II + III)	> 10% (7%–13%)	> 5% (3%–7%)	> 10% (7%–13%)	> 40% (35%–45%)
3	% Most dominant intermediate tolerant taxa (Att IV)	< 50% (45%–55%)		—	
3	% Tolerant (Att V) individuals	< 20% (15%–25%)		—	
3	% Most dominant tolerant taxa (Att V)	—		< 10% (7%–13%)	
3	% Sensitive EPT taxa (Att I + II + III)	> 10% (7%–13%)		> 10% (7%–13%)	
		Rule		Rule	
4	# Total taxa	≥ 8 (6–10)		≥ 14 (11–16)	
4	% Sensitive taxa (Att II + III)	> 10% (7%–13%)		> 10% (7%–13%)	
4	% Sensitive individuals (Att II + III)	> 5% (3%–7%)		> 6% (4%–8%)	
4	% Tolerant (Att V) individuals	< 40% (35%–45%)		< 60% (55%–65%)	
4	Number of sensitive EPT taxa (Att I + II + III)	present		present	
		Rule		Rule	
5	# Total taxa	≥ 8 (6–10)		≥ 14 (11–16)	
5	% Tolerant (Att V) individuals	< 60% (55%–65%)		—	
5	% Most dominant tolerant taxa (Att V)	—		< 60% (55%–65%)	

Table 16. Fish taxa: Decision rules for fish assemblages in coldwater and coolwater (cold-cool transitional) streams. Rules show the midpoints of fuzzy decision levels, where membership in the given BCG level is 50% for that metric.

BCG Level	Metrics	Coldwater				Coolwater	
		Brook Trout (BT) Native		BT Non-native		BT Native	BT Non-native
1						Meets Coldwater level 1, OR Coolwater rules below:	
1	# Total taxa	≤4 (2–5)				> 3 and < 14 (2–5 and 11–16)	
1	% Most sensitive taxa (Att II)	Present				Present	
1	% Brook trout individuals	Present		Absent		Present	Absent
1	% Sensitive taxa (Att II + III)	> 50% (45%–55%)				> 40% (35%–45%)	
1	% Sensitive individuals (Att II + III)	> 60% (55%–65%)				> 40% (35%–45%)	
1	% Tolerant (Att V + Va + VIa) individuals	< 5% (3%–7%)				< 5% (3%–7%)	
1	% Non-native salmonids (Att VI)	Absent				Absent	
2	Metrics	BT Native		BT Non-native		BT Native	BT Non-native
		Alt 1	Alt 2	Alt 1	Alt 2		
2	# Total taxa	If watershed size ≤ 10 mi^2, < 8 (6–10) If watershed size > 10 mi^2, > 3 and < 14 (2–4 and 11–16)				< 20 (16–24)	
2	% Most sensitive taxa (Att II)	Present		NA		Present	NA
2	% Brook trout individuals	Present		NA		Present	NA
2	% Sensitive taxa (Att II + III)	> 40% (35%–45%)	> 20% (15%–25%)	> 20% (15%–25%)		> 30% (35%–45%)	
2	% Sensitive individuals (Att II + III)	NA		> 70% (65%–75%)	NA	> 12% (9%–15%)	
2	% Brook trout: total salmonid individuals	> 40% (35%–45%)		NA		> 40% (35%–45%)	NA
2	% Tolerant non-salmonid (Att V + Va + VIa) individuals	< 10% (7%–13%)	Absent	NA	< 10% (7%–13%)	< 20% (15%–25%)	

BCG Level	Metrics	Coldwater		Coolwater	
		Rule	Alt Rule	Rule	Alt Rule
		(brook trout native/non-native status not used)			
3	# Total taxa	If watershed size > 10 mi^2, > 5 (3–7)		< 20 (16–24)	
	% Salmonid individuals	Present		–	
	% Sensitive & non-native salmonid (Att I + II + III + VI) taxa	> 25% (20%–30%)		–	
	% Sensitive & non-native salmonid (Att I + II + III + VI) individuals	> 20% (15%–25%)		–	
	% Non-native salmonid (Att VI): total sensitive (Att I + II + III + VI) individuals	< 70% (65%–75%)		–	
	% Sensitive taxa (Att II + III)	–		≥ % Tolerant (Att V + Va + VIa) taxa	NA
	% Sensitive individuals (Att II + III)	–		NA	≥ 2*Tolerant (Att V + Va + VIa) % individs
	% Most dominant intermediate tolerant taxa (Att IV)	–		If watershed size > 10 mi^2, < 40% (35%–45%)	
	% Extra tolerant individuals (Att Va + VIa)	–		< 5% (3%–7%)	
4	**Metrics**	**(no alternate rules)**			
	% Sensitive & salmonid taxa (Att II + III + VI)	> 5% (3%–7%)		> 5% (3%–7%)	
	% Sensitive & salmonid individuals (Att II + III + VI)	> 5% (3%–7%)		> 5% (3%–7%)	
	% Tolerant taxa (Att V + Va + VIa)	< 45% (40%–50%)		–	
	% Extra tolerant individuals (Att Va + VIa)	< 10% (7%–13%)		< 20% (15%–25%	
5	**Metrics**	**(no alternate rules)**			
	# Total taxa	> 2 (1–3)		> 3 (2–4)	
	% Intermediate tolerant taxa (Att IV)	> 10% (7%–13%)		> 10% (7%–13%)	

<u>Model Performance</u>

In general, the fuzzy model identified 75%–80% of samples as primarily a single BCG level (75% membership or greater). Approximately 10%–15% of samples had a large minority membership in an adjacent BCG level to the "nominal" level (25%–40% membership), and approximately 10%–15% of assessments are ruled ties or near-ties between adjacent BCG levels (minority membership > 40%).

To measure model performance with the calibration data sets, two matches in BCG level choice were considered: an exact match, where the BCG decision model's nominal level matched the panel's majority choice; and a "minority match," where the model predicted a BCG level within one level of the majority expert opinion. When model performance was evaluated in this calibration data set, the coldwater macroinvertebrate model matched exactly with the regional biologists' BCG level assignments on 97.6% of the coldwater samples (Table 17). In the single sample without agreement, the model assignment was one level better than the majority expert opinion.

In order to confirm the model, panelists made BCG level assignments on additional samples. When nominal level assignments from the BCG decision model were compared to the panelists' nominal level assignments in the confirmation data set, the model matched exactly with the regional biologists' BCG level assignments on 80% or more of the samples (Table 17). In both cold and coolwater, three confirmation samples were rated differently by model and panel, where the model rated the samples as being one BCG level better than the majority expert opinion. Based on the combined results, in 89% of cases, the macroinvertebrate model predicts the same BCG level as the majority expert opinion.

Table 17. Benthic macroinvertebrate and fish taxa: Model performance—cold and coolwater samples

	Benthic macroinvertebrates				**Fish**			
Model	**Coldwater**		**Cool-transitional**		**Coldwater**		**Cool-transitional**	
Difference	**Calib.**	**Conf.**	**Calib.**	**Conf.**	**Calib.**	**Conf.**	**Calib.**	**Conf.**
2 better	0	0	0	0	0	0	0	1
1 better	2	3	1	3	3	3	3	5
same	39	13	31	15	47	21	38	17
1 worse	1	0	2	0	2	1	1	2
2 worse	0	0	3	0	0	0	0	0
Total # Samples	**42**	**16**	**34**	**18**	**52**	**25**	**42**	**25**
% Correct	**98%**	**81%**	**91%**	**83%**	**90.4%**	**84%**	**90%**	**68%**

4.1.2.4 Example #2: Quantitative Rules and Decision System for Diatoms, New Jersey

New Jersey DEP developed and calibrated a BCG model for sampled diatoms in northern New Jersey streams (Gerritsen et al. 2014). The models were developed using data collected by the Academy of Natural Sciences for New Jersey DEP. Workshop participants included scientists from around the United States. The calibrated BCG models will allow New Jersey to express and assess goals for classes of water bodies in terms of their biological condition.

<u>Study sites</u>

The data set consisted of 42 samples collected from streams and rivers in northern New Jersey. Sites were located in the Northern Piedmont (25), the Northern Highlands (6), the Ridge and Valley (7), the Atlantic Coastal Pine Barrens (3), and the Middle Atlantic Coastal Plain (1) ecoregions (Omernik 1987; Woods et al. 2007). Land-use in the Piedmont is primarily urban and agriculture, whereas in the Highlands and the Ridge and Valley it is predominantly forest and agriculture (USEPA 2000a). Within ecoregions, the study sites had relatively similar natural environmental conditions (e.g., geology, geomorphology), but with a wide range of nutrient concentrations.

A narrative description was derived from discussions with the panelists about why individual sites were assessed at a certain level (Table 18). The rules were calibrated from the narrative description and the 30 calibration samples rated by the group, and the rules were adjusted so that the model would replicate the panel's decisions as closely as possible. Panel members were highly quantitative in their thinking and deliberations, and they developed the first iteration of quantitative rules based on the narrative descriptions.

Rule Development

Rules adopted for the quantitative decision model are listed in Table 19. BCG level 1 has five rules: one on taxa richness, two rules on abundance of sensitive taxa, and two rules on abundance of tolerant taxa. For BCG level 1, sensitive taxa are required to be dominant, and tolerant taxa are very minor constituents of the community. The rules for BCG level 2 are similar to level 1, but all have been relaxed to some extent. The largest relative difference between levels 1 and 2 is that attribute II individuals are required to be highly abundant in level 1 (roughly 35% or more), but they are subdominant in level 2 (10% or more).

In BCG level 4, sensitive individuals are greatly diminished, but still present (9% or more), and tolerant taxa can occur at higher abundances. There are only three rules for BCG level 5: tolerant taxa may not exceed 40% of taxa or 80% of individuals. Samples that fail to meet the BCG level 5 requirements would be assigned to BCG level 6, but no such samples were encountered in this data set.

Model Performance

To evaluate the performance of the 40-sample calibration data set and the 10-sample confirmation data set, the number of samples where the BCG decision model's nominal level exactly matched the panel's majority choice ("exact match"), and the number of samples where the model predicted a BCG level that differed from the majority expert opinion ("anomalous" samples) were assessed. Then, for the anomalous samples, the degree of differences among the BCG level assignments, and also whether there was a bias was examined (e.g., did the BCG model consistently rate samples better or worse than the panelists?).

Two types of ties were taken into account: (1) BCG model ties, where there is nearly equal membership in two BCG levels (e.g., membership of 0.5 in BCG level 2 and membership of 0.5 in BCG level 3); and (2) panelist ties, where the difference between counts of panelist primary and secondary calls is less than or equal to 1 (e.g., 4–4 or 4–3 decisions). If the BCG model assigned a tie, and that tie did not match with the panelist consensus, it was considered to be a difference of half a BCG level (e.g., if the BCG model assignment was a BCG level 2/3 tie and panelist consensus was a BCG level 2, the model was considered to be "off" by a half BCG level; or more specifically, the model rating was a half BCG level worse than the panelists' consensus). The BCG model was also considered to differ by a half level if the panelists assigned a tie and the BCG model did not.

Results show that the diatom BCG model performed well (Table 20). The models assigned scores that are within a half BCG level or better on 100% of the samples in both the calibration and confirmation data sets (Table 18). When half levels were considered, the BCG model rated three of the calibration samples a half level worse than the panelists, and five confirmation samples (two better, three worse). Based on results from the calibration data set, the model has a slight bias towards rating samples a half level worse than the panel consensus.

Table 18. Narrative description of diatom assemblages in six BCG levels for streams of northern New Jersey. Definitions are modified after Davies and Jackson (2006).

BCG level 1	**Definition:** Natural or native condition—*native structural, functional, and taxonomic integrity is preserved; ecosystem function is preserved within the range of natural variability*
	Narrative: BCG level 1 streams in northern New Jersey highlands are oligotrophic, with a mature forested watershed. Unlike macroinvertebrates, the diatom community is relatively depauperate, with typically 15–20 taxa in a 500-count sample. The top dominant taxa are extreme low-nutrient adapted taxa of attributes II and III (e.g., *Achnanthes subhudsonis* or *Achnanthidium rivulare)*. Subdominants (up to 10% abundance) may include attribute IV taxa. Tolerant taxa (attribute V) make up a very small fraction of the community.
BCG level 2	**Definition:** Minimal changes in structure of the biotic community and minimal changes in ecosystem function—*virtually all native taxa are maintained with some changes in biomass and/or abundance; ecosystem functions are fully maintained within the range of natural variability*
	Narrative: BCG level 2 streams are very similar to level 1, however, a slight increase in disturbance or enrichment has allowed more diatom taxa to colonize (20–40 total taxa). Richness is slightly higher than level 1, but low nutrient taxa (attribute II and III) are dominant. There may be several tolerant taxa, but their abundance is low.
BCG level 3	**Definition:** Evident changes in structure of the biotic community and minimal changes in ecosystem function—*Some changes in structure due to loss of some rare native taxa; shifts in relative abundance of taxa but intermediate sensitive taxa are common and abundant; ecosystem functions are fully maintained through redundant attributes of the system*
	Narrative: Richness is higher than level 2 (> 30 taxa). Dominant taxon may or may not be sensitive (attribute II or III). Tolerant taxa have increased to more than 10% of the assemblage, and some of the tolerant taxa are now in the subdominant category.
BCG level 4	**Definition:** Moderate changes in structure of the biotic community and minimal changes in ecosystem function—*Moderate changes in structure due to replacement of some intermediate sensitive taxa by more tolerant taxa, but reproducing populations of some sensitive taxa are maintained; overall balanced distribution of all expected major groups; ecosystem functions largely maintained through redundant attributes*
	Narrative: BCG level 4 sites tend to have the highest taxa richness as more diatom niches open up with increased enrichment, light penetration (from canopy loss), and moderate sedimentation. Sensitive species and individuals are still present but in reduced numbers. The persistence of some sensitive species indicates that the original ecosystem function is still maintained albeit at a reduced level. Intermediate and tolerant taxa may be dominant, sensitive taxa are often still subdominant.
BCG level 5	**Definition:** Major changes in structure of the biotic community and moderate changes in ecosystem function—*Sensitive taxa are markedly diminished; conspicuously unbalanced distribution of major groups from that expected; organism condition shows signs of physiological stress; system function shows reduced complexity and redundancy; increased build-up or export of unused materials*
	Narrative: Overall diversity is still high, but may be slightly reduced from level 4. Sensitive species may be present but their functional role is negligible within the system. The most abundant and dominant taxa are tolerant or have intermediate tolerance, and there may be relatively high diversity within the tolerant organisms.
BCG level 6	**Definition:** Major changes in structure of the biotic community and moderate changes in ecosystem function—*Sensitive taxa are markedly diminished; conspicuously unbalanced distribution of major groups from that expected; organism condition shows signs of physiological stress; system function shows reduced complexity and redundancy; increased build-up or export of unused materials*
	Narrative: Heavily degraded from urbanization and/or industrialization. No level 6 samples were encountered by the panel.

Table 19. BCG quantitative decision rules for diatom assemblages in northern New Jersey streams. The numbers in parentheses represent the lower and upper bounds of the fuzzy sets. BCG level 6 is not shown, because there are no specific rules for level 6: If a site fails level 5, it falls to level 6. Shaded rules under BCG level 3 are alternate rules, that is, at least one must be true for a site sample to meet BCG level 3.

Attribute metric	Threshold
BCG Level 1	
# Total taxa	≤ 20 (15–25)
% Attribute II+III individuals	≥ 65% (60%–70%)
% Attribute II individuals > % Attribute III individuals; expressed as (% Att II–% Att III)	> 0% (-10% to 10%)
% Attribute V+VI individuals	< 2.5% (1%–4%)
% Most dominant Attribute V or VI taxon	≤ 1% (0%–2%)
BCG Level 2	
# Total taxa	≤ 40 (35–45)
% Attribute II individuals	≥ 10% (5%–15%)
% Attribute II+III individuals	≥ 50% (45%–55%)
% Attribute II+III taxa	≥ 15% (10%–20%)
% Attribute V+VI individuals	≤ 10% (5%–15%)
% Most dominant Attribute V or VI taxon	≤ 5% (3%–7%)
BCG Level 3	
# Attribute II+III taxa	≥ 5 (2–8)
# Attribute II taxa	≥ 1 (0–1)
Most dominant taxon*	Att II or 3
Alt 1: % Attribute II+III taxa	≥ 15% (10%–20%)
Alt II: % Attribute II+III individuals	≥ 15% (10%–20%)
% Attribute V+VI individuals	≤ 30% (25%–35%)
% Most dominant Attribute V or VI taxon	≤ 10% (5%–15%)
BCG Level 4	
% Attribute II+III individuals	≥ 9% (5%–13%)
% Attribute V+VI individuals	≤ 65% (60%–70%)
% Most dominant Attribute V or VI taxon	≤ 40% (35%–45%)
BCG Level 5	
% Attribute V+VI taxa	≤ 40% (35%–45%)
% Attribute V+VI individuals	≤ 80% (75%–85%)

* Dominant taxon must be sensitive (Att II or III); membership = 0 if rule fails

Table 20. Model performance for calibration and confirmation samples. "½ better" indicates models scored the sample ½ BCG level higher than the panel; e.g., Panel score was 4 and model score was 3–4 tie. Half-level mismatches are counted half the value of full matches. No mismatches exceeded ½ BCG level.

Difference (model vs. panel consensus call)	Calibration		Confirmation	
	Number	Percent	Number	Percent
model 1 level better	0	0	0	0
model ½ level better	0	0	2	17
exact match	27	90	7	58
model 1/2 level worse	3	10	3	25
model 1 level worse	0	0	0	0
Total # Samples	30	95	12	79

4.2 Calibrating Indices to the Biological Condition Gradient

Most states have developed biological indices for their streams and wadeable rivers (USEPA 2002). In the initial development of BCGs, common questions asked by states included:

- What is the relationship between the BCG and the state's existing biological index, or indices?
- Does the BCG replace the existing biological index, or indices?
- How can the BCG and the existing biological index, or indices, be used together to better assess ALUs?

The linkage between a biological index and the BCG could be addressed in a state program review (USEPA 2013a) and/or as a topic of discussion within the expert panel. Existing indices could be evaluated for how extensively they include attributes of the BCG or how the BCG decision criteria match up with the metrics that comprise the index. If needed, recommendations for specific technical improvements and analyses can then be made to guide the redevelopment of an index and/or refine the BCG model.

As in section 4.1., the objective is to calibrate a BCG model with a quantitative model, or in this case, an index that will duplicate the expert panel BCG assessments for new samples and water bodies, without having to reconvene the panel. In this approach, a conventional IBI (e.g., Karr 1986) or predictive biological index model (e.g., Hawkins et al. 2000b; Wright 2000) could be calibrated to the expert-derived BCG. While the seminal works about these indices preceded the BCG, they are based on parallel ecological concepts, and to varying degrees each incorporates BCG attributes. As an example of this, Table 21 illustrates the overlap between the 10 BCG attributes and a selection of fish and macroinvertebrate indices for freshwater streams and wadeable rivers. For the fish indices, the metrics used for each capture the more commonly measured attributes I–VI (taxa composition and effects of non-native taxa), but they also address attributes VII (organism condition), VIII (ecosystem function), and X (ecosystem connectance). The routine inclusion of the deformities, erosions, lesions, and tumors (DELT) anomalies metric (e.g., measure of deformities, erosion, lesions, and tumors) in all fish indices contains attribute VI. Functional feeding and reproduction guilds that are routinely included in fish indices might provide a surrogate for attribute VIII. The inclusion of diadromous metrics provides for the direct inclusion of species that depend on access to and from coastal rivers for completing their life cycles. Other metrics that include species that are dependent on free access to a drainage network can illustrate the concept of connectivity in inland streams and rivers. Attribute IX (spatial and temporal extent of detrimental effects) can be accounted for by the spatial extent of the sampling design and is independent of the composition of fish IBIs. For the macroinvertebrate metrics in Table 21, coverage of attributes I–V is provided by most biological indices used by states. It is also possible to develop non-native taxa metrics for attribute VI (presence and effect of non-native taxa) and metrics for attribute X (ecosystem connectance). Biological metrics could serve as a surrogate for attribute X—Unionid mussels might be a good choice given their dependency on fish hosts for dispersal and to sustain their populations. The key point is that (MMIs) have been developed from the same or parallel concepts as the BCG.

Table 21. Cross referencing the 10 BCG attributes with selected fish IBI and macroinvertebrate MMI metrics for streams and wadeable rivers

BCG Attribute	Fish IBI Metrics	Macroinvertebrate Metrics
I. Historically documented, sensitive, long-lived, or regionally endemic taxa	Great River species Sensitive sucker species Native salmonid species American eel numbers & size classes Selected diadromous species	Unionid mussels # of *Pteronarcys* species
II. Highly sensitive taxa	Highly intolerant species Sensitive species Temperate stenotherms Native salmonids	Mayfly & EPT metrics
III. Intermediate sensitive taxa	Moderately intolerant species sensitive species Round-bodied suckers	Mayfly, caddisfly, Tanytarsini midge, EPT metrics
IV. Intermediate tolerant taxa	Included in native species richness Number of minnow species Number of sunfish species	Taxa richness, caddisfly, Dipteran taxa, Non-insect & Other Dipteran taxa
V. Tolerant taxa	Highly tolerant species	Tolerant taxa % Abundance tolerant Taxa
VI. Non-native or intentionally introduced species	Exotic and introduced species of intracontinental origin Non-native species	%*Corbicula; Dreissenid mussels*
VII. Organism condition	DELT anomalies Total native species biomass	Head capsule deformities
VIII. Ecosystem function	Proportion in functional feeding groups Specialist metrics, i.e., fluvial specialists & dependents	%Other Dipteran & non-insects %Filterers %Grazers/scrapers %Clingers
IX. Spatial and temporal extent of detrimental effects	Accounted for in spatial sampling design	(Same as fish)
X. Ecosystem connectance	Diadromous species Native Salmonids Non-indigenous species	Unionid mussel

Indices that are currently in widespread use are of two basic types:

- Indices comprised of metrics that are the aggregation of species/taxa abundance data based on taxonomy, environmental tolerance, functional role, assemblage condition, and organism condition. Each metric is calibrated on a range from best to poorest conditions and also with respect to natural factors such as watershed size. The index development process usually includes an examination of tens to hundreds of candidate metrics and reducing this list to the most relevant and/or responsive 8–12 metrics (approximately). The metrics can be somewhat independent in response to each other and, when summed together, can either dilute or amplify an interpretation. They are useful in observing trajectory, but they may require recalibration to the BCG attributes before they can produce a BCG assessment. Most of this class of indices have been developed for fish, macroinvertebrates, and algae although development for other groups such as Unionid mussels have been attempted (Barbour et al. 1999). Within this broad class of indices are the classic IBIs that follow the seminal guidance of Karr et al. (1986), most of which have been developed for fish assemblages, but some for macroinvertebrates. While the original IBI was developed for central Illinois fish assemblages, Karr et al. (1986) provided guidelines about the possible application to other regions and other aquatic assemblages. This was done knowing that different metrics would be needed, but the goal was to maintain the essential attributes and ecological content of an IBI. Other multimetric approaches have been developed and applied for macroinvertebrates that, while utilizing a generally similar process, are somewhat distinctive from IBIs in having metrics that are predominantly based on taxa attributes (Plafkin et al. 1989; Barbour et al. 1999).
- Predictive models, where the observed species composition at a site is compared to an idealized reference site predicted from a multivariate statistical model. These models develop an expected taxon list and use the O/E ratio (e.g., the River InVertebrate Prediction and Classification System, RIVPACS, e.g., Wright (2000) and the AUStralian RIVer Assessment System, AUSRIVAS, Simpson and Norris (2000)). A second approach has been to use a multivariate similarity index between a specific sample and a centroid defined by undisturbed reference sites (e.g., Percent Model Affinity, Novak and Bode 1992; BEAST, Reynoldson et al. 1995; dissimilarity, Van Sickle 2008). Predictive approaches have also been applied in a multimetric framework, in which expectations for the metrics are based on environmental variables (Chen et al. 2014; Esselman et al. 2013; Moya et al. 2011; Oberdorff et al. 2002; Pont et al. 2006; Pont et al. 2009).

Ideally, the calibration of MMIs are based on minimally disturbed reference sites and with respect to natural classification strata such as bioregions, thermal gradients, and other factors that determine the baseline expectations of a regional aquatic fauna (Stoddard et al. 2006). Some have used all the data assuming that the best, or least disturbed, sites reflect the highest possible condition (Blocksom 2003; Stoddard et al. 2006). Such an assumption should be evaluated by expert opinion before it is accepted that the best condition found in a data set reasonably represents the highest expected condition. Calibration techniques have also evolved from the ordinal approach of Fausch et al. (1984) to continuous calibration techniques (Blocksom 2003; Mebane et al. 2003) that could be applied to BCG development. The expectations for achieving a high level of rigor in this process are described in EPA's Biological Assessment Program Review document (USEPA 2013a). As such, the level of technical rigor achieved in these important calibration steps can also affect the ability to measure condition along the BCG.

As with the development of the BCG, it is also necessary to test an index or model across a gradient of different environmental stressors. The ability to quantify departures from reference-derived thresholds is an important step in evaluating any assessment model.

4.2.1 Biological Condition Gradient Thresholds for Multimetric Indices and Multivariate Models

Indices and models as generally described herein should accurately translate to a position along the BCG. However, the proficiency of a particular index or model to actually accomplish this, at a particular level of resolution, is dependent on the level of detail and rigor applied in construction of the index or model and the calibrated BCG model. EPA (2013a) provides a standardized way to evaluate the technical strengths and gaps in a biological assessment program and to determine how well a particular biological assessment protocol discriminates incremental changes in biological condition (i.e., the higher the level of rigor, the more precision is achieved in incremental measurement along a gradient of stress).

However, simply stratifying an index scoring range along the BCG is neither sufficient nor recommended, especially if an index has not been explicitly developed within the conceptual framework of the BCG or the BCG attributes have not be reconciled with the metrics that comprise the index. For example, metrics in a MMI may have been selected because of strong known response to current or selected stressors and may not comprehensively characterize the full range of biological conditions, while the BCG decision rules are based on benchmarks for undisturbed or minimally disturbed conditions. This has been a challenge, especially with the upper BCG levels where reference analogs to BCG levels 1, 2, 3, or sometimes even 4 either do not exist or have not been identified. If this is the case, it will be necessary to revisit the existing index derivation and BCG model calibration and possibly revise either one, or both, for better correspondence. This task can be accomplished by the state biological assessment and criteria program, but it should be done in collaboration with the full expert panel that developed the BCG model and the underlying quantitative decision rules. As described in Chapter 3, through an iterative process, scoring criteria can be developed for new or refined indices that correspond with biologists' consensus about narrative descriptions of the levels in the BCG.

4.2.1.1 Calibrating Index Scores: Connecticut Stream Example

The set of sites that have been assigned to levels of the BCG are used to calibrate index scores. Index scores for the sites are examined, and, if separation of the index scores among levels is good, then index thresholds can be selected to maximize the ability to discriminate among the levels. This is demonstrated in the Connecticut case example below and by the Minnesota case study where IBI thresholds for refined ALUs were based on the correspondence between their IBIs and BCG levels (section 6.4). In the Connecticut example, BCG calibration and a macroinvertebrate MMI were developed at the same time. The MMI consisted of seven metrics (Table 22; Gerritsen and Jessup 2007b), including an abundance-weighted average of BCG attributes II through VI.

Table 22. Correlations (Pearson r) among Connecticut MMI index metrics

#	Metric	1	2	3	4	5	6	7
1	Ephemeroptera taxa (adj.)	•						
2	Plecoptera taxa	0.58	•					
3	Trichoptera taxa	0.57	0.50	•				
4	% sensitive EPT (adj.)	0.69	0.54	0.52	•			
5	Scraper taxa	0.67	0.50	0.75	0.52	•		
6	BCG Taxa Biotic Index	-0.76	-0.76	-0.68	-0.74	-0.69	•	
7	% dominant genus	-0.61	-0.54	-0.62	-0.59	-0.60	0.66	•

Note: Adj. = Metric scoring was adjusted for catchment size.

The Connecticut stream MMI uses metrics that are similar in objective to the BCG attributes, but which are calculated somewhat differently (e.g., EPT taxa metrics in the MMI include taxa considered to be attributes II, III, IV; and attribute II includes taxa from the EPT orders, as well as a few dipteran and beetle taxa). The total MMI score is based on the average of all metrics, while BCG decisions are based on decision-specific critical attributes (e.g., attributes II and III for the higher levels and attribute V for lower levels). Concordance of the two assessment endpoints is strong (Figure 20). Figure 20 shows the predicted results of the BCG inference model.

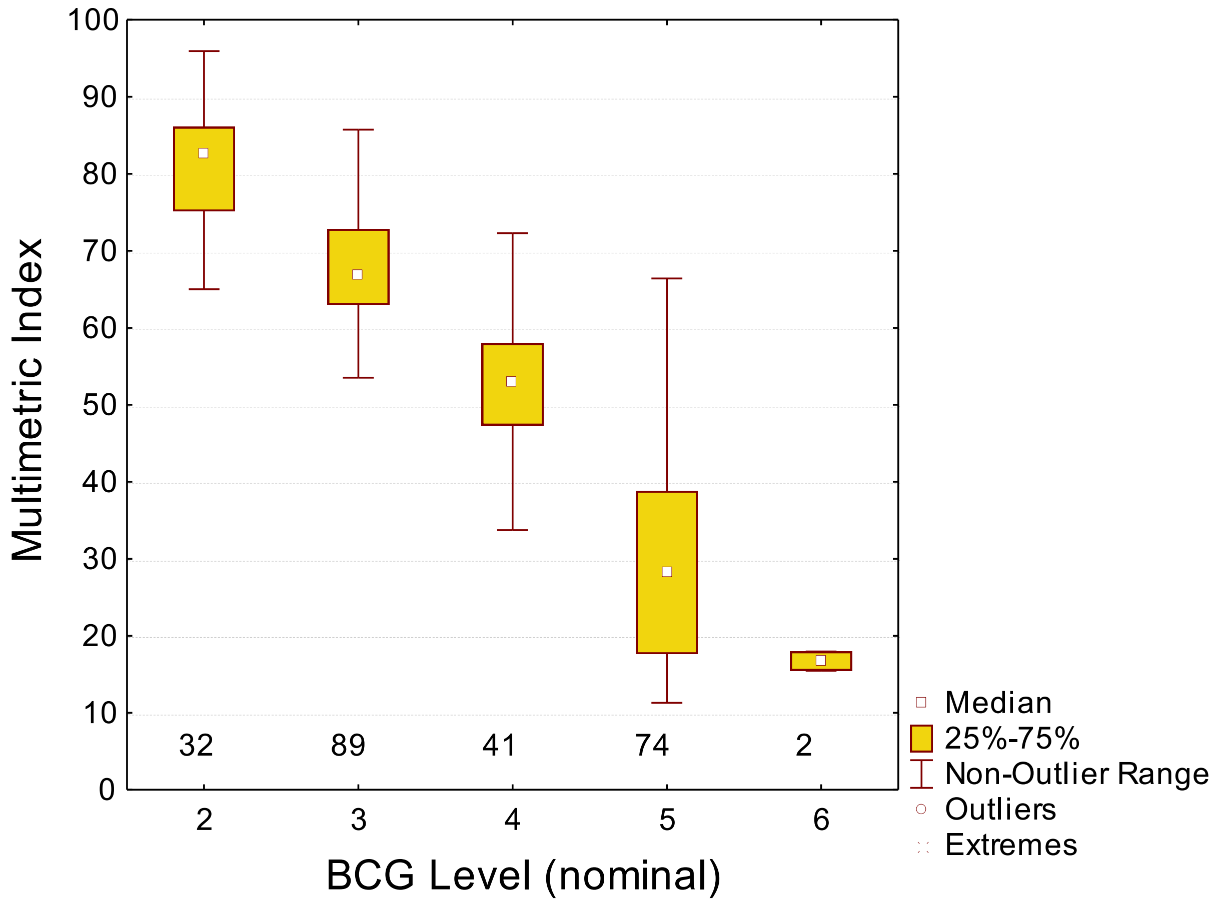

Figure 20. Connecticut MMI by BCG levels, estimated from decision analysis model. Number of samples given below boxes.

In spite of these differences, MMI scores could be used to separate levels (Figure 20). Potential MMI scoring thresholds are given in Table 23.

Table 23. Scoring thresholds for the Connecticut MMI to correspond to BCG levels

BCG Level	MMI Scoring Range
Levels 1, 2	> 75
Level 3	60–74.9
Level 4	43–59.9
Level 5	20–42.9
Level 6	> 20

The BCG decision model and the MMI were in overall concordance on the assessments from the two methods. The scoring range of the MMI was broken into categories corresponding to BCG levels. This resulted in disagreement of 32% of multimetric scores compared to the BCG decision model, but disagreements were never by more than a single level. There was no bias in the direction of disagreement among models, determined by the similar number of MMI assessments that were better or worse than the corresponding BCG assessments.

An additional example of an approach to reconcile an existing index to the BCG is included in Appendix B. This example involves an innovative technique to "back calculate" a historically representative IBI (Appendix B1). In this case it helped to clarify the position of an IBI based on current-day stressors for the Upper Mississippi River.

4.3 Statistical Models to Predict Expert Decisions: Multivariate Discriminant Model Approach

Another approach to quantify expert consensus and develop a BCG model is use of multivariate statistical models to predict expert judgment. For example, Maine DEP developed a set of multivariate linear discriminant models to simulate the expert consensus and predict a site assessment (Danielson et al. 2012; Davies et al. In press), and the United Kingdom Environmental Agency defined ranges of scores of two indices (their RIVPACS index and a tolerance index) that correspond to expert consensus (Hemsley-Flint 2000). Both of these approaches utilize one or more multivariate statistical models to predict the expert judgment in assessments. The following section describes Maine's use of linear discriminant models to discern levels of biological condition.

4.3.1 Approach

The objective of the discriminant model approach is the same as that of the quantitative rule development approach described in section 4.1: to develop a predictive model that will duplicate the decisions of the expert panel, so that new water bodies can be assessed without having to reconvene the panel. As with the rule development, the discriminant model (a multivariate statistical model) uses the same data available to the expert panel.

Discriminant analysis can be used to develop a model that will divide, or discriminate, observations among two or more groups whose membership characteristics have been defined *a priori* (i.e., in advance) of the construction of the model. This is accomplished through use of a model-building or "learning" data set in which samples have been assigned into the groups of interest, for example by expert consensus much like the expert panel process discussed in section 4.1.1. In short, for purposes of calibrating a BCG model, a discriminant function model can be developed from a biological data set where sites in a training data set have previously been assigned to BCG levels. A discriminant function model is a linear function combining those input variables that most successfully contribute to group definition and discrimination among groups. The resulting model yields the maximum separation (discrimination) among the groups (e.g., levels of the BCG). The analysis objectively identifies the best discriminatory variables and weights their relative contribution to the discriminatory model using coefficients. Selection of input variables is aided by initial exploratory data analysis to investigate relationships between biological response variables and physical stream characteristics (width, depth, velocity, elevation, temperature), and by data reduction techniques to eliminate highly correlated variables.

The linear discriminant model (LDM) approach may reveal subtle discriminatory variables within the data set that the biologists might not have recognized as important. This feature of statistical selection of variables contributes to building a highly discriminatory model. In construction of an LDM, input variables can also be included in the model on the basis of the judgment of experts that the variable provides an important link to assessment of the specific biological values that are stated in narrative biological criteria. Once constructed, the model can be used to objectively and consistently determine membership in a BCG level for new observations where the level is unknown. Maine uses this method to determine whether streams are meeting biological criteria for the state's tiered ALUs.

Although it requires statistical expertise to develop, another advantage of discriminant analysis is that it uses established and well-documented statistical methodology, with known confidence limits, and it reports group membership of a sample as probability statements, providing an understanding of the degree of certainty of the reported result. While LDMs require a relatively large set of assigned sites to calibrate the model (approximately 20 per group due to dependence upon having a suitable number of degrees of freedom, Manly 1991; Wilkinson 1989), accuracy of the model to the expert-assigned calibration and test sites can be as high as 89%–97%[6] (Davies et al. In press; Shelton and Blocksom 2004).

Using a discriminant model to develop biological criteria requires both a set of model-building data to develop the model and confirmation data to test the model. If a sufficient number of samples are available, the training and confirmation data may be from the same biological database, randomly divided into two sets (60% to 70% of data for calibration), or they may be drawn from two or more years of survey data. All sites in each data set are assigned to BCG levels by the expert workgroup.

Depending upon the required precision of the model, one or more discriminant function models that function in a hierarchical fashion may be developed from the model-building set to predict level membership from biological data. Building a set of nested, hierarchical models is an effective way of improving overall predictive accuracy (Davies et al. In press). Once developed, the model is applied to the confirmation data set to determine how well it can assign sites to levels using independent data not used to develop the model. More information on discriminant analysis can be found in many available textbooks on multivariate statistics (e.g., Jongman et al. 1987; Legendre and Legendre 1998; Ludwig and Reynolds 1998; Rencher 2003).

4.3.1.1 Example—Maine Discriminant Model for Benthic Macroinvertebrate Assemblages (Source: Shelton and Blocksom 2004)

Maine has four designated use classifications for its streams, AA, A, B, and C, with three corresponding ALUs. Classes AA (Maine's outstanding natural resource waters) and A correspond to BCG levels 1 and 2 (per Maine's narrative criteria, "as naturally occurs"), and they are not distinguishable based on Maine's biological assessment method. Class B ("no detrimental change") corresponds approximately to BCG level 3, and Class C ("maintain structure and function") corresponds approximately to BCG level 4.[7] Streams in poorer condition than Class C, comprising BCG levels 5 and 6, are not in attainment (NA) of minimum state ALU standards. Section 6.5 provides details of implementation and application of

[6] Based on jack-knife tests of the combined nested LDMs in Maine's two-stage hierarchy of LDM analysis. Results for a new test data set, not used to build the model were 75%–100% accuracy (Davies et al. In press).

[7] The percentage of river and stream miles assigned to each ALU classification in Maine is: Class AA/A-49%; Class B-51%; Class C- 0.4%.

Maine's biological criteria models. After testing multiple statistical modeling techniques (e.g., k-means clustering, Two-Way Indicator Species Analysis, multivariate ordination), the use of best professional judgment of expert aquatic biologists and construction of a set of hierarchical linear discriminant models was selected as the most promising approach to accomplish both technical and regulatory policy goals.

Maine's tiered ALUs and calibration process for benthic macroinvertebrate samples utilizing professional judgment actually predated the formalization of the BCG, and development of the BCG was in fact based, in part, on Maine's approach to biological assessment and biological criteria (Davies and Jackson 2006). The calibration approach in Maine was similar to that described in section 4.1, except that professional judgment was used to place streams into Maine's designated ALU classes (Class A, Class B, Class C) instead of into BCG levels. Maine's tiered ALUs provide an ecologically descriptive gradient of condition tiers, with detailed definitions, to express the expected goal condition for each class. These clearly articulated goals provided the "guiding image" (Poikane et al. 2014; Willby 2011) for biologists to assign samples to classes. Maine DEP developed a set of multivariate linear discriminant models to predict the expert site assessment (Davies et al. 1995; Shelton and Blocksom 2004; State of Maine 2003; Davies et al. In press). The description of the model-building data set below is modified from Shelton and Blocksom (2004):

> The MEDEP [MDEP] originally developed the linear discriminant models based on 145 rock basket samples collected from across the state and representing a range of water quality during 1983–1989. They recalibrated the models in 1998 using a much larger macroinvertebrate database with a total of 376 sampling events (Davies et al. 1999). The final step involved assigning each of the 376 sites in the database to one of four *a priori* groups using the quantifiable measures.

MEDEP also conducts biological assessments of stream algal, wetland macroinvertebrate, and wetland phytoplankton and epiphytic algal assemblages (Danielson et al. 2011, 2012). MEDEP used Maine's narrative biological criteria and the BCG as the foundation of biological assessment models for stream algae, also using the LDM approach outlined here (Danielson et al. 2012). A first step in model-building was to empirically compute tolerance values for algal and macroinvertebrate species that had been collected in Maine's monitoring program. After computing tolerance values, the species were grouped into the BCG framework's sensitive, intermediate, and tolerant attribute groups. MEDEP then modified the model BCG framework for stream macroinvertebrates for stream algae and wetland macroinvertebrates, describing how those assemblages empirically respond to anthropogenic stressor gradients. MEDEP used those modified BCG frameworks and tolerance metrics along with the narrative biological criteria and other metrics to build predictive biological assessment models for the additional assemblages. MEDEP has completed LDM statistical models to predict ALU attainment for both stream algal and wetland macroinvertebrate community data. These models currently are used to help interpret narrative biological criteria. Following adequate testing and standard public review protocols, MEDEP will amend the Maine Biological Criteria Rule[8] to include the stream algal and wetland macroinvertebrate models as numeric biological criteria.

8 See Code of Maine Rules, MEDEP, Chapter 579, http://www.maine.gov/dep/water/rules/index.html. Accessed February 2016.

To define *a priori* groups for stream macroinvertebrates, biologists were given data from a set of sites and asked to place the sites into Maine's use classes based on the biological data only (Willby 2011). This set of sites was then used as the calibration data (or "learning" data) for an LDM. The objective of the discriminant model is to replicate ("predict") the professional judgment of the panel of biologists. The excerpt below describes how MEDEP biologists assigned calibration sites to Maine's three classes and to NA (from Davies et al. In press):

> Maine's statutory classes are goal-based and thus do not necessarily correspond to actual biological condition of streams in Maine so legislatively assigned classes could not be used to define groups ... As an alternative approach to defining stream classes, we used "expert knowledge/prior experience" to identify response signals (to different levels of human disturbance) for 30 quantifiable measures of macroinvertebrate community structure (Table 24 below). This classification process was then followed by validation using objective methods to confirm that the *a priori* groupings were, in fact, statistically distinguishable. This approach has been well developed (Anderson 1984; Press 1980). Discriminant analysis and function derivation does not have to rely on classes that only occur in nature. As long as classes are statistically distinct and their members possess a Gaussian distribution within a class, then most assumptions are met (Anderson 1984). To establish *a priori* groups, MDEP biologists, along with independent biologists from other states, and the private stakeholder sector, evaluated benthic macroinvertebrate community data for each stream sample (without knowing site locations or pollution influences) and assigned samples to an aquatic life condition category. The methodology was based on the degree to which each biologist found the sampled community conformed to one of the narrative aquatic life criteria (Class AA/A, B, C; or NA if the community assemblage did not conform to the narrative criteria of the lowest class) as described in the statute and accompanying definitions (Shelton and Blocksom 2004). The panel of biologists received limited habitat data (e.g., depth, water velocity, substrate composition, temperature) in order to evaluate the intrinsic biotic potential of the sampled habitat, but biologists had no knowledge of the site locations, or degree of human disturbance.

<u>Biologist's Classification Criteria</u>

Each biologist reviewed the sample data for the values of a list of measures of community structure and function. Criteria used by biologists to evaluate each measure are listed in Table 24. In 64% of the cases, there was unanimous agreement among the independent raters, and in an additional 34% of the samples, two of the raters were in agreement and one had assigned a different classification. In three of the rated samples, there was disagreement among all three raters (2%).

Table 24. Maine Biologists' Relative Findings Chart Using Macroinvertebrates (Source: Davies et al. In press)

Measure of Community Structure	Relative Findings by Water Body Class			
	A	B	C	NA
Total Abundance of Individuals	often low	often high	variable to high	variable: often very low or high
Abundance of Ephemeroptera	high	high	low	low to absent
Abundance of Plecoptera	highest	some present	low to absent	absent
Proportion of Ephemeroptera	highest	variable, depending on dominance by other groups	low	zero
Proportion of Hydropsychidae	intermediate	highest	variable	low to high
Proportion of Plecoptera	highest	variable	low	zero
Proportion of *Glossoma*	highest	low to intermediate	very low to absent	absent

Measure of Community Structure	Relative Findings by Water Body Class			
	A	B	C	NA
Proportion of *Brachycentrus*	highest	low to intermediate	very low to absent	absent
Proportion of Oligochaetes	low	low	low to moderate	highest
Proportion of Hirudinea	low	variable	variable	variable to highest
Proportion of Gastropoda	low	low	variable	variable to highest
Proportion of Chironomidae	lowest	variable, depending on the dominance of other groups	highest	variable
Proportion of *Conchapelopia* & *Thienemannimyia*	lowest	low to variable	variable	variable to highest
Proportion of *Tribelos*	low to absent	low to absent	low to variable	variable to highest
Proporation of *Chironomus*	low to absent	low to absent	low to variable	variable to highest
Genus Richness	variable	highest	variable	lowest
Ephemeroptera Richness	highest	high	low	very low to absent
Plecoptera Richness	highest	variable	low to absent	absent
EPT Richness	high	highest	variable	low
Proportion Ephemeroptera Richness	highest	high	low	zero
Proportion Plecoptera Richness	highest	high	low	low to zero
Proporation Diptera Richness	low to variable	variable	highest	variable to high
Proporation Ephemeroptera & Plecoptera Richness	highest	high	low to variable	low to absent
EPT Richness divided by Diptera Richness	high	highest	low to variable	lowest to zero
Proporation Non-EPT or Chronomid Richness	lowest	low	intermediate to high	highest
Percent Predators	low	low	high to variable	high to variable
Percent Collectors, Filterers, & Gatherers divided by Percent Predators & Shredders	high	highest	low	lowest
Number of Functional Feeding Groups Represented	variable	highest	variable	lowest
Shannon-Weiner Generic Diversity	low to intermediate	highest	variable to intermediate	lowest
Hilsenhoff Biotic Index	lowest	low	intermediate	highest

Once these groups were determined subjectively and independently by three biologists, univariate and multivariate analysis of variance (ANOVA and MANOVA, respectively) confirmed that the assigned groups were in fact statistically distinct. Following establishment and statistical validation of the groups, MEDEP applied additional analyses to evaluate the necessity to develop stratified models to account for natural factors, such as geographic location and stream size. The uni- and multivariate analyses (cluster analysis, multidimensional scaling, and principle components analysis, in part) suggested that a physically or geographically stratified model for Maine was not warranted. To determine variability in expert judgment assignments, a new test data set was assigned to *a priori* groups by two non-MEDEP biologists, yielding an average concurrence with MEDEP biologists' assignments of 80%. Furthermore, as a check against potential circularity in the model (i.e., "this site looks good, so this must be what good sites look like"), MEDEP chose 27 minimally disturbed sites based on non-biological criteria. These sites were not originally used in the expert assessment or to build the model. This reference data set was used to determine the success of the model to assign them to Class A conditions. These sites had no known point sources and land uses were characterized as 97% forested (3% logged); 2% crop; and 1% residential, industrial, or commercial.

Next, statistical methods and expert judgment were used to identify 26 biological community variables from a list of over 400 variables using stepwise discriminant analysis and iterative backward selection procedures to best assess attainment of the biological goals in the state's ALUs, and to best predict membership of an unknown stream sample to one of the four water quality classes (A, B, C, and NA). These were the methods used by Maine; for alternative approaches to variable selection and optimizing group separation, see Van Sickle et al. (2006). The 26 variables are in Table 25 (four original variables were discontinued following recalibration of the model). Linear discriminant functions were developed from the 26 quantitative macroinvertebrate variables. The discriminant functions determine the probability that a site belongs to a given water quality class. Using a linear optimization algorithm to calculate the discriminant function coefficients, multivariate space distance was minimized between sites within a class, while the distance between classes was maximized. Note that three variables used as predictors in the second-stage models were not calculated directly from the biological data, but instead were probabilities of group membership reported by the First Stage (four-way) discriminant model (see below).

The final, overall discriminant function is calculated using one four-way model and three two-way models. First, using only nine variables and calculated coefficients, the four-way model calculates the probability (range 0.0–1.0) that a site fits into each of the three attainment classes (AA/A, B, or C) and the non-attainment class (NA). The resultant probabilities are then transformed and used as variables in the three two-way models (Table 25). Use of the second stage, two-way models significantly improves the predictive accuracy of the overall model.

Table 25. Measures of community structure used in linear discriminant models for Maine (from MEDEP 2014; State of Maine 2003). Means refer to the mean of three rock baskets sampled at each site.

Model	No.	Measure
First Stage (four-way) model	1	Total mean abundance
	2	Generic richness
	3	Plecoptera mean abundance
	4	Ephemeroptera mean abundance
	5	Shannon-Wiener generic diversity (Shannon and Weaver 1963)
	6	Hilsenhoff Biotic Index (Hilsenhoff 1987a, 1987b)
	7	Relative Chironomidae abundance
	8	Relative Diptera richness (Diptera richness/generic richness)
	9	Hydropsyche mean abundance
Class C or Better model	10	Probability (A+B+C) from First Stage Model
	11	Cheumatopsyche mean abundance
	12	EPT:Diptera richness ratio
	13	Relative Oligochaeta abundance
Class B or Better model	14	Probability (A+B) from First Stage Model
	15	Perlidae mean abundance
	16	Tanypodinae mean abundance
	17	Chironomini mean abundance
	18	Relative Ephemeroptera abundance
	19	EPT generic richness
	21	Sum of mean abundances of: *Dicrotendipes*, *Microspectra*, *Parachironomus,* and *Helobdella*
Class A model	22	Probability of Class A from First Stage Model
	23	Relative Plecoptera richness (Plecoptera richness/generic richness)
	25	Sum of mean abundances of *Cheumatopshyche*, *Cricotopus*, *Tanytarsus,* and *Ablabesmyia*
	26	Sum of mean abundances of *Acroneuria* and *Stenonema*
	28	Ratio of EP generic richness (EP richness/14; 14 is maximum)
	30	Ratio of Class A indicator taxa (Class A taxa/7)

Note: Variable numbers are not sequential; variables 20, 24, 27, and 29 were discontinued following re-parameterization of the model.

The three two-way models further refine the discrimination among classes AA/A, B, or C. These models distinguish between a given class plus any higher classes as a group and any lower classes as a group (i.e., Classes AA/A + B + C vs. NA; Classes AA/A + B vs. Class C + NA; Class AA/A vs. Classes B + C + NA) as depicted in Figure 21, and model performance is shown in Table 26 below (MEDEP 2014; State of Maine 2003; Davies et al. In press). The two-way models are not strictly independent of the four-way model, because they use output probabilities of the four-way model as predictor variables.

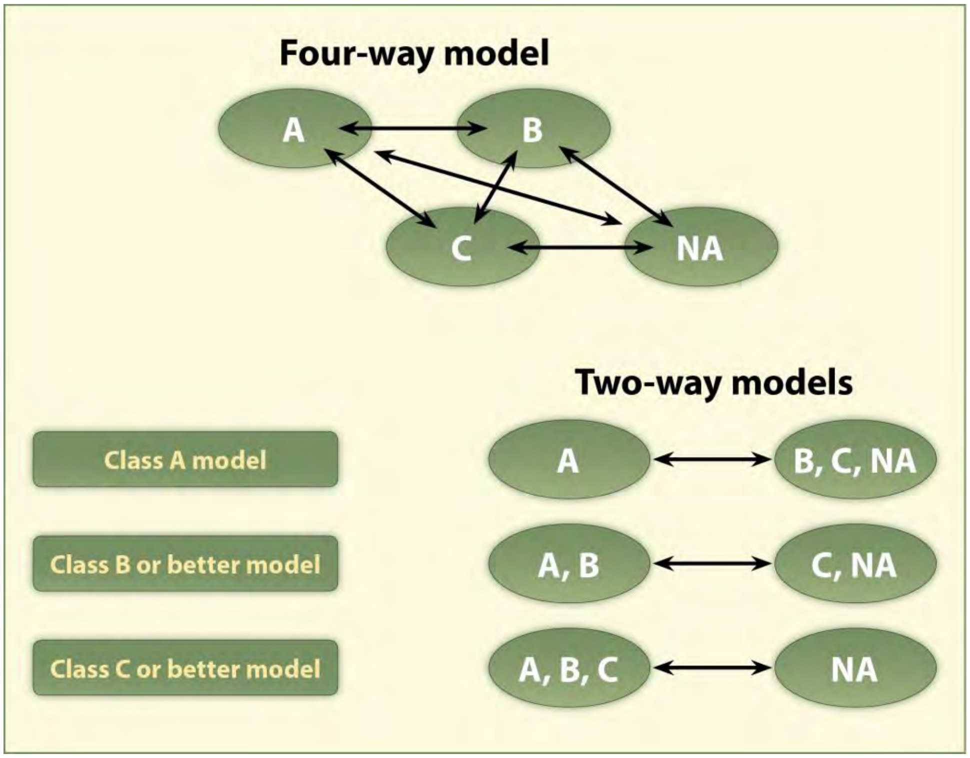

Figure 21. Schematic of four-way and two-way model relationships used by Maine DEP to refine the discrimination among classes (Source: MEDEP 2014).

Table 26. Classification of stream and river sites by two-way linear discriminant models for three classifications. Numerical entries represent the percent of sites classified from *a priori* classes (row) into predicted classes (columns). Therefore, diagonals are % correct classification.

Final A Classification		
Model Predicted Class		
***A priori* class**	**Class A**	**Classes B,C, or NA**
Class A	90.00% (108)	10.00% (12)
Classes B, C, NA	10.28% (26)	89.72% (227)
Final B or Better Classification		
Model Predicted Class		
***A priori* class**	**Class B or better**	**Classes C or NA**
Class B or better	96.57% (225)	3.43% (8)
Classes C, NA	11.43% (16)	88.57% (124)
Final C or Better Classification		
Model Predicted Class		
***A priori* class**	**Class C or better**	**NA**
Class C or better	96.07% (293)	3.93% (12)
NA	14.71% (10)	85.29% (58)

Note: Number in parentheses indicates the number of sites.

Once the probability that a site belongs to a certain class is calculated, the Maine Biocriteria Rule describes the assessment process the Department follows to conclude whether the site attains the minimum standards of its assigned classification (MEDEP 2014; State of Maine 2003). In order to determine whether a site attains at least Class C or is in non-attainment, the probability outcome using the "Class C or better model" is used. If the probability is greater than 60%, then the sample attains Class C or higher, but if it is less than 40% then the site is in non-attainment. If a site falls within 40%–60%, then best professional judgment is used to determine whether the site attains Class C, does not attain Class C, or is indeterminate of Class C. For any site found to be indeterminate, additional monitoring is scheduled in order to make a decision.

Those samples that attain Class C are then tested for Class B attainment using the probability of Class B outcome from the "Class B or better model." If the probability is greater than 60%, then the sites are deemed to attain at least Class B status. Those values below 40% are now considered to be sites that attain to Class C. If a value falls between 40% and 60%, then the outcome is indeterminate of Class B. If the site designated ALU is Class A or Class B, then additional monitoring is conducted to determine to which attainment class the site belongs.

When the probability outcome for a site is 60% or greater using the Class B or better model, it is then tested using the "Class A Model." If the probability of Class A is 60% or greater, then the site attains class A standards. If the value is 40% or less, then the site attains to Class B. If the value is between 40% and 60%, the finding is indeterminate of Class A (though it does attain Class B). Additional sampling will be required if the designated use of the site is Class A. Maine's WQS state that sites determined to attain the standards of the next higher class must be reviewed and considered for re-classification to the next higher class in order to maintain the higher water quality conditions that are being achieved (State of Maine 2004).

The LDM provides a probability of membership result. It explains model performance on a particular sample and can be used to assess the strength of the model decision. Additionally, each of variables can be examined to determine the strength of their contribution to the decision. After the LDM predicts the class attained by a site, a provision in MEDEP regulations (State of Maine 2003) allows for professional judgment to make an adjustment to the evaluation. Any adjustment may be made using analytical, biological, and habitat data. Professional judgment also may be employed when the condition of the stream does not allow for the accurate use of the linear discriminant models. Such factors may include habitat influences (e.g., lake outlets, impounded waters, substrate characteristics, tidal waters), sampling issues (e.g., disturbed samples, unusual taxa assemblages, human error in sampling), or analytical and sample processing issues (e.g., subsample vs. whole sample analysis or human error in processing) (MEDEP 2014; State of Maine 2003).

4.4 Automation of Decision Models

Any of the BCG decision models described above (sections 4.1–4.3) can be automated in databases, spreadsheets, or other commonly available software. Multimetric models have been incorporated into spreadsheet formulas and relational databases (e.g., Environmental Data Acquisition System [EDAS] and many state databases). Discriminant models and other statistical tools can also be coded in R and combined with a database or interactive web pages. More recently, several BCG multiple attribute decision models have been incorporated into MS-Access® applications.

For example, user-friendly automated models have been developed in Microsoft Excel® for the Upper Midwest (Gerritsen and Stamp 2012) and Northern Piedmont region of Maryland (Stamp et al. 2014). Additionally, the Little River Band of Ottawa Indians (LRBOI) has been using the Excel spreadsheets for the Upper Midwest BCG models to obtain BCG level assignments for all of their fish and macroinvertebrate samples from the lower Big Manistee watershed.

Geospatial database technology has advanced in recent years and shows promise for application in water quality management programs, including condition assessments. For example, Maine's discriminant model is incorporated into Maine's Oracle® relational database that is fully georeferenced and linked to the state's spatial database. The state's spatial database and selected, quality assured environmental data, including biological criteria assessment results, are publicly accessible via Google Earth.[9] Linkage between traditional databases that report biological assessment outcomes, and geo-spatial databases connected to natural bio-geophysical factors and disturbance parameters at multiple spatial scales, represent the growing edge of the emerging science of biological assessment.

4.5 Conclusion

A core objective of BCG calibration, from conceptualization to quantification, is to explicitly and transparently link science with management decisions in using biology to interpret ALU goals. This linkage can lead to enhanced stakeholder understanding and engagement in public decision making on goal setting and in assessing current conditions in relation to the ALU goals. However, information on stressors, their sources, and mechanism will be needed to identify actions to restore degraded waters and protect current conditions. Chapter 5 provides a conceptual framework, or template, to assist states in identifying the primary stressors and their sources and mechanisms of action, that impact their waters. This framework can be used by the states to organize data and information on watershed characteristics, hydrologic modifications, and stressors related to ALU goals.

[9] http://www.maine.gov/dep/gis/datamaps/index.html#blwq. Accessed February 2016.

Chapter 5. The Generalized Stress Axis

The x-axis of the BCG, the GSA, conceptually describes the full range, or gradient, of anthropogenic stress that may adversely affect aquatic biota in a particular geographic area. It is a theoretical construct that in application has been defined by states using known, quantitative stress gradients typically representing a portion of the stressors impacting a water body. The GSA provides a template for development of a quantified stress axis using available databases. Since the BCG curve represents the *in-situ* response of the resident biota to the sum of the stressors to which they are exposed, the GSA should be developed for the same geographic area and water body type for which the BCG is to be developed.

Once quantified, a GSA can serve several purposes. First and foremost, it can be used in development of decision rules for BCG model calibration. Second, the GSA and its underlying data can be used to inform management decisions and assess outcomes. Key applications of a GSA include:

Guide to selection of samples to be used in BCG decision rule development:

- Guide the selection of sites from a data set to ensure that the assessed sites cover as wide and full a range of stressors as possible, within the limits of the data set (see Chapter 3, section 3.3.1).
- Guide the assignment of different taxa to the different tolerance categories specified in the BCG (see Chapter 3, section 3.3.2).

Better link management decisions and outcomes:

- The data collected for developing a stress gradient might be used to help identify and rank sources and stressors within a region, watershed (e.g., 8- or 12-digit hydrologic unit code (HUC8 or HUC12, respectively)), and/or catchment[10] and improve the linkage between biological goals and management actions. Ideally, an improved connection between biological condition and stressors will assist state agencies in prioritizing sources and stressors for action, select effective BMPs, and track improvements. This application will likely occur after BCG development and require causal analysis (e.g., CADDIS; Suter et al. 2002; Norton et al. 2015).
- The data collected in development of the GSA might also be repurposed to inform additional management tools. For example, field-based stressor-response relationships can be used to help develop benchmarks for ALU (protective thresholds for contaminants or excess nutrients or conductivity; e.g., Cormier and Suter 2013; Cormier et al. 2013; USEPA 2011a). In addition, data analyses that describe the distribution of stressors that occur naturally can be repurposed to define background conditions.

This chapter describes the conceptual foundation of the GSA; discusses technical issues to be considered in developing a GSA for specific geographic areas and water body types; and, provides an overview of some approaches for quantifying a GSA.

[10] *Catchment* is defined as an incremental watershed that drains directly into a stream reach and excludes upstream areas. See: http://nhd.usgs.gov/. Accessed February 2016.

To date, GSAs have been used to develop decision rules to assign sites to BCG levels using known stress gradients and available regional, state, and/or county data (as described in first two bullets above). Some of these GSA applications were explained in the case studies in Chapter 3; they include quantitative gradients based on use of land cover indicators as surrogates for stressors (Minnesota, Alabama; see section 3.3.1.1), and an ordinal gradient based on the sum of cumulative stressors present at a site (Connecticut; see section 3.3.1.2). However, a systematic review and testing of the full suite of potential technical approaches to define and apply a GSA to BCG development has not been conducted. Opportunities in the future may include piloting methods for application of national, regional, or watershed scale data and methods to support state efforts to define and quantify the GSA. Examples of sources of data include EPA's National Aquatic Resource Surveys,[11] the StreamCat data set[12] (Hill et al. 2015), and EPA Office of Research and Development's watershed integrity indicators and map of the ecological condition of watersheds across the country (Flotemersch et al. 2015). Examples of methods that are currently available include the Healthy Watershed Methodology,[13] the Recovery Potential Screening tool (Norton et al. 2009),[14] the Analytical Tools Interface for Landscape Assessments (ATtiLA),[15] and the National Land Cover Database (NLCD).[16] Sources for both data and methods include the Watershed Index Online (WSIO)[17] and EnviroAtlas.[18]

5.1 The Conceptual Foundation of the Generalized Stress Axis

The purpose of this section is to provide a broad conceptual framework and terminology that describes the effects of human activities on biological communities and forms the basis for constructing a GSA. This framework can also be used to facilitate application of research to advance the development and application of the GSA as part of a quantitative BCG model.

The intent of the GSA is to reflect the cumulative degree of anthropogenic stress experienced by aquatic biota. Five major ecological factors that reflect environmental processes and materials determine the biological condition of freshwater aquatic resources: flow regime, water quality, energy source, physical habitat structure, and biotic interactions (Figure 22) (Karr and Dudley 1981). The first four of these factors (flow regime, water quality, energy source, and physical habitat structure) form the construct for a GSA. Appendix A-1 provides an organizing framework for a GSA and illustrates how a GSA might classify sites as high, medium, or no/low levels of stress for two general regions of the U.S., humid temperate and arid, based on these major factors.

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[11] http://www.epa.gov/national-aquatic-resource-surveys. Accessed February 2016.

[12] http://www.epa.gov/national-aquatic-resource-surveys/streamcat. Accessed February 2016.

[13] http://www.epa.gov/hwp. Accessed February 2016.

[14] http://www.epa.gov/rps. Accessed February 2016.

[15] http://www2.epa.gov/eco-research/analytical-tools-interface-landscape-assessments-attila-landscape-metrics. Accessed February 2016.

[16] http://landcover.usgs.gov/. Accessed February 2016.

[17] http://www.epa.gov/watershed-index-online. Accessed February 2016.

[18] http://www.epa.gov/enviroatlas. Accessed February 2016.

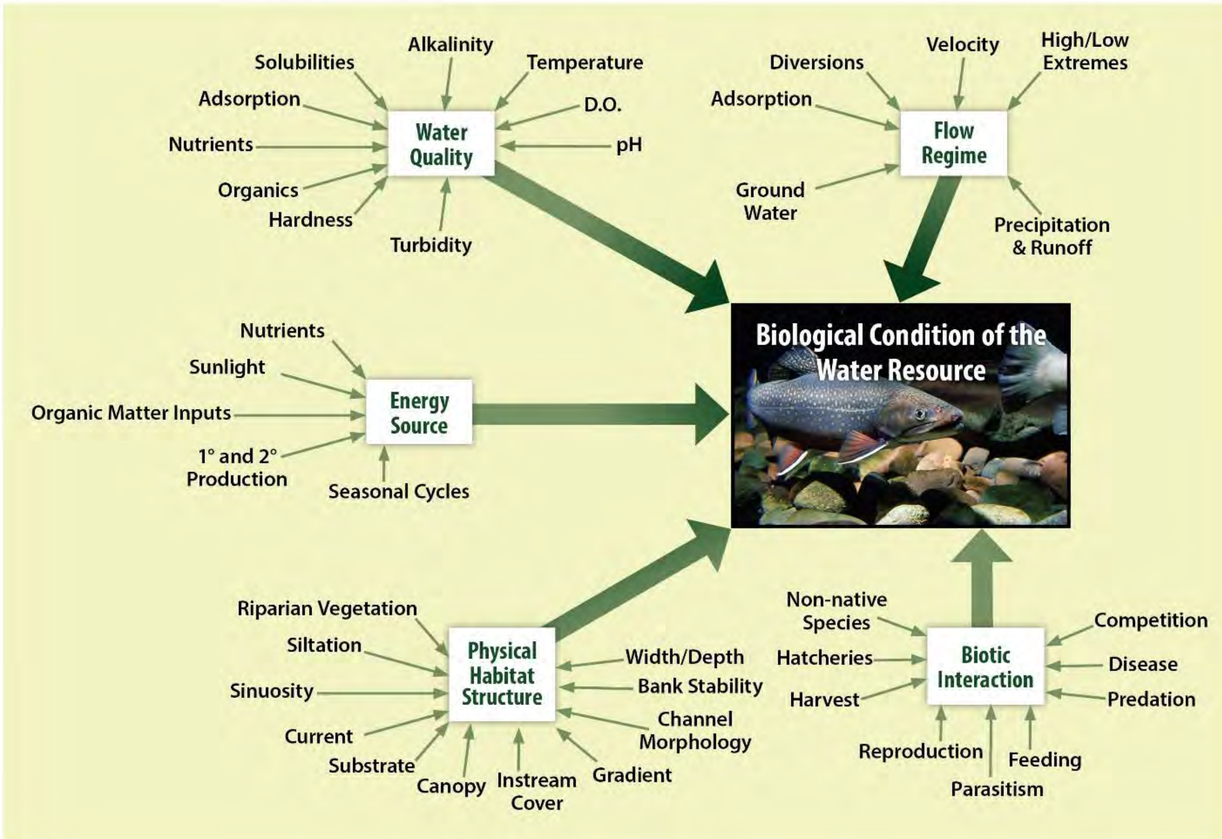


Figure 22. The five major factors that determine the biological condition of aquatic resources (modified from Karr and Dudley 1981). Four of the five factors, flow regime, water quality, energy source, and physical habitat structure, are the basis for the conceptual GSA as described in this document. The fifth factor, biotic interaction, is incorporated as part of the BCG y-axis levels and attributes.

An event or activity that alters one or more of these five factors is called a *disturbance*. Disturbances can occur outside of the stream and riparian zone (e.g., land use changes within the watershed, climate) or within it (e.g., dams, point source discharges). Ecosystems normally have some level of disturbances that occurs within a range of natural variability (e.g., Berger and Hodge 1998; White and Pickett 1985). Anthropogenic activities can cause disturbances that exceed the range of natural variability, and they are said to exert *pressure*[19] upon an aquatic system, or *state*, by altering ecosystem processes and materials, ultimately generating *stressors* that adversely impact biological condition (Niemi and McDonald 2004). The term *pressure* conceptually and mechanistically links larger scale landscape and hydrological alterations to the in-stream stressors that affect aquatic biota (Crain and Bertness 2006; Rapport and Friend 1979; Samhouri et al. 2010; Villamagna et al. 2013). Though different terminology is employed, the *Stressor-Exposure-System Response* paradigm (e.g., Barnthouse and Brown 1994) typically employed in water quality criteria development is comparable in that both conceptual models ultimately help accomplish the same objective—linking human activities to stressors to changes in biological condition (Figure 23) so action can be taken to protect or restore aquatic resources.

[19] The use of the word pressure in this context has a well-established history in the European environmental literature. Pressure is a term originally proposed by the Organisation for Economic Co-operation and Development (OECD 1998) and used by the European Union in its Water Framework Directive (European Environment Agency 1999).

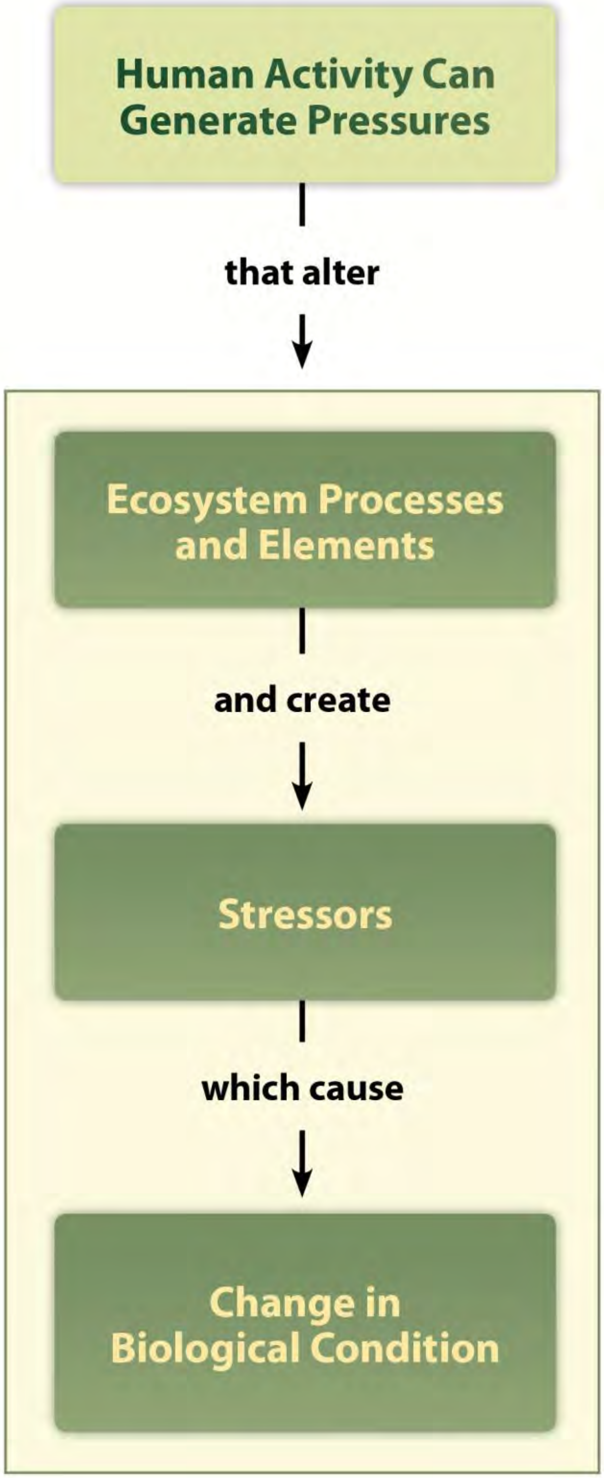


Figure 23. Human activities can cause *disturbances* in the environment that exceed the range of natural variability, generating *pressure* upon an aquatic system that results in altered *environmental processes and materials,* which, in turn, create *stressors* that adversely impact biological condition.

Stressors are the proximate causes of biological effects. They are the link between human activities and the change in biological condition (Figure 23). Stressors can co-occur in time and space when they are generated by the same human activity or source and/or any overlapping activity or source. Stressors may affect more than one aspect of biological condition, and a particular change in biological condition can also be the result of multiple stressors acting simultaneously. Since multiple stressors are usually present, the x-axis is intended to reflect their cumulative spatial/temporal co-occurrence in a GSA, much as the y-axis generalizes biological condition.

Point source discharges of pollutants were the dominant pressures to fresh waters addressed in the initial implementation of the CWA. While this pressure still exists today, water quality managers also face additional challenges stemming from in-stream hydrological modifications, forest harvest, agriculture, and urbanization, as well as emerging pressures associated with the inadvertent or deliberate introduction of invasive species (Ricciardi and MacIsaac 2000), the consequences of greenhouse gas emissions (e.g., Bierwagen et al. 2012), use of pharmaceutical products (Rosi-Marshall and Royer 2012; Rosi-Marshall et al. 2013), and even recreation (Bryce et al. 1999; Poff et al. 2002; Richter et al. 1997). Additionally, stressors can exert both direct effects on the biota and indirect effects through modification of habitat and interactions with other stressors (Karr and Dudley 1981; Karr et al. 1986; Poff et al. 1997; Slivitzky 2001) (Figure 24).

For example, a GSA that considers flow regime changes would consider many stressors and their interactions. Stream flows directly influence stream biota, but they also interact in multiple ways with other in-stream factors including water quality parameters, such as DO and temperature. Altered stream flows are strongly associated with many habitat variables such as channel structure, erosion, bank instability, and lower base flows (Poff et al. 1997; Richter et al. 2003; Poff et al. 2010). All of these factors associated with the flow regime have the capability of affecting species distributions, abundances, life history traits, and competitive interactions (Greenberg et al. 1996; Kennen et al. 2008; Poff and Allan 1995; Poff et al. 1997; Robson et al. 2011; Walters and Post 2011).

Many of the changes to the natural flow regime can be attributed to human activities, such as dam creation, channelization, and impervious surfaces, along with associated removal of natural vegetation, water extraction, and loss of surface water storage capacity (e.g., wetlands) (Poff et al. 1997). Altered flow regimes are also the result of changing climate, with changes observed in precipitation and runoff amounts, seasonal patterns, and timing, frequency, and intensity of large storms (Frich et al. 2002; Karl and Trenberth 2003; Poff et al. 2002). Still, flows vary naturally, and it can be difficult to distinguish anthropogenic disturbance from the range of variation produced by natural processes (e.g., see review by Berger and Hodge 1998). All of these issues should be considered when developing a GSA that reflects the stress associated with flow regime changes.

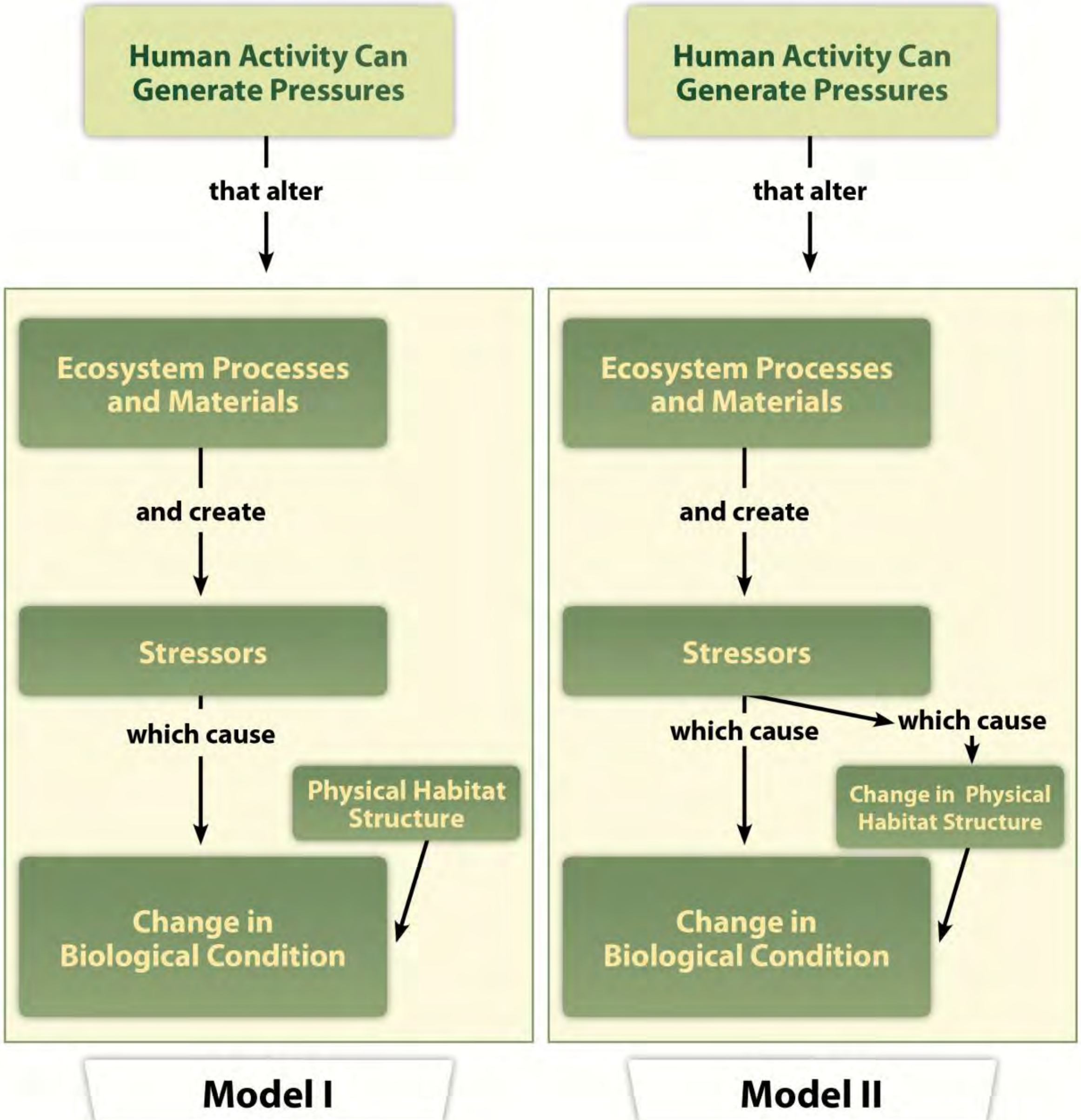


Figure 24. Hierarchical effects of disturbance. When assessing the relationship between stressors and biological effects, one of two implicit models is assumed. Model 1—the biota at a site are determined by the environmental covariates characteristic of the habitat. The stressors associated with a human-related disturbance directly influence biota. Model 2—the biota at a site are determined by the environmental characteristics of the site. However, the stressors associated with a human-related disturbance influence both the physical habitat structure and the biota itself. Consequently, the biological effects reflect the combined direct effects of the stress and the disturbance-mediated habitat alteration (From: Ciborowski et al. unpublished). Comprehensive and integrated monitoring data (biological, chemical, physical) coupled with causal assessment will help distinguish direct from indirect effects (USEPA 2013a).

5.1.1 Technical Issues in Developing a Generalized Stress Axis

This section discusses some of the technical issues to be considered in defining a GSA, including temporal and spatial scales, multiple stressors, legacy effects, and predicted impacts of climate change on aquatic systems. The concepts of spatial and temporal scale are critical issues in adequately defining the GSA. Pressures, stressors, and their effects on biota (e.g., biotic response) operate at different spatial and temporal scales (Glasby and Underwood 1996). Stressors are expressed over temporal and spatial scales ranging from a one-time, localized event (pulse event; Bender et al. 1984) to long-term chronic exposures occurring continuously (press events) over vast landscapes. Additionally, stressors may be introduced through diffuse or point sources delivered from upstream in the channel or watershed, or laterally from riparian, floodplain, or upland sources. Pollutants can also be delivered to a stream, river, lake or wetland from above through atmospheric sources, or below from groundwater sources. Activities in the watershed or along the water body corridor will influence the connectivity and integrity of the water resource. Additionally, climate change can exacerbate the intensity of local stressors (e.g., more heavy rainfalls can produce increased runoff and sediment load).

As discussed previously, human activities can produce multiple stressors, which in turn will affect biological condition. Stressors can interact with one another to create a synergistic response, behaving in an additive or multiplicative manner; they also may counteract one another. The steady accumulation of small pressures in watersheds results in cumulative effects, which add to the challenges of characterizing, evaluating, and managing stressors.

The influence of individual stressors on biological condition in specific water bodies can be particularly difficult to disentangle because each stressor potentially exerts indirect and direct forces. The complexity of interactions among stressors makes it difficult to identify single stressor-single biological effect relationships (Hodge 1997; Noss 1990; Vander Laan et al. 2013). Stressor identification is one causal assessment approach useful for identifying the stressors that cause biological effects (USEPA 2000; Norton et al. 2015).[20]

However, when sufficient data are available, quantitative modeling approaches can be used to describe the complex relationships between pressures, stressors, and their effects on the biota. Niemeijer and deGroot (2008a, 2008b) advocated summarizing the interactions among stressors to create causal networks as a means of better understanding the complex relationships between pressures and their ultimate effect on the biota, and this approach has been applied to streams with qualified success. Allan et al. (2012) used Bayesian Belief Network analysis to characterize the effects of sedimentation on macroinvertebrates in agricultural streams in the U.S. Midwest and in New Zealand affected by sedimentation due to grazing and forestry practices. Riseng et al. (2010, 2011) used Structural Equation Modeling to document relationships between stress and stream biota. They determined that land use effects in total were more important influences on metrics of fish and invertebrate biota than effects of point source discharges.

The concept that human activities produce multiple stressors provides the foundation for one common approach to describing an overall gradient of stress using land cover information as a surrogate for stressor information. In this approach, the GSA is developed using broadly defined, relatively easily measured factors that produce many stressors simultaneously (e.g., amount of urban development or road density in a catchment). Mapping the distribution of pressures, for example land uses associated

[20] See also http://www3.epa.gov/caddis/. Accessed February 2016.

with particular human activities, has proven to be an effective way of documenting the location of possible sources that produce the stressors that lead to biological degradation (Allan et al. 2013; Brooks et al. 2009; Danz et al. 2005, 2007).

Stressor indicators can be developed from such measures as population density, proportion of land devoted to agriculture or urban development, total miles of roadway, or quantities of water used/released (e.g., Allan et al. 2013; Host et al. 2005, 2011; Hunsaker et al. 1992; Jones et al. 1999, 2001; O'Neill et al. 1988, 1997; Riitters et al. 1995, 1996, 1997). The advent of improved remote sensing, digital technology, and the ability to map land uses has provided an important tool for documenting the location and extent of pressures on the landscape. This approach has been used effectively to assess watershed and coastal conditions such as in the Laurentian Great Lakes for decades where Danz et al. (2005, 2007) and Allan et al. (2013) documented the distribution of the composite stress contributed by human activity throughout the Great Lakes (Figure 25). A simplified form of the Danz et al. (2005) system, the Watershed Stress Index (Host et al. 2011), is currently used to report on the condition of Great Lakes watershed, including tracking progress towards achieving the overall purpose of the binational Great Lakes Water Quality Agreement "to restore and maintain the physical, chemical and biological integrity of the Great Lakes Basin Ecosystem."[21] Allan et al. (2013) used expert assessment to delineate threats to the biological integrity of the Great Lakes themselves. Host et al. (2011) mapped the distribution of watersheds in which specific groups of biota were at least and at greatest risk of degradation due to urban and agricultural pressures.

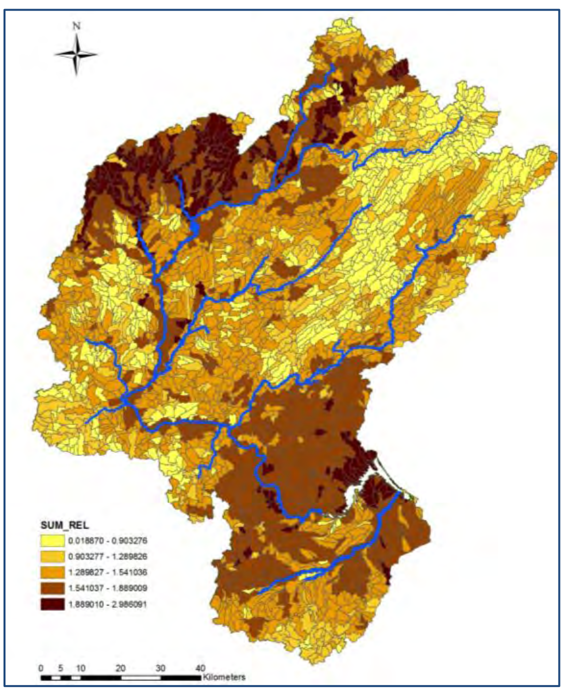


Figure 25. Cumulative stress within the St. Louis River watershed, a tributary to Lake Superior. Darker shading indicates increased stress. The stress score is based on the cumulative sum of % agricultural land use, population density, road density, and point source density. Values were each normalized to a 0–1 scale before summation. This index was used to calibrate water quality responses to stress in the St. Louis River Area of Concern (Bartsch et al. 2015). (Map by Tom Hollenhorst, EPA, Mid-Continent Ecology Division)

[21] https://www.ec.gc.ca/grandslacs-greatlakes/default.asp?lang=En&n=70FFEFDF-1. Accessed February 2016.

However, although land use can be a useful general pressure indicator, practices within a given land use category can change over time, which may reduce or increase the stressors that are produced by that land use. Local variables can exert important influences on biological conditions that are not captured by remote sensing or other land cover data alone. For example, the incidence of tile drainage is generally not mapped; drainage intensity has increased in some areas of the Midwest resulting in increased annual flows in ditches related to reduced evaporation off of land surfaces (Blann et al. 2009). Miltner (2015) used extensive biological, stressor, and pressure (agricultural practices) data in Ohio and demonstrated that conservation measures have contributed to improved environmental conditions in Ohio headwater streams. Miltner (2015) concluded "that stream physical habitat clearly influences water quality, and therefore structural measures that improve habitat function in channelized streams and drainage ditches are a necessary component of efforts to combat eutrophication." Analyses such as these would not be possible without the accumulation of substantial monitoring data collected at a higher spatial resolution (Blann et al. 2009; Miltner 2015). Additionally, documenting biological conditions at the local reach and watershed scale makes it apparent that broad scale use of indicators such as land cover are not in themselves adequate predictors of biological impairment in specific water bodies. The scale of application is a critical factor—important stressors that act at the local reach and watershed scale can be missed.

An additional caveat in using land cover as a sole basis for GSA development is that the indicators are typically based on current land uses although some types of past land use patterns are available as mapped information. Many human activities in watersheds leave permanent or semi-permanent changes, termed "legacy effects." For example, persistent contaminants such as DDT, PCBs, PAHs,[22] and metals can end up in sediments, and they may be resuspended or buried permanently, depending on the depositional environment. Excess phosphorus may be buried in lake or pond sediments. In eastern U.S. Piedmont and Appalachian highlands, stream valley morphology has changed permanently in many places due to historic land use changes from the colonial period to the present: from initial clearing, to colonial and early American hydropower development, early agriculture, subsequent agricultural abandonment and forest regrowth, followed by recent suburban development (e.g., Maizel et al. 1998; Walter and Merritts 2008). These legacies may account for intermittent stressors in the form of contaminants, nutrients, and sediments that can be eroded and resuspended from historic sedimentation during storm events, or permanent stressors in the form of hydrological modifications or sedimentation. Documenting previous land use and expanding monitoring programs to include appropriate parameters will assist in detection of these stressors.

Regardless of the information used in defining a GSA, the impact of climate change will increasingly need to be taken into account. Climate change is a widespread disturbance that is capable of moving the system outside its natural range of variation, even in the absence of other anthropogenic disturbances, by elevating air and water temperatures, altering flow regimes through changes in the seasonality of precipitation, altering soil moisture regimes, and through changes in the frequency and intensity of storm events and fires (IPCC 2014; Melillo et al. 2014). The effects of changing climatic conditions, whether considered naturally or anthropogenically driven, are superimposed on other anthropogenic stressors generally leading to an exacerbated effect (c.f. Comte et al. 2013; Palmer et al. 2009; Hoegh-Guldberg et al. 2007; Arnell 1999). In general, water quality is likely to be negatively impacted by effects of climate change through altered flow regimes leading to higher peak flows and lower base flows. Altered flow regimes in turn influence extremes in water temperature, DO concentrations, changes in

[22] DDT: dichlorodiphenyltrichloroethane; PCB: polychlorinated biphenyl; PAH: polycyclic aromatic hydrocarbon

biogeochemical processing, and biotic assemblage structure and function that these factors regulate (Melillo et al. 2014). The effects of heavy downpours are exacerbated by impervious surfaces, leading to greater sediment, contaminant, and nutrient loading. Appendix A-2 provides examples of stressors and potential indicators of climate change under low, medium, and high stress scenarios for humid and arid regions. The BCG with well-defined biological indicators (y-axis) and stress indicators (x-axis) can be used to determine current baseline conditions and track changes in parameters that are associated with climate change, such as flow and temperature.

5.2 Development of a Generalized Stress Axis

In preparation for BCG development (see Chapter 3, sections 3.2 and 3.3), the process to develop a GSA for a specific geographic area and water body type includes a series of steps: classifying sites to reduce natural variability; identifying undisturbed or minimally disturbed conditions; and identifying indicators and the data that will be used to define the gradient of stress.

The first step in GSA development is to classify the aquatic resource (e.g., biogeographic regions, basins, biological considerations) (Herlihy et al. 2008; McCormick et al. 2000; Van Sickle and Hughes 2000; Waite et al. 2000). Classification is also an important component of biological assessment program development (see section 3.2.1.1). The purpose of classification is to reduce variability in natural conditions that can contribute to or influence stressors and biological assemblages. Features such as latitude, climate, geology, and landforms can explain the dominant patterns of variation in stressors across large regions (e.g., Herlihy et al. 2008). These broad-scale classification systems can be supplemented by local-scale features (e.g., slope, groundwater seeps) that can contribute to site-scale patterns in biotic assemblages (Hawkins and Vinson 2000; Pyne et al. 2007; Snelder et al. 2004, 2008; Van Sickle and Hughes 2000).[23]

A second step in GSA development is characterizing undisturbed or minimally disturbed conditions for a particular area. This characterization is the benchmark against which areas to be evaluated will be compared (as discussed in section 3.2.1.1), allowing for development and calibration of indices such as the mIBI and O/E assessment models. For most state biological assessment programs for streams, this step involves use of the state's reference site database. An important consideration when selecting reference sites is whether the reference sites represent undisturbed, minimally disturbed, or least disturbed conditions (Hawkins et al. 2010; Herlihy et al. 2008; Hughes 1985, 1994; Hughes et al. 1986; Moss et al. 1987; Stoddard et al. 2008). In BCG development, descriptions of undisturbed and minimally disturbed reference conditions (e.g., BCG levels 1 and 2) are critical components of model calibration. In some places, calibration may be based solely on historic records or other sources of information. Like level 1 of the BCG, the "low stress" end of the stress axis is anchored in the "as naturally occurs" or undisturbed or minimally disturbed, condition (i.e., no/minimal anthropogenic stressors).

The third step is to identify indicators and data sets that will be used to define the GSA. The major environmental factors shown in Figure 22 can be used as prompts to identify indicators (e.g., Appendix A-3). When evaluating data sets to develop a GSA, it is important to bear in mind that the biological conditions will reflect effects of unknown sources and unmeasured stressors, as well as incorrectly

[23] A comprehensive review of recent classification systems is beyond the scope of this document. There is still much to be learned about how biotic effects from local vs. catchment scale disturbances differ between catchments that are largely disturbed, and those that are relatively undisturbed (see review by Johnson and Host 2010).

characterized data sets. In this regard, the GSA is only as robust as the data upon which it is based. Characterizing to the extent possible the degree of uncertainty around the stressor-response (i.e., effect) relationships is important. There will always be some level of unexplained variation. But, where relationships between stress, or stressors, and biological response are poorly predicted, further assessments should be conducted. For example, as mentioned above, legacy contaminants from long-defunct industrial activities are typically invisible to remote imaging, yet may wash out periodically in storm events. A water quality assessment conducted for screening purposes is unlikely to capture such rare events. Intensive, directed sampling is more likely to detect the contamination, possibly after determination that a downstream location is biologically impaired from unknown causes and historical land use records are researched.

As explained earlier, this document does not comprehensively review or evaluate the approaches available to define a GSA. The examples discussed below represent several approaches that have been used to define stress gradients and are intended to prompt ideas and enhancements.

5.2.1 Using Land Cover Measures as Stressor Indicators

One approach to quantify a GSA relies upon land cover data. The land cover indicators serve as surrogate indicators for stressors, typically multiple stressors associated with a specific land use. Many human activities that cause stress in aquatic systems can be summarized in land cover delineations. Because land cover can be expressed as a fraction or percent of a watershed, catchment, or zone within the catchment (e.g., riparian corridors), using land cover data provide an obvious initial approach for summing land uses for an overall index of pressure. Land cover data generally do not include information on legacy sources and stressors unless intentionally mapped, nor do the data usually incorporate in-stream measures of water quality or habitat quality. Thus, the methods that rely solely on land cover should be regarded as the "first cut" tool in a toolbox that may contain multiple approaches. If stress-response relationships are poorly predicted by land cover data, subsequent analyses should include a more complete portfolio of stressors that contain both local habitat and water quality variables, as well as potential legacy pressures. Although remote sensing is a useful coarse focus, stressors and their effects on the biota can vary substantially.

The simplest land cover-based GSA is comprised of one, or the sum of several, land covers calculated for the catchment of each aquatic sampling point in the database being used. For example, in the Maryland Piedmont, percent impervious surface was used as a single stressor gradient because of the extent of urban and suburban land use throughout the mid-Atlantic Piedmont (see Chapter 3, sections 3.3.1.1 and 3.3.2.1). As another example, developers of a BCG for fish assemblages in Minnesota lakes used a GSA composed of a simple sum of percentages of urban, agricultural, and mining lands (section 3.3.2.1).

The above land cover-based GSAs do not differentially weight various land uses (as measured by land cover) in terms of their effects on aquatic biota. For example, impervious surface strongly affects stream hydrology, habitat quality, and biology (e.g., Stranko et al. 2008) and effects of agricultural land use depend on its intensity and local agricultural practices. An alternative method, the landscape development intensity index (LDI), weighs the intensity of multiple land uses in a study area (Brown and Vivas 2005). The LDI is a measure of human activity based on a development intensity measure derived from non-renewable energy use in the surrounding landscape. The LDI is calculated using all nonrenewable forms of energy (e.g., electricity, fuels, fertilizers, pesticides, and water (both public water supply and irrigation) (Brown and Vivas 2005)) used directly or implicitly in various land use classifications. Land uses are classified, and an intensity factor is assigned to each land use type (Table 27).

Table 27. Land use classification and intensity factor (LDI coefficient) for Florida landscapes (modified from Brown and Vivas 2005)

Land Classification	Intensity Factor (LDI coefficient)
Natural system	1.00
Natural open water	1.00
Pine plantation	1.58
Recreational/open space – low intensity	1.83
Woodland pasture (with livestock)	2.02
Improved pasture (without livestock)	2.77
Improved pasture – low intensity (with livestock)	3.41
Citrus	3.68
Improved pasture – high intensity (with livestock)	3.74
Row crops	4.54
Single-family residential – low density	6.9
Recreational/open space – high intensity	6.92
Agriculture – high intensity	7.00
Single-family residential – medium density	7.47
Single-family residential – high density	7.55
Mobile home (medium density)	7.70
Highway (2-lane)	7.81
Low intensity commercial	8.00
Institutional	8.07
Highway (4-lane)	8.28
Mobile home (high density)	8.29
Industrial	8.32
Multi-family residential (low-rise)	8.66
High-intensity commercial	9.18
Multi-family residential (high-rise)	9.19
Central business district (average 2-stories)	9.42
Central business district (average 4-stories)	10.00

The LDI has been used as a human disturbance gradient for wetlands (Brown and Vivas 2005; Chen and Lin 2011; Lane 2003; Mack 2006, 2007; Reiss 2004, 2006; Reiss and Brown 2005, 2007; Surdick 2005; Vivas 2007; Vivas and Brown 2006), streams (Brooks et al. 2009; Fore 2003, 2004; Harrington 2014; Stanfield and Kilgour 2012), and lakes (Fore 2005). It has also been used for coral reefs (Oliver et al. 2011). Figure 26 shows application of the LDI for coral reefs. Land use indices similar to the LDI were used to develop BCG calibrations for Minnesota and Alabama (see section 3.3.1.1).

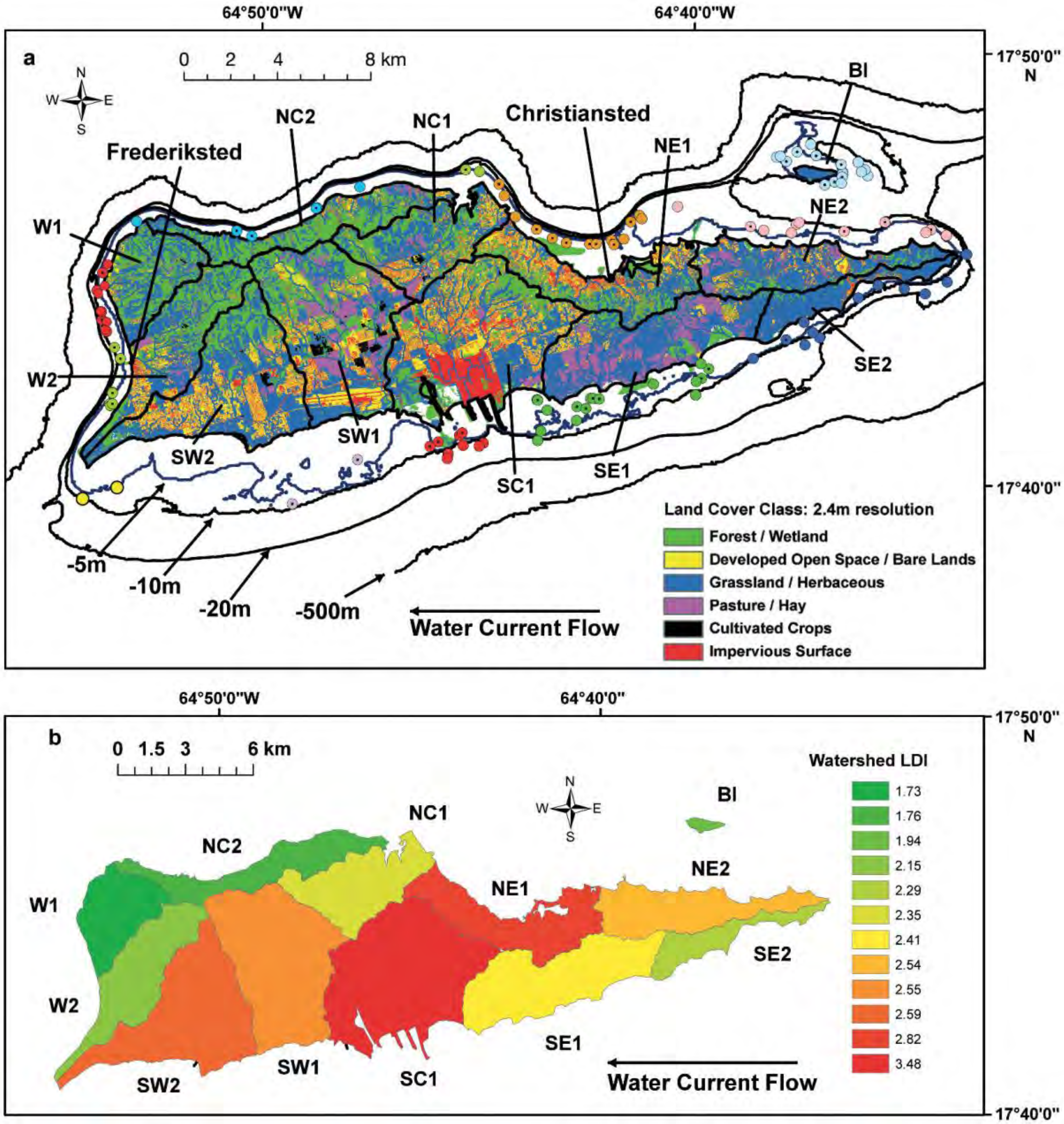


Figure 26. LDI applied to St. Croix watersheds and associated coral stations (Source: Oliver et al. 2011). Top figure shows land use/land cover and EPA coral reef stations. Land use/land cover used in the analysis is shown at 2.4 m resolution. Bottom figure show the watershed LDI values on a green– yellow–red continuum, where green indicates the lowest human disturbance and red indicates the highest. Watershed abbreviations: BI: Buck Island; NC: North Central; NE: Northeast; SC: South Central; SE: Southeast; SW: Southwest; W: West.

Nationally, the LDI has been mapped at HUC12 watershed as part of the WSIO data library using publicly available data from 2001. The WSIO contains mean, median, standard deviations, and sum of values for empower density (derivation of LDI) for a HUC12 watershed, its riparian zone, and hydrologic connected zone. Currently the WSIO data set is being updated nationally with the most recent NLCD data and should be available for use in near future.

5.2.2 Ranking Sites by Summing Stressor Indicators

Another approach to develop a GSA is to tally the number of stressor indicators observed at a particular site and establish a method to score the results. Many examples of this approach have been used across different regions, spatial extents, and ecosystem types (Chow-Fraser 2006; Uzarski et al. 2005). This approach entails identifying observed human activities and observed stressors (and their sources if information is available) and summing them to produce an overall index that can then be used to place sites in order from least to most stress.

The first step for the ordinal approach involves identifying and quantifying, for each site in a biological monitoring database, the relevant data available, including data on sources, in-stream measured water quality, riparian condition, land cover, riverscape alterations, known point source discharges, and observed nonpoint sources. For instream measures, it is important to distinguish non-detects (known and effectively absent) from not sampled (unknown; no data). A conceptual diagram of sources, stressors, mechanisms, and effects is helpful in organizing the information (e.g., Norton et al. 2015).

In the simplest implementation, each stressor indicator is evaluated as being present (1) or absent (0) at a site. The results are added to produce a score for each site. In the Connecticut case example (section 3.3.1.2), stressor indicators included reduced natural land cover, developed land, impervious surface, total chloride (a measure of total point source discharge), and four metals (copper, iron, nickel, zinc). Scoring in the case example was not simply 0–1; some stressor scores could range on an ordinal scale of 0–3, depending on the concentration or intensity of a given stressor. The results were used to divide sites into five overall stress categories ranging from "least stressed" to "severe stressed." The resultant gradient helped identify potential most-stressed, least stressed, and intermediately stressed sites in the BCG development data set. It is important to reiterate that the stress information was hidden from the expert panel during its deliberations.

For development of the BCG in Minnesota, MPCA developed a disturbance index (the HDS) that combined scores associated with land use metrics with additional indicators. The index includes eight primary metrics, which include measures of watershed land use, stream alteration, riparian condition, and known permitted discharges. The disturbance index scores can range from 1, representing completely altered and heavily stressed streams, to 81, representing nearly pristine watersheds. The HDS is described by MPCA (2014e) (see section 3.3.1.1, Table 7). Alabama DEM developed a similar index (see section 3.3.1.1, Table 8).

5.2.3 Using Statistical Approaches to Combine Stressor Indicators

In the U.S. Great Lakes coastal region, principal components analysis (PCA) was used by a team of researchers and investigators participating in the Great Lakes Environmental Indicators (GLEI) Project[24] (Niemi et al. 2007) to reduce over 200 variables into a single gradient, applying measures of anthropogenic pressures as surrogate measures of stressors (Danz et al. 2005). The Danz approach individually considered six different indicators of pressure: agriculture, atmospheric deposition, land cover, human population, point sources, and shoreline alteration. The GLEI team used a watershed-based approach to reflect the premise that the environmental effects of these activities in coastal watersheds can influence environmental conditions in downstream coastal ecosystems. The first principal component from the analysis explained 73% of the variance in the agricultural-chemical (Ag-Chem) variables (reflecting land use, agricultural chemical use, and agricultural-influenced nutrient and

[24] http://glei.nrri.umn.edu/default/default.htm. Accessed February 2016.

sediment loading) and was interpreted as an overall gradient in stressors across the basin (Figure 27). Environmental effects such as changes in water quality, fish assemblage metrics, and bird abundances were strongly correlated with scores of this stressor gradient, providing verification that the statistically extracted PCA was biologically meaningful (see description of this project by Niemi et al. 2007). The GLEI researchers created a flow diagram (Figure 28) that details their steps for quantifying a stressor gradient (modified from Danz et al. 2005).

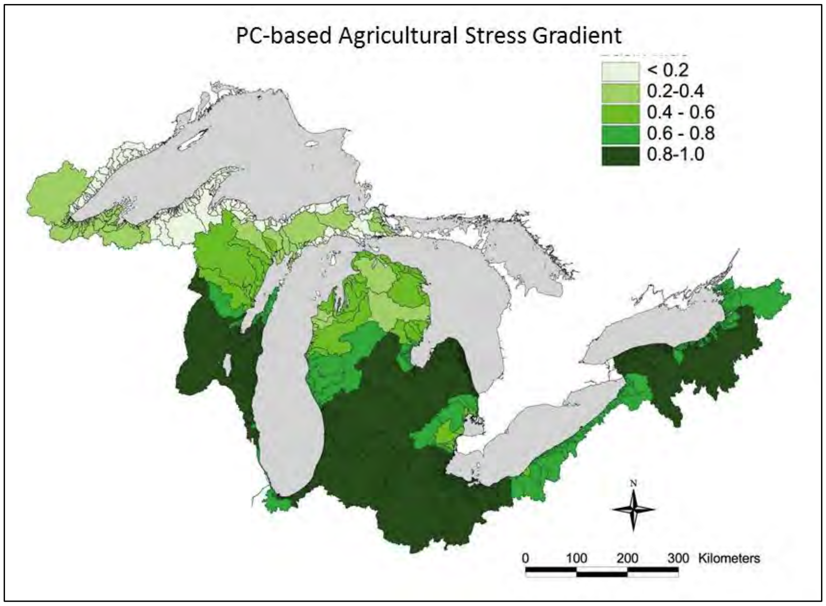


Figure 27. The first principal component of the agricultural variables for the U.S. Great Lakes basin. Darker shading indicates greater amounts of agriculture (Source: Danz et al. 2005).

While the pressure-stressor model eventually developed for the Great Lakes coastal region was visualized as a single gradient from low to high levels of stressors, different individual and combinations of stressors are expected to dominate in different regions. Furthermore, disaggregating the PCA into individual categories of stress could provide important information about potential mechanisms affecting the state of the system.

In addition to PCA, there are other statistical approaches to consider. For example, the use of non-metric multidimensional scaling (NMDS) provides a robust analysis. Unlike PCA, NMDS can deal with non-normal data, data of varying scales, and outliers in the data. Like PCA, NMDS is a multivariate statistical analysis that one can use to look at multiple stressors at the same time to create the GSA.

Biological data can also be used to statistically combine stressor indicators into a GSA. For example, Wang et al. (2008) used Canonical Correspondence Analysis (CCA) to derive the relationship among the biota and stressor and land use data and weight their disturbance index. They then plotted the calculated disturbance index against fish IBI scores and percentages of intolerant individuals, dividing the disturbance index values into five tiers. The first tier was the maximum disturbance index value at which the fish measures did not show an obvious decline. The remaining four tiers were determined by dividing the remainder of the disturbance index values into even categories. Use of biological data ensures that the stressor indicators will be biologically relevant. However, this approach can introduce some circularity into the analysis if the indicators of biological quality are the same as those used to develop the BCG.

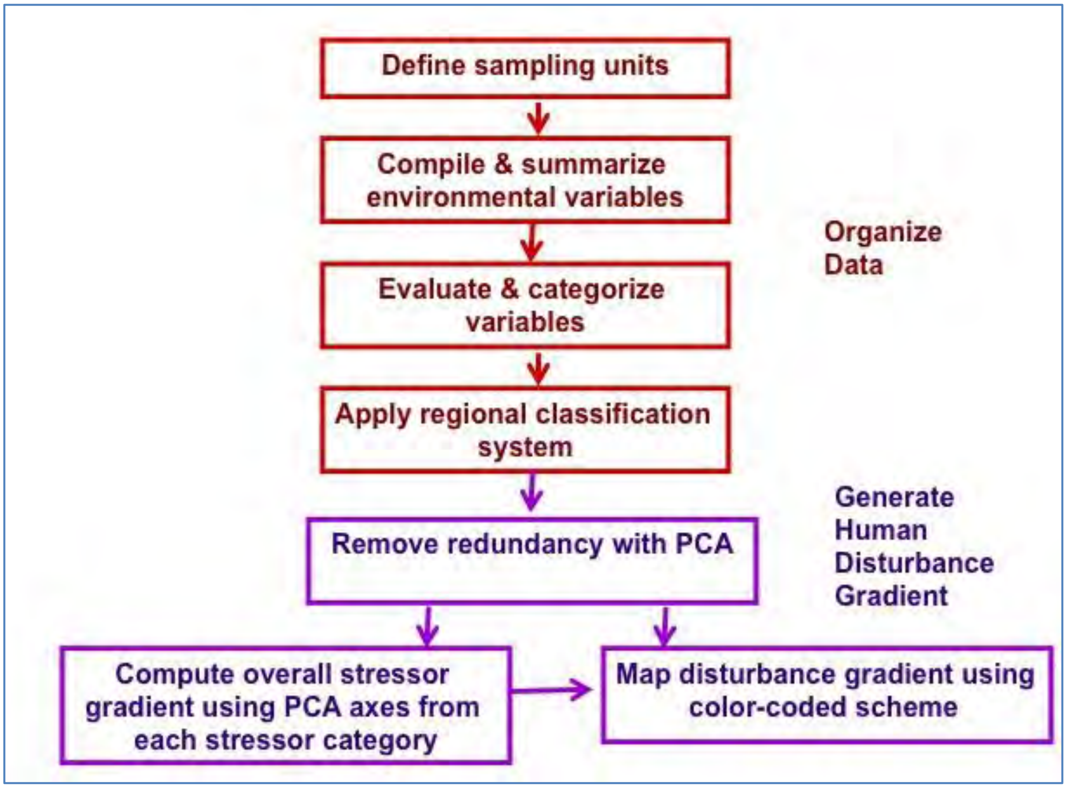


Figure 28. Flow diagram detailing the steps used by GLEI researchers in quantifying their stressor gradient (modified from Danz et al. 2005).

Stressor gradients like that developed by GLEI, or others as referenced above, can be developed at different spatial scales. The GLEI study assessed 5,971 watersheds comprising the Great Lakes basin. Watershed sizes (areas) were lognormally distributed, with a median watershed area of 4.3 km^2 and a mean watershed size of approximately 86.7 km^2 (Ciborowski et al. 2011). However, the gradient can be applied and scaled as needed to other geospatial units. For example, Nieber et al. (2013) conducted this same analysis for watersheds of the north shore of Lake Superior, and Bartsch et al. (2015) scaled their analysis to watersheds of the St. Louis River estuary to assess relationships between stressors and water chemistry.

5.3 Linking the Science with Management Actions

A quantitative BCG model provides a framework for assessing baseline biological condition and, with systematic monitoring, can be used to track changes in biological condition. Ideally, a well-defined GSA and the stressor effects and biotic response models underlying it can be used in conjunction with causal assessments to better link biologically-defined management goals to the actions taken to protect or restore the biological conditions.

A stressor can be traced back to its source or tracked forward to the biological effect via a causal pathway (Figure 29). For example, stream banks that become destabilized due to removal of riparian plants could be the source of excess fine sediment to a stream. Erosion by high flows is the mechanism by which the excess fine sediments are generated, and the resulting in-stream siltation is the stressor. Smothering of bottom substrate habitat and organism gills by these fine sediments are two mechanisms by which biota are exposed and adversely affected. Invertebrate mortality and fish emigration could be some of the environmental outcomes or changes in biotic condition. Further, degradation or loss of recreational fishing could be societal impact of these changes and may prompt a conservation or restoration effort depending upon the circumstances.

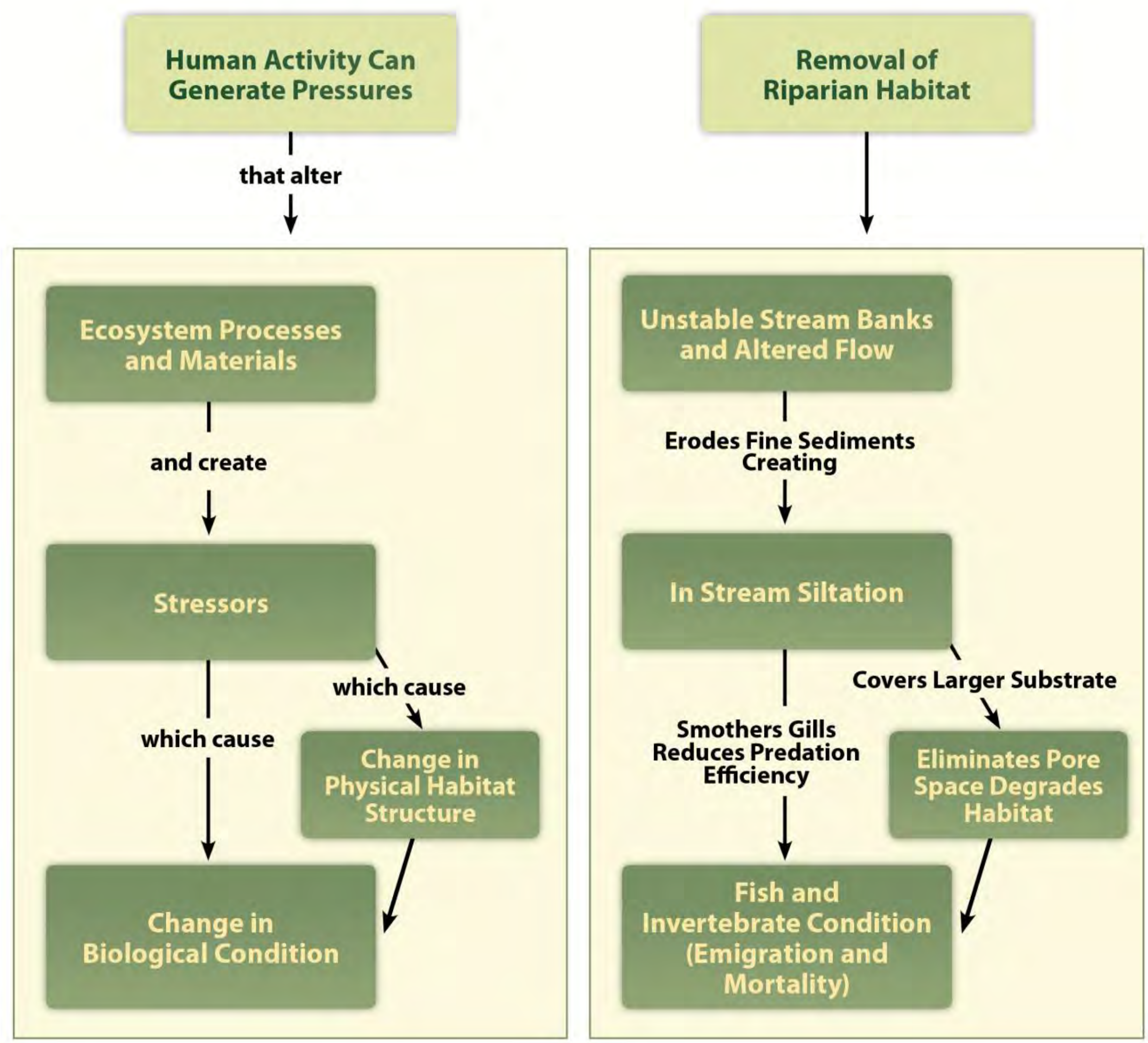


Figure 29. The specific stressor(s) and their intensity (the BCG x-axis—termed the GSA) are created by pressure(s) acting through specific mechanisms. BMPs can be implemented to prevent or reduce effect on the biota through restoration, remediation, and/or mitigation.

Actions can be taken that insulate the aquatic biota from the effects of anthropogenic pressures, helping to maintain or restore the ecological potential of an aquatic system. In the example above, re-establishing the riparian zone would stabilize the banks and prevent further erosion and unchecked flow into the stream. Appendix A-4 and MPCA (2015) provide examples of pressures linked to mechanisms and potential management actions that can mitigate the effect on biota.

Mechanistic processes operate between pressures and stressors and between stressors and their effects on biological condition (Figure 30; Appendices A-3 and A-4). Understanding these mechanisms and how they operate helps in predicting the potential effects of a particular management action. The BCG provides a framework for tracking and documenting incremental improvements in biological conditions resulting from implementation of a single BMP or combination of BMPs.

Integrating monitoring programs with frameworks like the BCG can improve understanding of how human activities, stressors, biological responses, and management actions are linked, providing feedback to guide management decisions. For example, Yoder et al. (2005) reviewed changes to fish assemblages over 25 years based on an intensive pollution survey designed to assess non-wadeable rivers in Ohio. They used the linkages between changes in point source pollution loadings, improvements in instream water quality, and reductions in the extent and severity of biological impairments to document the effectiveness of advanced wastewater treatment on a statewide scale beginning in the late 1970s. At that time the documented improvements in biological condition across all rivers and streams were almost solely in response to water quality-based NPDES permitting for point sources. Rivers predominantly impacted by nonpoint sources showed improvement over a longer timeframe where there was a concerted effort to apply BMPs over a wide enough region. Miltner (2015) was able to document widespread improvements in stream biota and water quality in smaller headwater streams in Ohio. Both of these studies were based on the state's routine biological monitoring and assessment of rivers and streams.

A well-defined GSA, and the underlying data set, can serve as a nexus between biological and causal assessments and provide a link between management goals and selection of management actions for protection or restoration. The basis of the BCG framework is that greater pressures can generate increased levels of stressors, and in turn, increased stressors are associated with reduced biological condition (Figure 30A and B). Typically, the stressors on aquatic systems increase as pressures increase, which results in a consequent decrease in biological condition. Effective management practices can target any point in the web of causal events, mitigating the effects of pressures and reducing stressors with resulting protection or improvement in biological condition (Figure 30C and D).

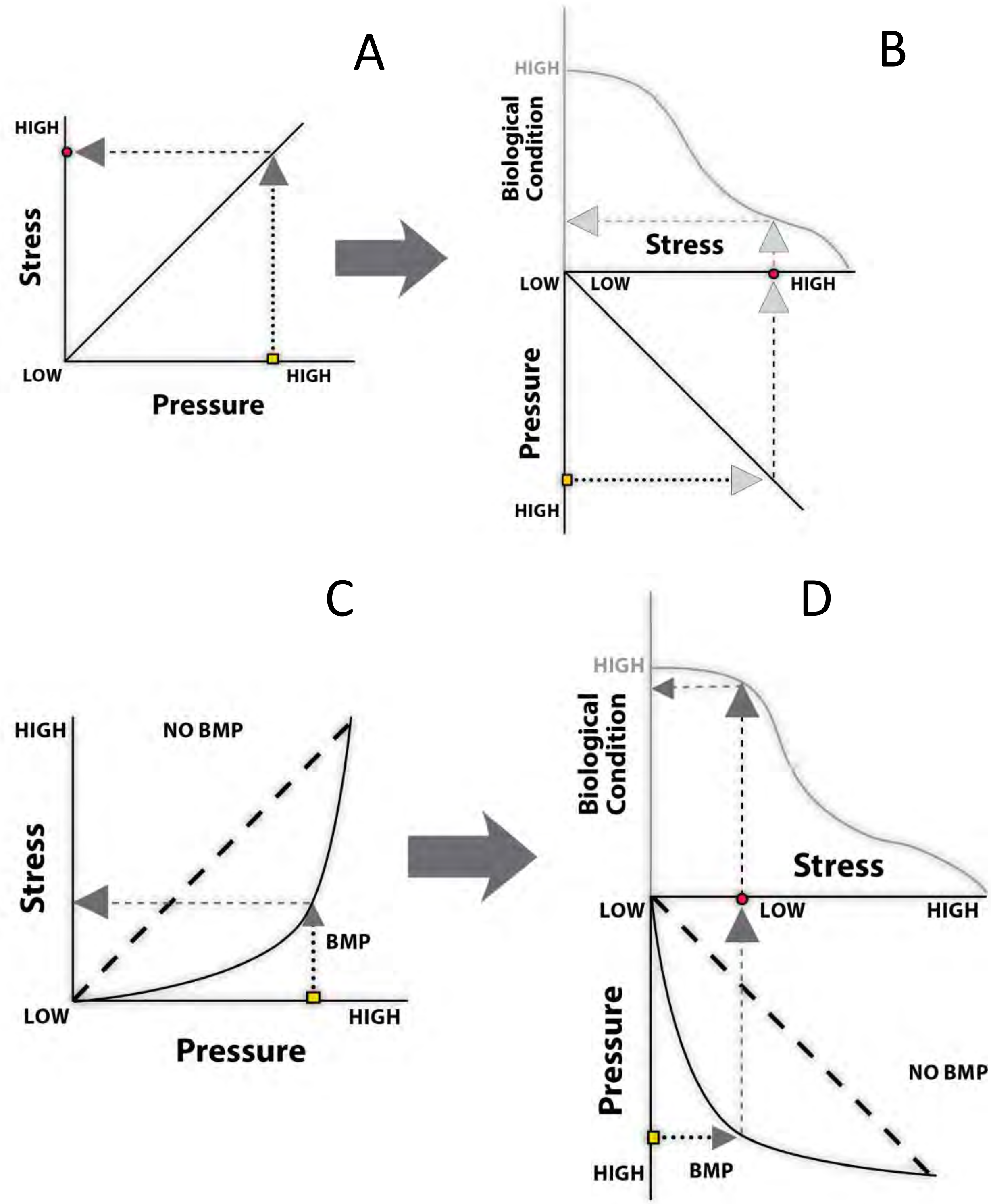


Figure 30. Conceptual Models (CM) A-B: Human activities can generate pressures, ultimately producing stressors (BCG x-axis) that adversely affect the aquatic biota (BCG y-axis). CM C-D: Implementation of a BMP can dampen the translation of pressures into the expression of stress and reduce the adverse effects on the biota.

5.4 Conclusions

Anthropogenic activities exert *pressures* on aquatic systems by altering ecosystem processes and materials and generating stressors that adversely impact biological condition. Many of these stressors co-occur in time and space, and effects on the biota are cumulative. The relationships between stressors and effects are complicated—stressors may affect more than one aspect of biological condition, and a particular change in biological condition can also be the result of multiple stressors acting simultaneously.

The conceptual GSA describes the range of anthropogenic stress experienced by aquatic biota in a particular geographic area. Once quantified, it is used in the development of the decision rules to assign sites to BCG levels (Chapter 3, section 3.3.1) and ensures that the BCG encompasses the full range of condition along a stress gradient. There is much complexity of interactions and effects from multiple stressors with varying effects on different biotic components of any aquatic system. The GSA represents the sum total of stressors and their sources in concept, but in implementation it is composed of multiple known, quantitative stress gradients that each represent a portion of the actual stress gradient to which the aquatic biota are exposed. The usefulness of the conceptual framework is to provide a template for as thorough and comprehensive a technical approach as possible to develop the BCG x-axis and relate level of stress to the BCG levels and attributes.

Additionally, developing a GSA that reflects the human activities and stressors in a particular geographical area helps in understanding how specific stressors are generated and how they affect biotic condition. The data generated in developing a GSA can be used to help identify and rank sources and their stresses in a particular area and inform management decisions on appropriate actions to protect or improve a water body. The case examples discussed in this chapter and in Chapter 3 illustrate how state and local governments have quantified a GSA as part of developing a BCG model for their specific region or watershed area. As further experience is gained and approaches to define and quantify the GSA evolve, EPA may supplement this document with additional information.

Chapter 6. Case Studies

The BCG can provide critical information to state water quality management programs at the watershed, statewide, and ecoregional scales. A comprehensive monitoring and assessment program is a critical aspect of implementation of the BCG to support water quality management programs. The same data and information that provide baseline condition assessments over time also can provide information to inform trend assessments and track incremental changes in condition. In conjunction with monitoring data, a BCG can be used to help address watershed-specific management needs such as detailed biological descriptions of designated ALUs, identification of high quality waters and impaired waters, and documentation of incremental improvements due to controls and BMPs. This information can also inform TMDL development. This chapter presents six case examples of how states, counties, or municipalities are using, or considering using, the BCG to support water quality management decision making.

The six case examples are:

- 6.1 Montgomery County, Maryland: Using the Biological Condition Gradient to Communicate with the Public and Inform Management Decisions
- 6.2 Pennsylvania: Using Complementary Methods to Assess Biological Condition of Streams
- 6.3 Alabama: Using the Biological Condition Gradient to Communicate with the Public and Inform Management Decisions
- 6.4 Minnesota: More Precisely Defining Aquatic Life Uses and Developing Biological Criteria
- 6.5 Maine: Development of Condition Classes and Biological Criteria to Support Water Quality Management Decision Making
- 6.6 Ohio: Tiered Aquatic Life Use Classes and Comprehensive Water Quality Management Program Support

6.1 Montgomery County, Maryland: Using the Biological Condition Gradient to Communicate with the Public and Inform Management Decisions

6.1.1 Key Message

Montgomery County helped to develop a BCG to better inform the public and county decision makers about a high quality watershed (e.g., undisturbed/minimally disturbed conditions) and the potential outcome of planned development. Local government decision makers were able to understand how these high quality streams compared to other streams in Montgomery County and Maryland. Development plans were modified to protect the streams and watershed and reduce environmental impacts, while allowing development to proceed.

6.1.2 Background: Early County Policy

In 1994, the Maryland-National Capital Park and Planning Commission (M-NCPPC) adopted the *Clarksburg Master Plan & Hyattstown Special Study Area*. The Plan established goals for development of Clarksburg, Maryland, at that time a mostly undeveloped area along a six to eight lane highway corridor outside the Washington, DC metropolitan area. The Plan's goals included development of the town with emphasis on maintaining farmland and open space and promotion of transit-oriented neighborhoods (M-NCPPC 1994). One critical objective of the plan was the protection of environmental resources while accommodating development, such as affording special protection to high quality stream systems, including tributaries to the streams and associated wetlands. The plan specified that development occur in four phases, with requirements that must be met in order for development to proceed from one phase to the next. This staging allowed for consideration of new data and information on the impacts of development on streams and rivers, as well as improvements in mitigation technology and changes in county, state, or federal policies or regulations that might affect implementation of the 1994 plan. For example, in 2008, the County revised the 1994 plan to meet the newly adopted state law requiring the use of Environmental Site Design (ESD) practices to minimize stormwater runoff throughout the county.

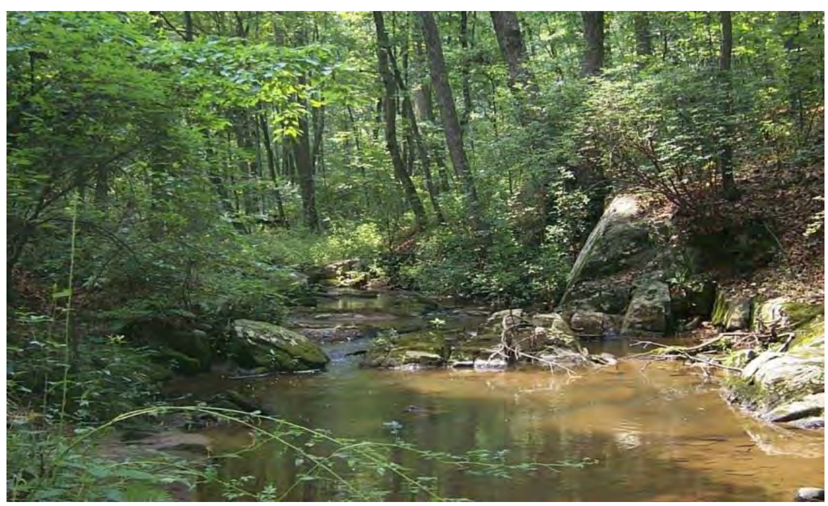


Figure 31. Ten Mile Creek, Maryland.

Development in one of the high quality areas slated for development, Ten Mile Creek (TMC) (Figure 31), was afforded special protection under the Master Plan. TMC, a subwatershed[25] of the Little Seneca Creek watershed, was assigned to stage four to ensure that the 1994 development plan could be reviewed and potentially adjusted based on relevant new data and information. This case example shows how the BCG was used to provide information on current conditions in TMC relative to other county subwatersheds and streams in *excellent*, *good*, *fair*,

[25] A subwatershed is the topographic perimeter of a stream catchment.

or *poor* condition. Information from the BCG was used in conjunction with other data to help inform the County Council in its deliberation on whether or not to adjust the stage four development plan.

6.1.2.1 Ten Mile Creek Subwatershed, Stream, and Tributaries

The TMC subwatershed, stream, and tributaries comprise a headwater stream system in which the majority of tributaries are small and spring fed. Abundant springs and seeps supply cold and clean water that supports a diverse community of fish, benthic macroinvertebrates, and amphibians (Boucher, personal communication, 2014) (Figure 32). The area is highly forested with a low level of impervious surface, < 1% to 3%. TMC is one of three reference watersheds remaining in the county and has supported *good* to *excellent* conditions based on a long term county data set using IBIs for benthic macroinvertebrates and for fish that were developed by the county (MCDEP 2012). TMC and its tributaries are adjacent to both Little Bennett Creek, a natural resource conservation management area, and to the county's agricultural reserve. The location of TMC provides not only a bridge between these two protected areas, but also a cost efficient opportunity to maintain natural flows, clean water, and high biological diversity, and provide for recreational use and appreciation by the public (Figure 33).

Figure 32. Important aquatic species in Maryland's Piedmont headwater streams. Salamanders (Long-tailed, Northern Dusky, and Northern Red); fish (Potomac Sculpin, Rosyside Dace, American Eel); insects (Sweltsa, Paraleptophlebia, Ephemerella).

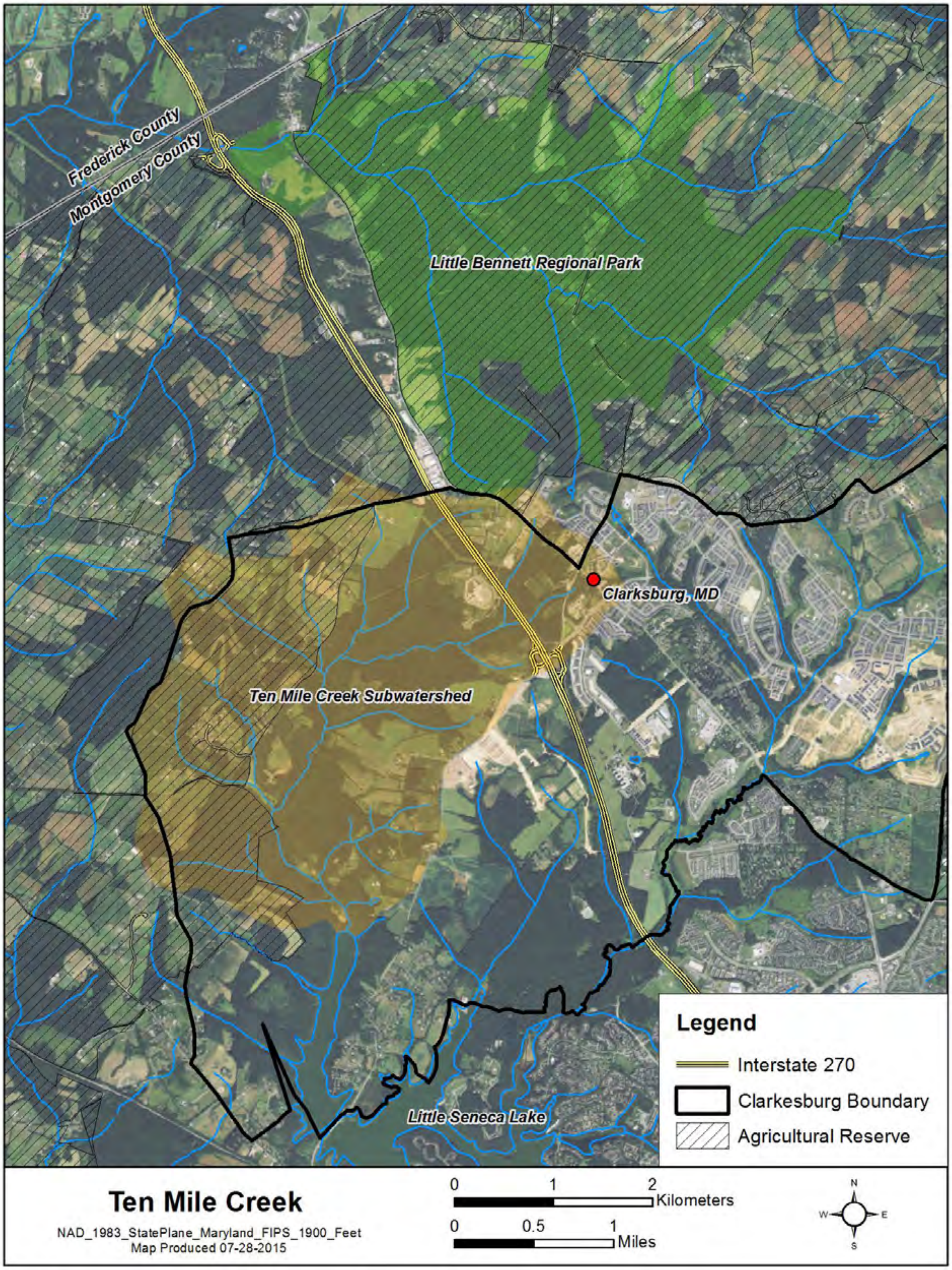


Figure 33. Clarksburg Area and Ten Mile Creek Subwatershed.

6.1.2.2 Monitoring the Impacts of Development

Beginning in 1994, the Montgomery County Department of Environmental Protection (MCDEP) monitored conditions throughout the Clarksburg development area as construction progressed. Analysis included evaluating the effectiveness of BMPs and regulations to minimize both the immediate impacts from construction and the longer term impacts from the subsequent development. Annual monitoring reports were published beginning in 2001 (e.g., MCDEP 2009, 2012). Initial monitoring found stream conditions in the Clarksburg development area ranged from *good* to *excellent* in most sensitive, high quality areas such as the TMC subwatershed. However, by the mid-2000s, the water quality at several good quality streams in the urbanizing areas began to degrade from *good* to *fair* (MCDEP 2009, M-NCPPC 2014a). In October 2012, the Montgomery County Council directed the County Planning Board to undertake a limited amendment of the 1994 Clarksburg Master Plan. Monitoring of earlier Clarksburg developments showed uncertainty about the ability to protect the sensitive environmental resources found in the stage four development area, such as TMC subwatershed, if full development were to occur according to the original 1994 plan.

A number of scientific analyses informed the development of the *Ten Mile Creek Area Limited Amendment to the Clarksburg Master Plan and Hyattstown Special Study Area*. County staff sought to use their extensive monitoring data to further characterize the watershed and to identify analytical ways to present information on the environmental status of County waters. Specifically, staff wanted to assess the current conditions in those waters and the expected changes that would occur in relation to further development in the area. In an effort to further characterize and assess incremental changes in local biological conditions, in 2013 the County embarked on the process of developing a BCG model for the Piedmont region of Maryland using both county and state data for fish and benthic macroinvertebrate assemblages (USEPA 2013b). Observations on the presence of salamanders were also incorporated where data were available. The presence of stream salamander species such as the northern dusky salamander, long tailed salamander, northern two-lined salamander, and the northern red salamander aided in confirming the high quality of streams.

6.1.3 Development of the Biological Condition Gradient

The County saw the BCG as one way to provide more detailed information on streams and their response to land use change. In 2013, scientists from agencies within the state, Delaware, Pennsylvania, Virginia, EPA, consulting groups, and academia convened as an expert panel to develop a BCG for the Northern Piedmont. The goal of this effort was to use data collected primarily from Montgomery County to develop a BCG model to describe changes in the biota in response to increasing stress in the landscape. For example, a BCG level 2 stream would be minimally disturbed and include the presence of native top predator fish (e.g., brook trout) as well as mayflies, stoneflies, and caddisflies. A BCG level 3 or 4 stream would include incrementally higher loss of sensitive species and an increased abundance of tolerant species (e.g., blacknose dace and northern two-lined salamander). A BCG level 5–6 stream would show an abundance of highly tolerant species (e.g., brown bullhead, tubificid and naidid worms).

Experts at the workshop were able to distinguish five distinct levels of biological condition for the Piedmont region within Montgomery County (BCG levels 2–6). There were no BCG level 1 sites. Most TMC sites ranged from a level 3+ to a level 4, although several sites (e.g., primarily headwater streams) were judged as very good quality (a level 2 rating). Narrative and numeric decision rules to consistently describe and quantify site assessments were developed based on mathematical set theory using the fuzzy logic method (Table 28, Table 29, Table 30) and taxa response relationships derived from the county data sets (Figure 34).

Table 28. Description of fish, salamander, and macroinvertebrate assemblages in each assessed BCG level. Definitions are modified after Davies and Jackson (2006).

BCG level 1	**Definition:** Natural or native condition—*native structural, functional and taxonomic integrity is preserved; ecosystem function is preserved within the range of natural variability*
	Narrative from expert panel: There are no BCG level 1 sites within the Piedmont. All sites have some degree of disturbance, including legacy effects from agriculture and forestry from 100 to 200 years ago. Conceptually, BCG level 1 sites would have strictly native taxa for all assemblages evaluated (fish, salamander, benthic macroinvertebrates), some endemic species, and evidence of connectivity in the form of migratory fish.
	Fish: Examples of endemic species that might be present (depending on the size of the stream) include: Bridle Shiner, Brook Trout, Chesapeake Logperch, Maryland Darter, Trout Perch
	Macroinvertebrates: Sensitive-rare, coldwater indicator taxa such as the mayfly Epeorus, and stoneflies Sweltsa and Talloperla are expected to be present
BCG level 2	**Definition:** Minimal changes in structure of the biotic community and minimal changes in ecosystem function—*virtually all native taxa are maintained with some changes in biomass and/or abundance; ecosystem functions are fully maintained within the range of natural variability*
	Narrative from expert panel: Overall taxa richness and density is as naturally occurs (watershed size is a consideration). These sites have excellent water quality and support habitat critical for native taxa. They have many highly sensitive taxa and relatively high richness and abundance of intermediate sensitive-ubiquitous taxa. Many of these taxa are characterized by having limited dispersal capabilities or are habitat specialists. If tolerant taxa are present, they occur in low numbers. There is connectivity between the mainstem, associated wetlands and headwater streams.
	Fish: Highly sensitive (attribute II) and intermediate sensitive (attribute III) taxa such as yellow perch, northern hog sucker, margined mad tom, fallfish and fantail darter are present, as are native top predators (e.g., brook trout). Migratory fish and amphibians (e.g., eel, lamprey, salamanders) are present or known to access the site. Long-tailed and Dusky salamanders are also good indicators, given a complimentary fish community. Non-native taxa such as brown trout or rainbow trout, are absent or, if they occur, their presence does not displace native trout or alter structure and function.
	Macroinvertebrates: Highly sensitive taxa are present—especially coldwater indicator mayflies, stoneflies, and caddisflies (e.g., Epeorus, Paraleptophlebia, Sweltsa, Tallaperla, and Wormaldia)—and occur in higher abundances than in BCG level 3 samples.

BCG level 3	**Definition:** Evident changes in structure of the biotic community and minimal changes in ecosystem function—*Some changes in structure due to loss of some rare native taxa; shifts in relative abundance of taxa but intermediate sensitive taxa are common and abundant; ecosystem functions are fully maintained through redundant attributes of the system*
	Narrative from expert panel: Generally considered to be in good condition. Similar to BCG level 2 assemblage except the proportion of total richness represented by rare, specialist and vulnerable taxa is reduced. Intermediate sensitive-ubiquitous taxa have relatively high richness and abundance. Taxa with intermediate tolerance may increase but generally comprise less than half total richness and abundance. Tolerant taxa are somewhat more common but still have low abundance. Taxa with slightly broader temperature or sediment tolerance may be favored.
	Fish: Intermediate sensitive (attribute III) taxa such as fallfish and fantail darter are common or abundant. Taxa of intermediate tolerance (attribute IV) such as channel catfish, least brook lamprey, pumpkinseed and tessellated darter are present in greater numbers than in BCG level 2 samples. Some tolerant (attribute V) taxa such as mummichog and white suckers may be present, but highly tolerant taxa are absent. Pioneering species such as blacknose dace, creek chubs and white suckers may be naturally common in smaller streams. Migratory species such as American Eel may be absent. Two-lined salamanders may occur.
	Macroinvertebrates: Similar to BCG level 2 assemblage except sensitive taxa (e.g., Sweltsa, Tallaperla and Wormaldia) occur in lower numbers. Level 3 indicator taxa include the caddisfly Diplectrona, the mayfly Ephemerella and the stonefly Amphinemura.
BCG level 4	**Definition:** Moderate changes in structure of the biotic community and minimal changes in ecosystem function—*Moderate changes in structure due to replacement of some intermediate sensitive taxa by more tolerant taxa, but reproducing populations of some sensitive taxa are maintained; overall balanced distribution of all expected major groups; ecosystem functions largely maintained through redundant attributes*
	Narrative from expert panel: Sensitive species and individuals are still present but in reduced numbers (e.g., approximately 10%–30% of the community rather than 50% found in level 3 streams). The persistence of some sensitive species indicates that the original ecosystem function is still maintained albeit at a reduced level. Densities and richness of intermediate tolerance taxa have increased compared to BCG level 3 samples.
	Fish: 2 or 3 sensitive taxa may be present but occur in very low numbers (e.g., Blue Ridge Sculpin, Fantail Darter, Potomac Sculpin, Fallfish, Rosy-side Dace, River Chub). Taxa of intermediate tolerance (attribute IV) such as tesselated darter, least brook lamprey, longnose dace are common, as well as tolerant taxa like yellow bullhead, red-breast sunfish and bluntnose minnow. Level 4 streams may harbor two to three salamander species (Dusky, Red, and Two-lined).
	Macroinvertebrates: Sensitive taxa (including EPT taxa) are present but occur in low numbers. Taxa such as Diplectrona and Dolophilodes may occur, but other key taxa such as Ephemerella and Neophylax are absent. Taxa of intermediate tolerance (e.g., Baetis, Stenonema, Caenis, Chimarra, Cheumatopsyche, Hydropsyche) occur in greater numbers. Tolerant taxa such as Chironomini and Orthocladiinae are present but do not exhibit excessive dominance.

BCG level 5	**Definition:** Major changes in structure of the biotic community and moderate changes in ecosystem function—*Sensitive taxa are markedly diminished; conspicuously unbalanced distribution of major groups from that expected; organism condition shows signs of physiological stress; system function shows reduced complexity and redundancy; increased build-up or export of unused materials*
	Narrative from expert panel: Overall abundance of all taxa reduced. Sensitive species may be present but their functional role is negligible within the system. Those sensitive taxa remaining are highly ubiquitous within the region and have very good dispersal capabilities. The most abundant organisms are typically tolerant or have intermediate tolerance, and there may be relatively high diversity within the tolerant organisms. Most representatives are opportunistic or pollution tolerant species.
	Fish: Facultative species reduced or absent. Tolerant taxa like yellow bullhead, red-breast sunfish, and bluntnose minnow are common. Blacknose dace, creek chubs and white suckers may dominate. Two-lined salamanders might be the only salamander present.
	Macroinvertebrates: Highly sensitive macroinvertebrate taxa are usually absent and Chironomid midges (mostly tolerant Orthocladiinae and Chironomini) often comprised > 50% of the community in level 5 streams.
BCG level 6	**Definition:** Major changes in structure of the biotic community and moderate changes in ecosystem function—*Sensitive taxa are markedly diminished; conspicuously unbalanced distribution of major groups from that expected; organism condition shows signs of physiological stress; system function shows reduced complexity and redundancy; increased build-up or export of unused materials*
	Narrative from expert panel: Heavily degraded from urbanization and/or industrialization. Can range from having no aquatic life at all or harbor a severely depauperate community composed entirely of highly tolerant or tolerant invasive species adapted to hypoxia, extreme sedimentation and temperatures, or other toxic chemical conditions.
	Fish: Fish are low in abundance or absent, represented mainly by blacknose dace, green sunfish, bluntnose minnow, or creek chub.
	Macroinvertebrates: May be dominated by tolerant non-insects (Physid snails; Planariidae; Oligochaeta; Hirudinea; etc.)

Table 29. BCG quantitative decision rules for macroinvertebrate assemblages. The numbers in parentheses represent the lower and upper bounds of the fuzzy sets.

BCG Level 2	rule	
# Total taxa	> 17 (13–22)	
% Attribute II taxa	≥ 8% (5–10)	
% Attribute II+III taxa	≥ 50% (45–55)	
% Attribute II individuals	≥ 3% (2–5)	
% Attribute II+III individuals	≥ 60% (55–65)	
% Attribute V individuals	≤ 15% (10–20)	
BCG Level 3	**alt 1**	**alt 2**
# Total taxa	> 17 (13–22)	
% Attribute II+III individuals	≥ 40% (35–45)	
# Attribute II taxa	—	≥ 1 (0–2)
% Attribute II+III taxa	≥ 25% (20–30)	≥ 45% (40–50)
% Attribute V individuals	≤ 40% (35–45)	≤ 50% (45–55)
% Most dominant Attribute V individual	≤ 20% (15–25)	—
BCG Level 4	**rule**	
# Total taxa	≥ 15 (10–20)	
% Attribute II+III taxa	≥ 20% (15–25)	
% Attribute II+III individuals	≥ 10% (5–15)	
% Attribute V individuals	≤ 70% (65–75)	
% Most dominant Attribute V individual	≤ 60% (55–65)	
BCG Level 5	**rule**	
# Total taxa	≥ 8 (6–10)	
% Attribute V individuals	≤ 85% (80–90)	
% Most dominant Attribute V individual	≤ 70% (65–75)	

Table 30. BCG quantitative decision rules for fish assemblages in small (0.5–1.4 mi^2), medium (1.5–7.9 mi^2) and larger streams (> 8 mi^2). The numbers in parentheses represent the lower and upper bounds of the fuzzy sets. The mid-water cyprinid taxa metric is comprised of notropis, luxilus, clinostomus, and cyprinella, minus swallowtail shiners.

BCG Level 2	Small		Medium		Large
	rule	alt rule	rule	alt rule	rule
# Attribute I taxa	> 0 (present)		> 0 (present)		–
# Attribute I+II taxa	–		≥ 2 (1–4)		≥ 4 (2–6)
# Attribute I+II+III taxa	> 1 (0–3)	–	–		–
# Sensitive salamander taxa (if surveyed)	–	> 0	–	> 0	–
% Attribute I+II+III taxa	≥ 35% (30–40)		≥ 35% (30–40)		≥ 35% (30–40)
% Attribute I+II+III individuals	–		≥ 50% (45–55)		≥ 50% (45–55)
# Attribute VIt taxa	≤ 2 (1–3)		≤ 2 (1–3)		≤ 2 (1–3)
% Attribute VIt individuals	≤ 5% (3–7)		≤ 5% (3–7)		≤ 5% (3–7)
# Attribute X taxa	–		> 0		> 0
BCG Level 3	**Small**		**Medium**		**Large**
# Attribute I+II taxa	–		–		≥ 1 (0–2)
# Attribute I+II+III taxa	≥ 2 (0–4)		–		–
% Attribute I+II+III taxa	–		≥ 25% (20–30)		≥ 25% (20–30)
% Attribute I+II+III individuals	≥ 25% (20–30)		≥ 25% (20–30)		≥ 25% (20–30)
% Attribute V individuals	–		–		≤ 40% (35–45)
# Attribute VIt taxa	≤ 2 (1–4)		≤ 2 (1–4)		–
% Attribute VIt individuals	≤ 15% (10–20)		≤ 15% (10–20)		≤ 15% (10–20)
# Mid-water cyprinid taxa	> 0		> 1		> 1
BCG Level 4	**Small**		**Medium**		**Large**
# Attribute I+II+III taxa	> 1 (0–3)		> 1 (0–3)		> 1 (0–3)
% Attribute I+II+III individuals	≥ 5% (3–7)		≥ 10% (7–13)		≥ 10% (7–13)
% Most dominant Attribute Va or VIt individual	≤ 65% (60–70)		≤ 65% (60–70)		≤ 65% (60–70)
BCG Level 5	**Small**		**Medium**		**Large**
# Total taxa	> 4 (3–6)		> 4 (3–6)		> 4 (3–6)
# Total individuals	> 100 (90–110)		> 100 (90–110)		> 100 (90–110)
% Attribute V+VIt taxa	–		≤ 65 (60–70)		≤ 65 (60–70)
% Attribute V+VIt individuals	–		≤ 90 (85–95)		≤ 90 (85–95)

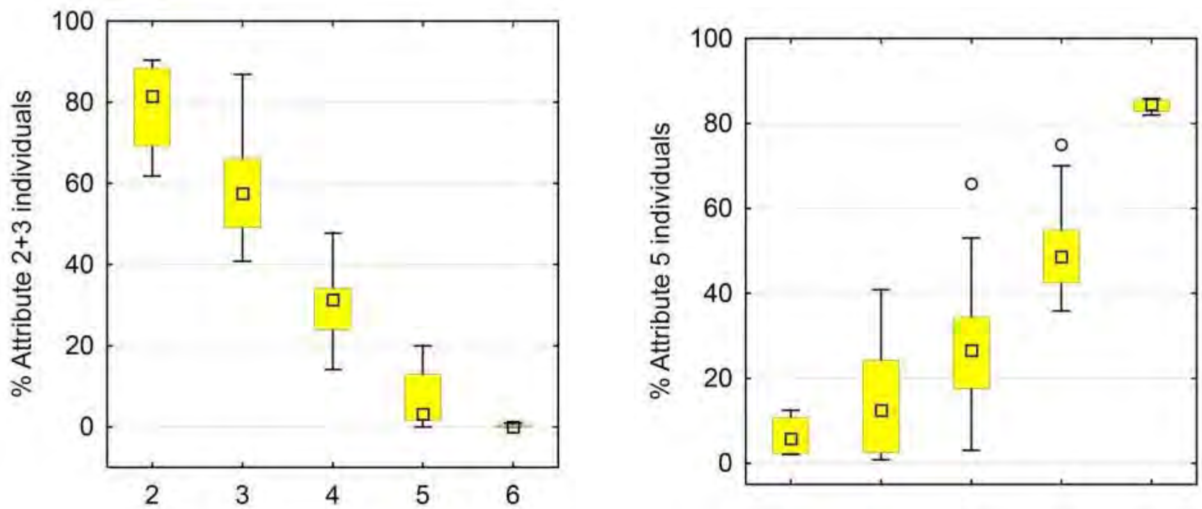


Figure 34. Box plots of sensitive (attribute II+III) and tolerant (attribute V) percent taxa and percent individual metrics for macroinvertebrate calibration samples, grouped by nominal BCG level (expert consensus) (Source: Stamp et al. 2014).

Additional expert panel findings include:

- One headwater site within the TMC watershed (King Spring) was identified as a high quality stream (BCG level 2) with taxa comparable to streams in the adjacent regional park (Little Bennett Regional Park) and with State of Maryland Sentinel Sites for the Piedmont region (Figure 35). Impervious cover for these BCG level 2 sites was at 3% or less. Three other TMC sites with impervious cover ranging between 4% and 11% were rated between BCG levels 3 and 4 (lower condition but considered comparable to "good to fair" conditions). The sites that were approaching BCG level 4 were considered by the experts as candidates for cost effective restoration.
- Sites within the TMC watershed having higher levels of impervious surface were assessed as lower quality. These more degraded sites had elevated levels of specific conductance, an indicator of urban runoff. However, tributaries in excellent to good condition, like King Spring, diluted specific conductance in the lower mainstem TMC.
- Sites within the Piedmont with levels of impervious surface typically higher than 4% showed increasingly degraded aquatic communities. Figure 36 shows average BCG level assignment for benthic macroinvertebrate sampling sites with % sensitive species plotted against % impervious surface. Increased level of impact on the aquatic biota can also be caused by confounding and synergistic effects of other stressors. Additionally, the degree of degradation can be moderated by implementing BMPs. These two considerations likely account for the observed scatter.
- Across Montgomery County both fish and benthic macroinvertebrate assemblages are assessed and may show divergent ratings of condition because of different responses to type and mechanistic pathway of stressors. In some instances, the experts assigned lower condition ratings for the fish community, because there were no or fewer than expected native species. This result was generally attributed to prevention of native fish migration due to dams and other obstacles. Additionally, there was evidence of intrusion of lake fish species from reservoirs so that lake species were dominant over the expected stream species. However, there was sufficient fish habitat and food supply (the benthic macroinvertebrates) to support re-

introduction of native species or migration of other species, such as eel. Depending upon existing temperature regimes, these sites might be excellent sites for re-introduction of native and migratory species.

The decision rules were considered by experts to be applicable to the larger Piedmont region and with minor modification to reflect climate and other latitudinal gradients, useful for assessing biological condition in Piedmont regions in Virginia, Delaware and Pennsylvania.

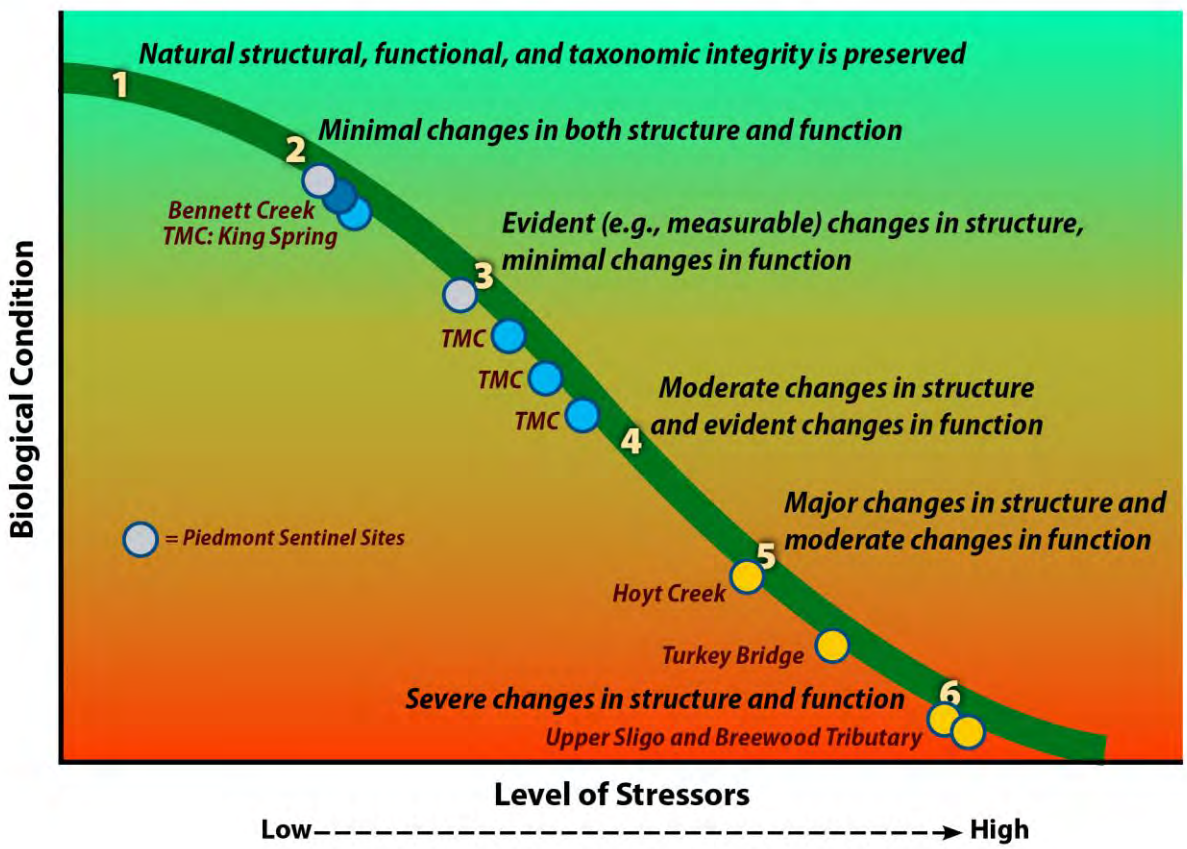


Figure 35. Comparative BCG ratings of macroinvertebrate community data from the county monitoring data set for streams in the TMC watershed and comparable county streams in other watersheds. Data from streams in the State of Maryland Piedmont Sentinel data set were also rated by the experts. The sites were mapped on the gradient according to the expert-derived decision rules for assigning sites to BCG levels.

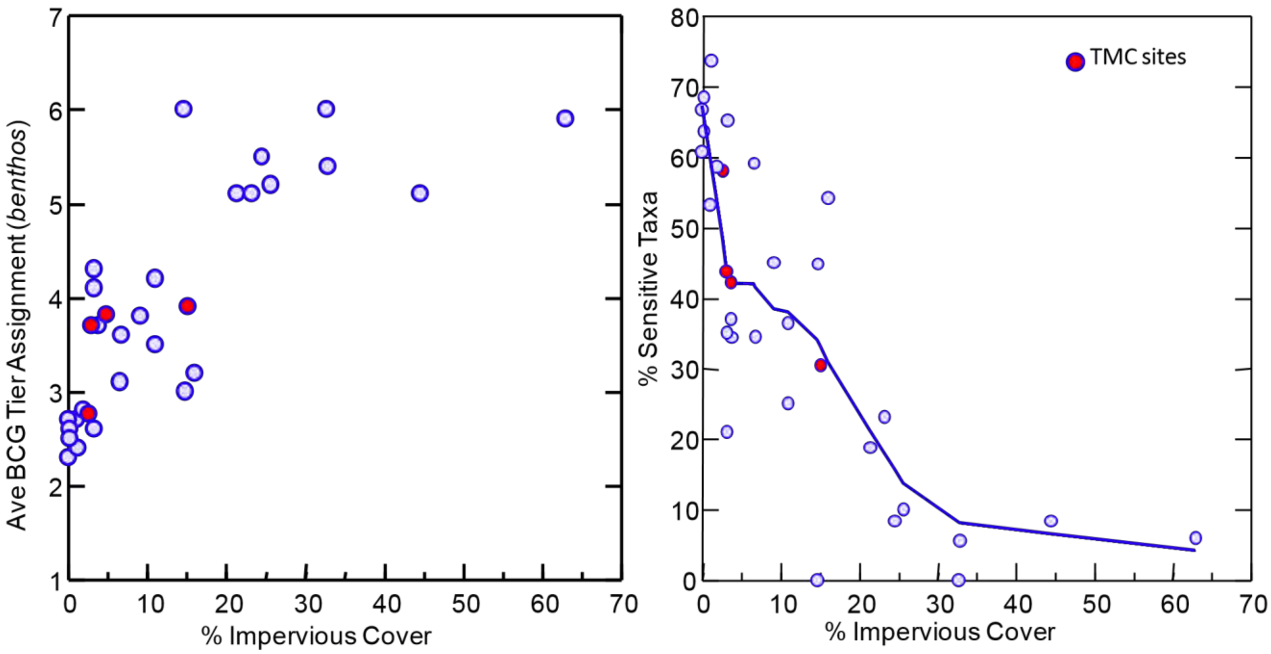


Figure 36. Relationship between average BCG level assignments (left) and % Sensitive Taxa (right) versus % impervious cover. This analysis included sites from throughout the Piedmont Region in Maryland. Ten Mile Creek sites are indicated (red dots).

6.1.4 Use of the Biological Condition Gradient Model in County Planning Decisions

Based on the findings in the environmental analyses associated with the proposed Limited Amendment, the County planning staff and MCDEP scientists concluded that there was significant uncertainty whether high quality aquatic resources assigned special protection, such as TMC subwatershed and streams, would be protected under the 1994 plan. The county planning and MCDEP staff provided several possible development scenarios with predicted outcomes and recommended one option that would modify development in the TMC area while maintaining good environmental conditions (M-NCPPC 2014b). The County Council accepted the recommended option, and it was adopted on April 1, 2014.

The BCG was used in conjunction with expert testimony, peer reviewed literature, research, modeling, and the environmental analysis to inform the County's decision to adopt the 2014 Limited Amendment for Clarksburg. This amendment revised zoning restrictions outlined in the 1994 Master Plan to reduce the impact of development on TMC. The 1994 Master Plan allowed a total impervious cap of 9.8%, while the Limited Amendment proposed a 6.3% impervious surface cap for new development in the most sensitive subwatersheds but allowed a maximum of 15% impervious cover in the Town Center District. The amendment also included a recommendation for increasing forest cover to 65% of the watershed and increasing the size of riparian buffers to better protect the streams and tributaries (M-NCPPC 2014b).

In 2014, the Montgomery County Council adopted the Limited Amendment to the 1994 Clarksburg Master Plan, which focused on TMC. The 2014 Limited Amendment concluded that TMC "warrants extraordinary protection," and offered recommendations for additional zoning restrictions that would allow for continued development, while continuing to study how development and mitigation activities (e.g., implementation of ESD) might affect sensitive water resources in the TMC watershed (M-NCPPC 2014a). The most sensitive streams or tributaries in the TMC system, such as King Spring, are currently at less than 1% impervious cover, so a cap of 6% will likely result in loss of some sensitive species and change from *excellent* to *good,* or potentially *fair*, condition depending on what other development activities occur or protective measures are put in place. For example, the amendment provides for consideration of additional measures (e.g., expanded stream buffer protections) and technology (e.g., ESD) that might minimize these changes (M-NCPPC 2014a). The use of the BCG in conjunction with other data, information, and expert testimony, successfully brought scientific information into the decision-making process and provided for informed decision making that balanced multiple public and private concerns and priorities.

6.1.5 Lessons Learned

Montgomery County found that the BCG framework was a good tool to better articulate current conditions in TMC and illustrate how water quality could be impacted by future development as outlined in the 1994 Master Plan. The 2014 Limited Amendment will allow for continued development with some restrictions on impervious cover. Because the BCG can be used in conjunction with monitoring data to detect incremental changes in stream health, county scientists will be able to closely monitor the effects of using ESD and other BMPs to mitigate the impacts of development on sensitive waters. County officials found that the BCG gave experts and the public a common understanding of water quality issues and allowed for informed policy making.

In the future, the County plans to use the BCG as an interpretative framework to examine restored sites and identify incremental improvements or declines in biological condition. Future use of this information might also include using county data for restoration modeling. In addition, the BCG might be used as one way to reconcile databases maintained at the County-level with those at the state level. Ultimately, one goal of such an effort could be to have county-level data used by the state when classifying streams.

6.2 Pennsylvania: Using Complementary Methods to Assess Biological Condition of Streams

6.2.1 Key message

Pennsylvania Department of Environmental Protection (PA DEP) implements a multi-tiered benchmark decision process for assessing attainment of ALU for wadeable, freestone, riffle-run streams in Pennsylvania. This multi-tiered approach incorporates stream size and sampling season as factors for determining ALU attainment based on benthic macroinvertebrate sampling. A BCG calibrated for freestone, riffle-run streams is used to supplement the state's primary screening tool, the IBI for benthic macroinvertebrates (PA DEP 2013a).

6.2.2 Using Index of Biological Integrity to Assess Aquatic Life Uses

PA DEP has developed a multimetric benthic macroinvertebrate IBI for the wadeable, high gradient, freestone[26] streams in Pennsylvania using the reference condition approach (PA DEP 2012). These streams are non-calcareous, or softwater, free flowing streams and comprise the majority of the state's streams. PA DEP has alternative assessment methods in place for other stream types (i.e., low-gradient pool-gliders, karst- [limestone]-dominated). The IBI provides an integrated measure of the overall condition of a benthic macroinvertebrate community in a water body by combining multiple metrics into a single index value. A number of different metric combinations were evaluated during IBI development. Based on discrimination efficiencies, correlation matrix analyses, and other index performance characteristics, PA DEP selected the following six metrics for inclusion as core metrics in the MMI (PA DEP 2012):

1. **Total Taxa Richness—**This taxonomic richness metric is a count of the total number of taxa in a subsample. Generally, this metric is expected to decrease with increasing anthropogenic stress to a stream ecosystem, reflecting loss of taxa and increasing dominance of a few pollution-tolerant taxa.
2. **Ephemeroptera + Plecoptera + Trichoptera Taxa Richness (EPT)—**This taxonomic richness metric is a count of the number of taxa belonging to the orders Ephemeroptera, Plecoptera, and Trichoptera in a sub-sample—common names for these orders are mayflies, stoneflies, and caddisflies, respectively. The aquatic life stages of these three insect orders are generally considered sensitive to, or intolerant of, many types of pollution (Lenat and Penrose 1996), although sensitivity to different types of pollution varies among specific taxa in these insect orders. This metric is expected to decrease in value with increasing anthropogenic stress to a stream ecosystem, reflecting the loss of taxa from these largely pollution-sensitive orders.
3. **Beck's Index—**This taxonomic richness and tolerance metric is a weighted count of taxa. The name and conceptual basis of this metric are derived from the water quality work of William H. Beck in Florida (Beck 1955). This metric is expected to decrease in value with increasing anthropogenic stress to a stream ecosystem, reflecting the loss of pollution-sensitive taxa.
4. **Shannon Diversity—**This community composition metric measures taxonomic richness and evenness of individuals across taxa in a sub-sample. This metric is expected to decrease in value with increasing anthropogenic stress to a stream ecosystem, reflecting loss of pollution-sensitive

[26] Freestone is a term familiar to fly-fisherman, denoting streams with little groundwater influence showing high annual variation in flow (spring freshet, summer drought).

taxa and increasing dominance of a few pollution-tolerant taxa. The name and conceptual basis for this metric are derived from the information theory work of Claude Elwood Shannon (Shannon 1948).

5. **Hilsenhoff Biotic Index—**This community composition and tolerance metric is calculated as an average of the number of individuals in a sub-sample, weighted by pollution tolerance values. Developed by William Hilsenhoff, the Hilsenhoff Biotic Index (Hilsenhoff 1977, 1987a, 1987b, 1988; Klemm et al. 1990) generally increases with increasing ecosystem stress, reflecting increasing dominance of pollution-tolerant organisms.
6. **Percent Sensitive Individuals—**This community composition and tolerance metric is the percentage of individuals in a sub-sample and is expected to decrease in value with increasing anthropogenic stress to a stream ecosystem, reflecting loss of pollution sensitive organisms.

PA DEP determined that these six metrics all exhibited a strong ability to distinguish between reference and stressed conditions in testing with benthic invertebrate assemblage data from riffle run habitats in wadeable, freestone streams. When used together in an MMI, these metrics provide PA DEP with a consistent and defensible index for assessing the biological condition of these streams (PA DEP 2012).

6.2.3 Use of the Biological Condition Gradient to Complement Aquatic Life Use Assessments

PA DEP is exploring use of a BCG to describe the biological characteristics of wadeable, freestone streams along a gradient of stress. More than 75% of Pennsylvania is in the hills and low mountains of the Appalachian Highlands, so streams throughout the state are predominantly relatively high gradient (> 1% slope) (Figure 37 and Figure 38). Pennsylvania is largely forested, but there are significant areas where agricultural land use, including row-crops and pasture, is dominant (Figure 39). Limestone and spring-dominated streams occur in parts of southeast, south-central and east-central Pennsylvania. The BCG assessments and model discussed in the case study do not apply to this subset of streams.

Figure 37. Top: Carbaugh Run, Adams County; Bottom: Rock Run, Lycoming County (Photos courtesy of PA DEP).

Between 2006 and 2008, PA DEP conducted a series of expert workshops to calibrate a BCG along a gradient from minimally to heavily stressed conditions (PA DEP 2013b). To develop the BCG for the wadeable, freestone streams, biologists from PA DEP, in conjunction with external taxonomic experts and scientists (e.g., the Delaware River Basin Commission, Western Pennsylvania Conservancy, and EPA), used the BCG attributes that characterize specific changes in community taxonomic composition (PA DEP 2013b). For example, in the highest levels of the BCG, locally endemic, native, and sensitive taxa are well represented, and the relative abundances of pollution-tolerant organisms are typically lower. With increasing stress, more pollution-tolerant species may be found with concurrent loss of pollution-sensitive species. At the beginning of the expert workshop, the participants assigned a BCG attribute for sensitivity to stress (i.e., attributes I–V) to each macroinvertebrate taxon based on expert knowledge and biological response data. The data used was from sampling sites that spanned a range of condition from reference quality (e.g., at or close to minimally disturbed conditions) to heavily stressed sites (PA DEP 2013b). Using the BCG level descriptions of predicted changes in the attributes as a guide, the expert panel then assigned each site to one of the six BCG levels and developed candidate decision rules (Figure 40, Table 31).

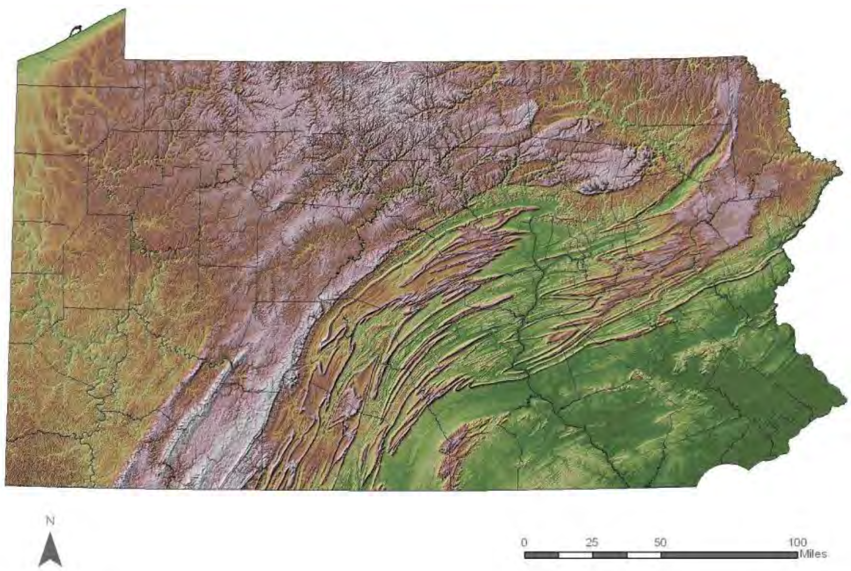


Figure 38. Topographic Map of Pennsylvania.

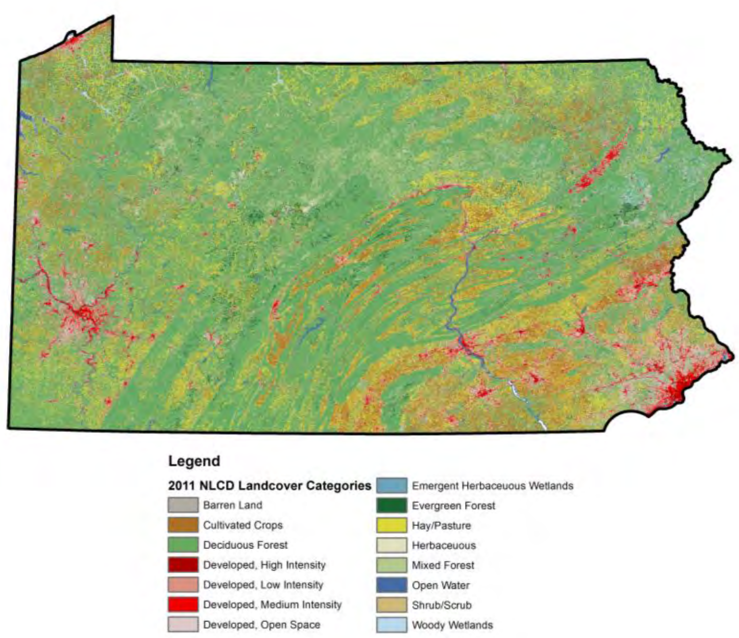


Figure 39. Pennsylvania Land Use.

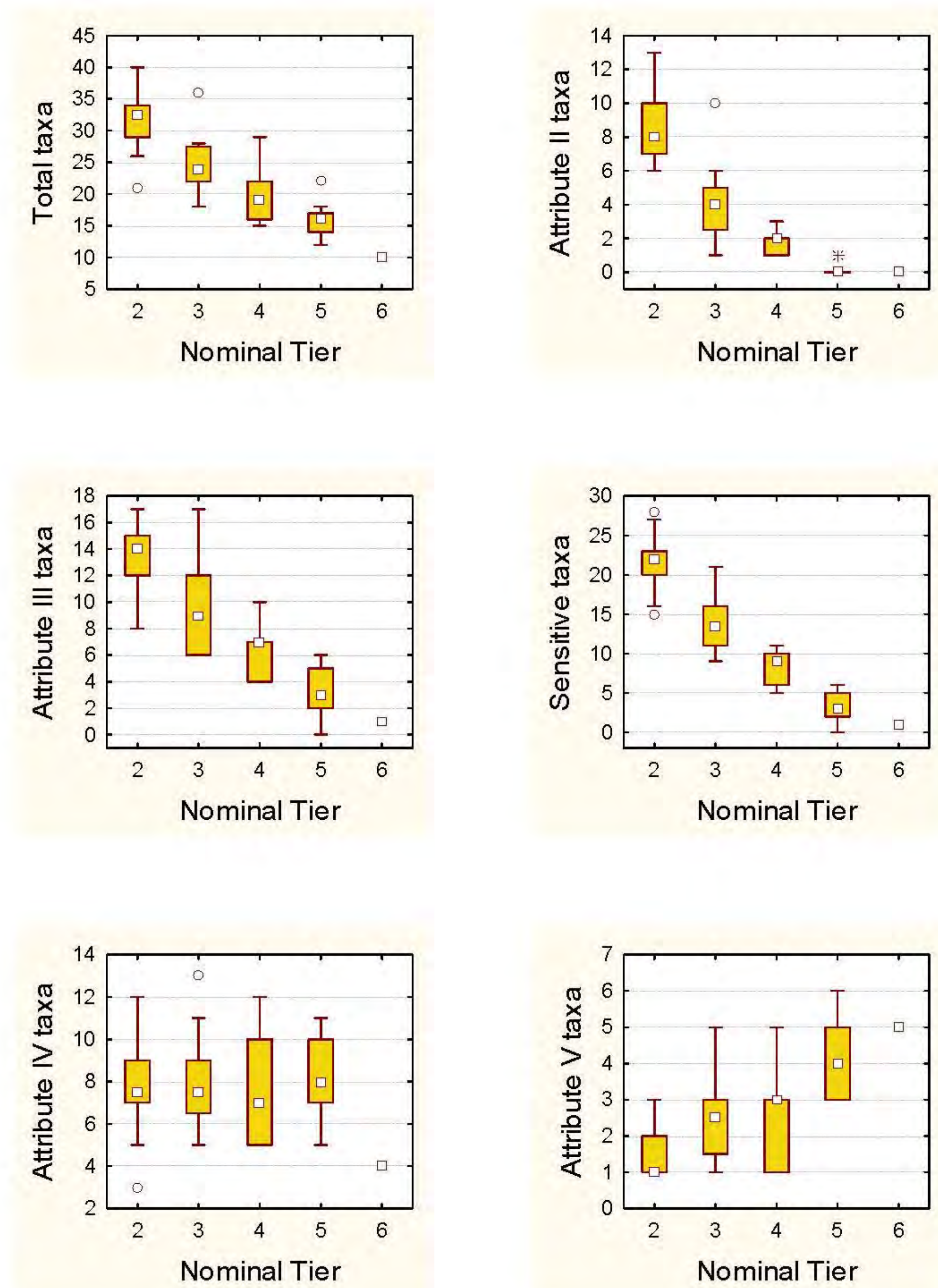


Figure 40. Box plots of BCG metrics, by nominal level (group majority choice). Sensitive taxa are the sum of both attribute II (highly sensitive) and attribute III taxa (intermediate sensitive) (Source: Gerritsen and Jessup 2007c).

Table 31. Potential narrative decision rules for invertebrate samples from Pennsylvania high gradient streams (modified from Gerritsen and Jessup 2007c)

Attributes	BCG Level				
	2	3	4	5	6
All Taxa	> 25 taxa	> 20 taxa		≥ 10 taxa No single taxon ≥ 50% of abundance ≥ 50 individuals in sample	Low richness or low abundance
I. Historically documented, sensitive, long-lived, or regionally endemic taxa	*No rules determined for attribute I*				
II. Highly sensitive taxa	Taxa II ≥ 33% of Taxa III	Taxa II present (> 0)	May be absent (no rule)		
III. Intermediate sensitive taxa	Taxa (II + III) ≥ 50% of all taxa Indiv (II + III) ≥ 50% of all indiv	Taxa (II + III) ≥ 30% of all taxa Indiv (II + III) ≥ 30% of all indiv	Taxa (II + III) present (≥ 10% of taxa, or 2 taxa) Indiv (II + III) ≥ 15%–20% of all indiv		
IV. Intermediate tolerant taxa	*No rules determined for attribute IV*				
V. Tolerant taxa	Few tolerant taxa; Tolerants are small % of total abundance (≤ 5%)	Tolerant individuals ≤ 20% of total abundance	Tolerant individuals ≤ 40% of total abundance		Tolerant individuals may dominate
Indicator taxa	Many EPT taxa; EPT ≥ 15	Tolerant Caddisflies ≤ 20% abundance EPT ≥ 12	Tolerant Caddisflies ≤ 40% abundance EPT ≥ 8	Tube worms not dominant; ≤ 50% of abundance	Mayflies may be absent; Tube worms may dominate

Each sampling site used to develop and test the BCG decision rules had corresponding IBI scores. The IBI uses metrics that are similar in objective to the BCG attributes, but which are calculated differently (PA DEP 2013a). The total IBI score is based on the sum or average of all metrics, while BCG decision rules are based on specific attribute groups and patterns of change along a gradient of stress (e.g., attributes II and III for the higher levels and attribute V for lower levels).

For all the evaluated samples, PA DEP biologists analyzed the relationship between a sample's BCG level assignment with its corresponding IBI score (PADEP 2013b). A strong correlation existed between the calibrated BCG level assignments and the IBI scores (Figure 41). On the basis of this comparative analysis, PA DEP determined that with further testing and evaluation, the IBI scores could potentially be used to discriminate BCG levels. PA DEP is evaluating using the BCG to describe the biological characteristics of streams assessed based on the IBI scores; for example, the reference sites clustered at IBI scores near 80 and above would be interpreted as primarily comparable to BCG levels 1–2. On the basis of taxonomic information, and without knowledge of the IBI scores, the experts assigned these sites to BCG levels 1.5 to 2.5. BCG level 2 represents close to natural conditions (e.g., minimal changes in structure and function relative to natural conditions; supports reproducing populations of native species of fish and benthic macroinvertebrates). This information can meaningfully convey to the public the biological characteristics of waters in the context of the CWA and the goal to protect aquatic life. PA DEP is evaluating use of the BCG to complement the IBI in assessing ALU attainment and to help identify potential high-quality (HQ) or exceptional value (EV) streams. As a first step in application of the BCG, PA DEP has incorporated BCG attributes for taxa sensitivity to stress as part of its protocol for wadeable, freestone streams (Figure 42) (PA DEP 2013a).

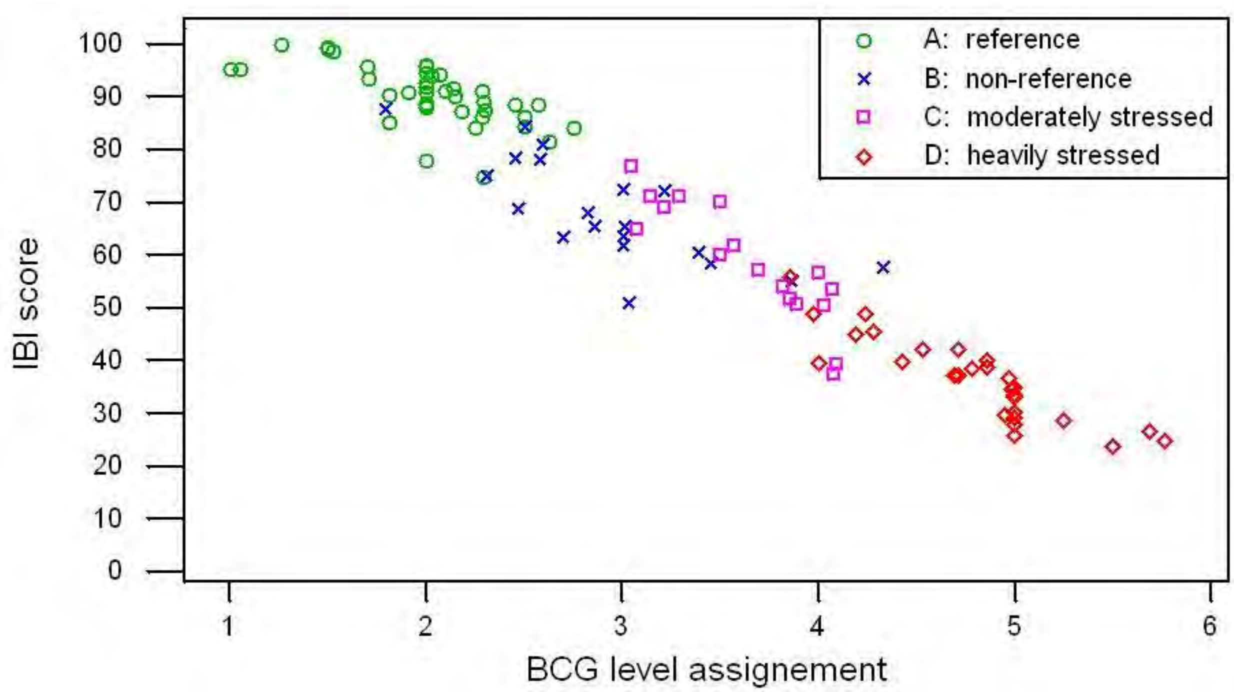


Figure 41. Comparison of calibrated BCG level assignments (mean value) and IBI scores for freestone streams representing range of conditions from minimal to severely stressed.

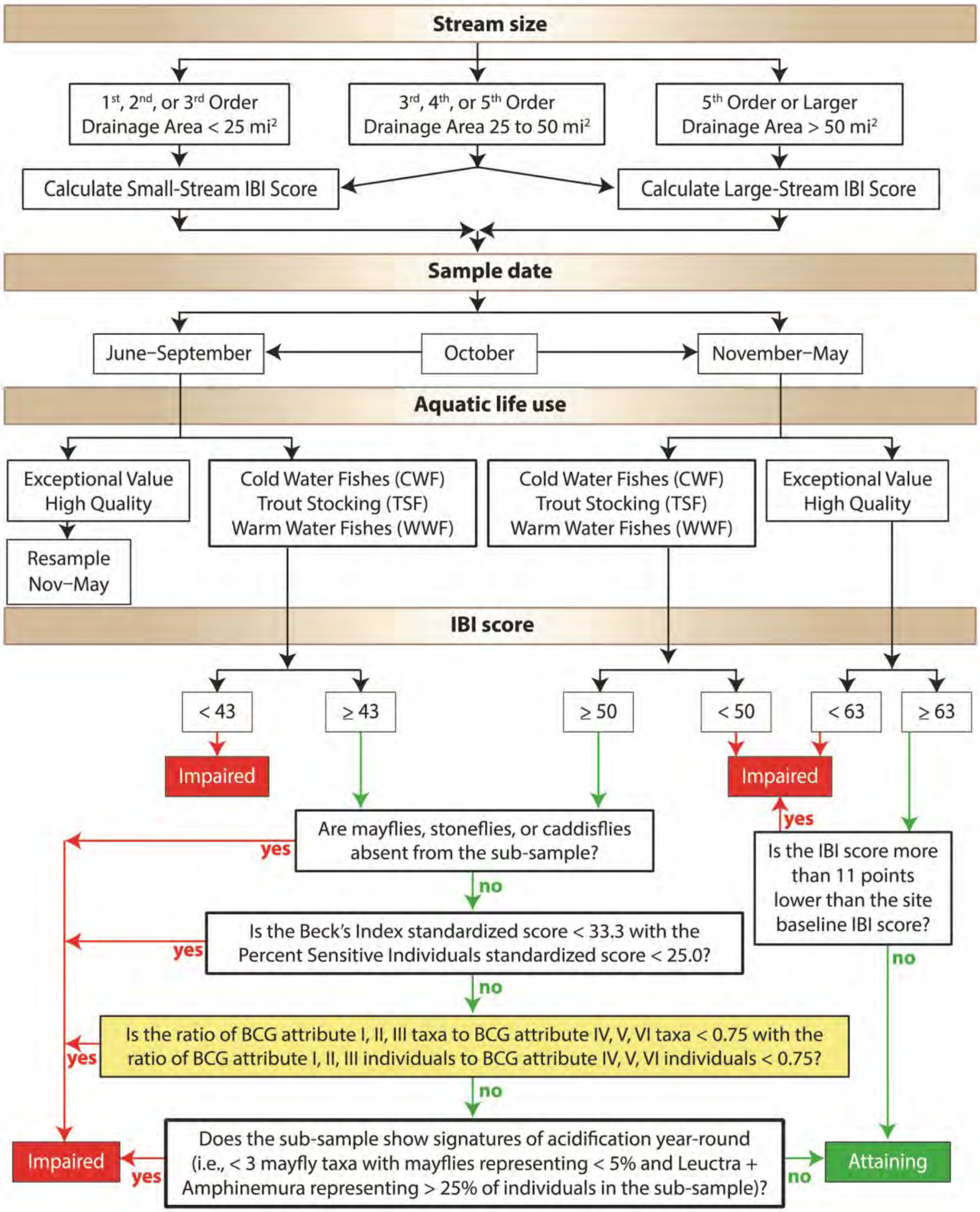


Figure 42. Multi-tiered benchmark decision process for wadeable, freestone, riffle-run streams in Pennsylvania (Modified from PA DEP 2013a). The ratio of BCG attributes for sensitive to tolerate taxa (i.e., attributes I, II, and III to attributes IV, V, and VI) are included as part of attainment determination (see yellow box). Rules have not been defined for attribute I and IV but these attributes are included in the assessment protocol if decision rules are developed in the future and determined to be appropriate to include.

6.2.4 Potential Application to Support Aquatic Life Use Assessments and Protection of High Quality Waters

Pennsylvania's regulations define waters of EV that are of unique ecological or geological significance. EV streams are given the highest level of protection and constitute a valuable subset of Pennsylvania's aquatic resources. To support protection of these waters, PA DEP is considering the use of a discriminant analysis model to evaluate the relationship between condition of the watershed, a stream, and its aquatic biota (e.g., the connection of riparian areas with a stream and the floodplain or the spatial extent of stressors and their sources in the watershed). PA DEP is evaluating the use of a discriminant model that incorporates measures of land use and physical habitat along with IBI scores and the BCG to make distinctions between EV and HQ waters. PA DEP is also evaluating how to consider effects of habitat fragmentation and spatial and temporal extent of stress. The results of this effort could potentially support state water quality management decisions on where to target resources for sustainable, cost-effective protection of EV waters and healthy watersheds. Through this work, PA DEP can provide EPA valuable feedback on the technical development and potential program application for BCG with specific focus on defining indicators for BCG attributes IX (spatial and temporal extent of detrimental effects) and X (ecosystem connectance).

6.3 Alabama: Using the Biological Condition Gradient to Communicate with the Public and Inform Management Decisions

6.3.1 Key Message

ADEM has strategically built a comprehensive biological monitoring program over the past four decades and has, more recently, invested in developing BCGs for streams in all regions of the state. ADEM has identified reference conditions in order to better characterize current water quality condition, and it has built increasing capability in terms of data management. As ADEM's capabilities have evolved, it is applying biological data, biological indices, and the BCG for a variety of management purposes, including identification of high quality waters and waters that need restoration. As part of this process, ADEM has improved its ability to communicate to the public on the condition of streams and to measure incremental improvements in condition. Though the state is developing and applying the BCG and biological assessments on a statewide basis, this case study reports on the development and application of a BCG for the high gradient streams of Northern Alabama.

6.3.2 Program Development

Since 1974, ADEM has been monitoring its surface water quality, and the capabilities of the monitoring program have evolved over time. In 1997, ADEM first formalized a coordinated monitoring strategy to outline its surface water quality monitoring efforts. Today, ADEM collects biological, chemical, and physical data and uses those data to inform management decisions, including assessing the health of state waters, determining whether those waters are meeting their designated uses, and identifying impacts from a variety of sources (ADEM 2012).

ADEM continues to build its monitoring program to meet emerging data needs, and it is currently evaluating the use of its biological data in new ways. ADEM conducted a preliminary critical elements review[27] of its biological assessment program in 2006 to assess the strengths of the technical program. The review highlighted ADEM's efforts to that point, and it included recommendations for enhancements relative to design, methodology, and execution for credible data as a basis of making informed decisions regarding the ecological condition of Alabama's streams. The review resulted in a recommendation that ADEM fully implement its monitoring strategy to accomplish a variety of goals, including more complete development of reference conditions and site criteria, and development and/or refinement of macroinvertebrate, fish, and diatom community assessment methods; ecological attributes; response patterns; and indices along a continuous BCG scale. The review also highlighted the need for an improved and enhanced database management system; improved technical capabilities to carryout survey needs; statewide completion of monitoring unit delineation; and incorporation of up-to-date land cover data sources.

Since the 2006 review, ADEM has continued to make improvements in the technical capabilities of its biological assessment program. In 2008, ADEM used data collected in 1994–2005 to develop MMIs for high and low gradient streams. The indices were used for site assessments with thresholds derived from the reference distribution. At the same time, the biological database was updated to a new platform, integrated into ADEM's centralized surface water database, Alabama Water-Quality Assessment and

[27] For more information about Critical Element Review, see *Biological Assessment Program Review: Assessing Level of Technical Rigor to Support Water Quality Management* (USEPA 2013, http://www.epa.gov/wqc/biological-assessment-technical-assistance-documents-states-and-tribes. Accessed February 2016.)

Monitoring Data Repository (ALAWADR), which houses chemical, physical, and biological data. In 2009, the database was modified to calculate macroinvertebrate metrics and indices. Incorporating these tools into ALAWADR assisted greatly in the development and testing of ecological attributes, stress-biological response patterns, and indices along continuous BCG and stressor scales. In 2013, ADEM expanded the effort to use data from the 1994–2011 period to incorporate additional reference site data to refine the site classes, and MMIs (Jessup 2013). In these efforts, ADEM considered regional differences in biological habitat and species distribution, and it found that variability was best explained using ecoregions[28] for classification. ADEM calibrated the MMIs to categorize water quality on a scale from *Very Good* to *Very Poor* (Jessup 2013).

In a similar effort spear-headed by the Geological Survey of Alabama, ADEM and the Alabama Department of Conservation and Natural Resources collaborated to develop statewide multimetric fish community indices. In 2004, the Geological Survey of Alabama completed refinement of collection methods developed by the Tennessee Valley Authority and established five site classes, or ichthyoregions, primarily based on ecoregions and basins. Statewide MMIs were completed in 2011–2012.

6.3.3 Index Development

As a result of the work and collaboration among state agencies discussed above, ADEM developed biological indices for both macroinvertebrates and fish statewide. Assessment thresholds were established for both assemblages using similar analytical methods though there were differences in site classification and threshold delineation. First, similar regions for classification were identified for each assemblage, but they were not identical (Figure 43). For site classification, the similarity of species composition relative to ecoregions, drainage basins, and other natural site characteristics was analyzed. Shared environmental variables associated with the ecoregional distinctions for both assemblages included elevation, temperature, and percent cobble and boulder substrate. However, differences in classification for the two assemblages were attributed to the dependence on drainage continuity for fish migrations, whereas macroinvertebrates (especially insects) can move among drainages by flying during adult stages.

Second, for benthic macroinvertebrates, candidate reference sites were identified based on measurements of disturbances both at the site and in the landscape. A watershed disturbance gradient (WDG) was calculated using land use coverage (e.g., percent urban, row crop, and/or pasture in the catchment) and road density (Brown and Vivas 2005; ADEM 2005). Figure 44 shows broad land cover patterns throughout the state. The 25th percentile of the WDG was used as the threshold for selecting candidate reference streams. These reference streams experienced minimal to moderate levels of stress and are considered "least disturbed" conditions (Stoddard et al. 2006). However, for some regions, land use intensity as measured by the WDG was considerably higher and more widespread, reflecting regional patterns in agricultural and urban land use. Reference streams in the regions with more intensive development (e.g., higher WDG scores) generally had lower biological scores (e.g., benthic macroinvertebrate scores) (Table 32). Figure 45 shows the range of land intensity scores in sites assessed by ADEM, including reference sites.

[28] Ecoregions describe areas with similar features related to geology, physiography, vegetation, climate, soils, land use, wildlife, and hydrology.

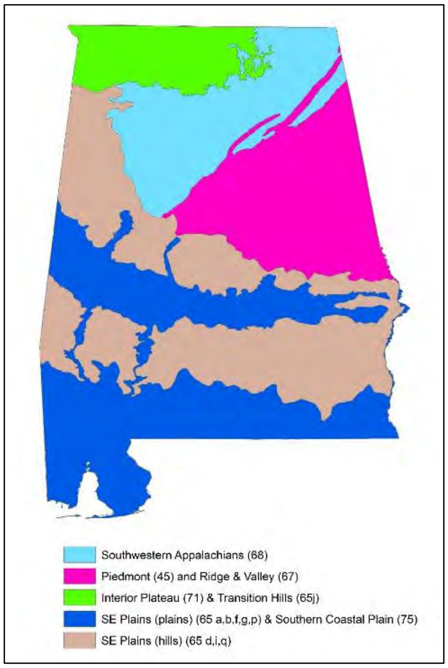


Figure 43. Left: Macroinvertebrate site classes in Alabama; Right: Fish site classes in Alabama.

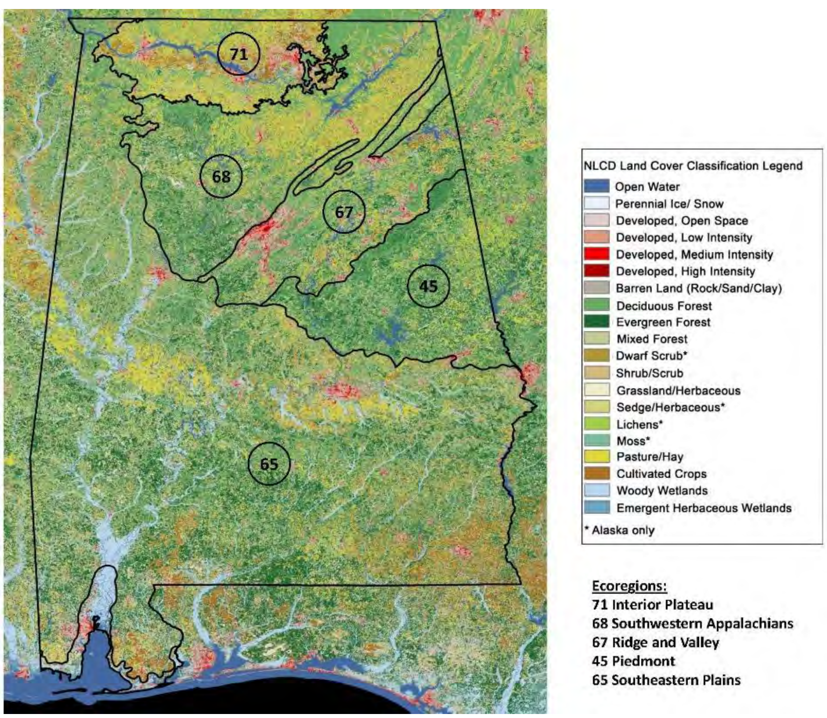


Figure 44. Alabama land use/land cover map.

Table 32. Characterization of Reference Conditions Using WDG and the Alabama Macroinvertebrate MMI for streams. WDG scores increase with level of land use activity.

Macroinvertebrate Site Class	Median Reference WDG Score	Benthic Macroinvertebrate MMI Score: 25th Quantile of Reference

Macroinvertebrate Site Class	Median Reference WDG Score	Benthic Macroinvertebrate MMI Score: 25th Quantile of Reference
Interior Plateau	61	43
Southeastern Plains–Hills	64	47
Piedmont, Ridge & Valley	46	69
Southwest Appalachians	31	58
Southeastern Plains–Plains	90	45

Additionally, there are differences in how the two assemblage indices were scored and benchmarks established. As described above, the benchmark for the macroinvertebrate index was based on a reference condition approach. Reference sites were selected based on abiotic parameters that met predetermined selection criteria and a 25% threshold was established (Table 32). However, for fish, the range of index scores from all sites was divided into five condition categories: excellent, good, fair, poor, and very poor (Figure 46). The thresholds between fish categories were selected to create a balanced distribution of conditions among the sampled sites, with most samples in the fair category, and similar numbers of excellent and good samples compared to poor and very poor samples (Figure 46; O'Neil and Shephard 2011). Thus, the reference condition for macroinvertebrates and the excellent and good categories for fish are not a one for one match. ADEM wanted to develop the BCG model and numeric decision rules so that benthic macroinvertebrate and fish assemblage data could be mapped on the BCG and interpreted against a uniform standard despite differences in sample collection and analysis.

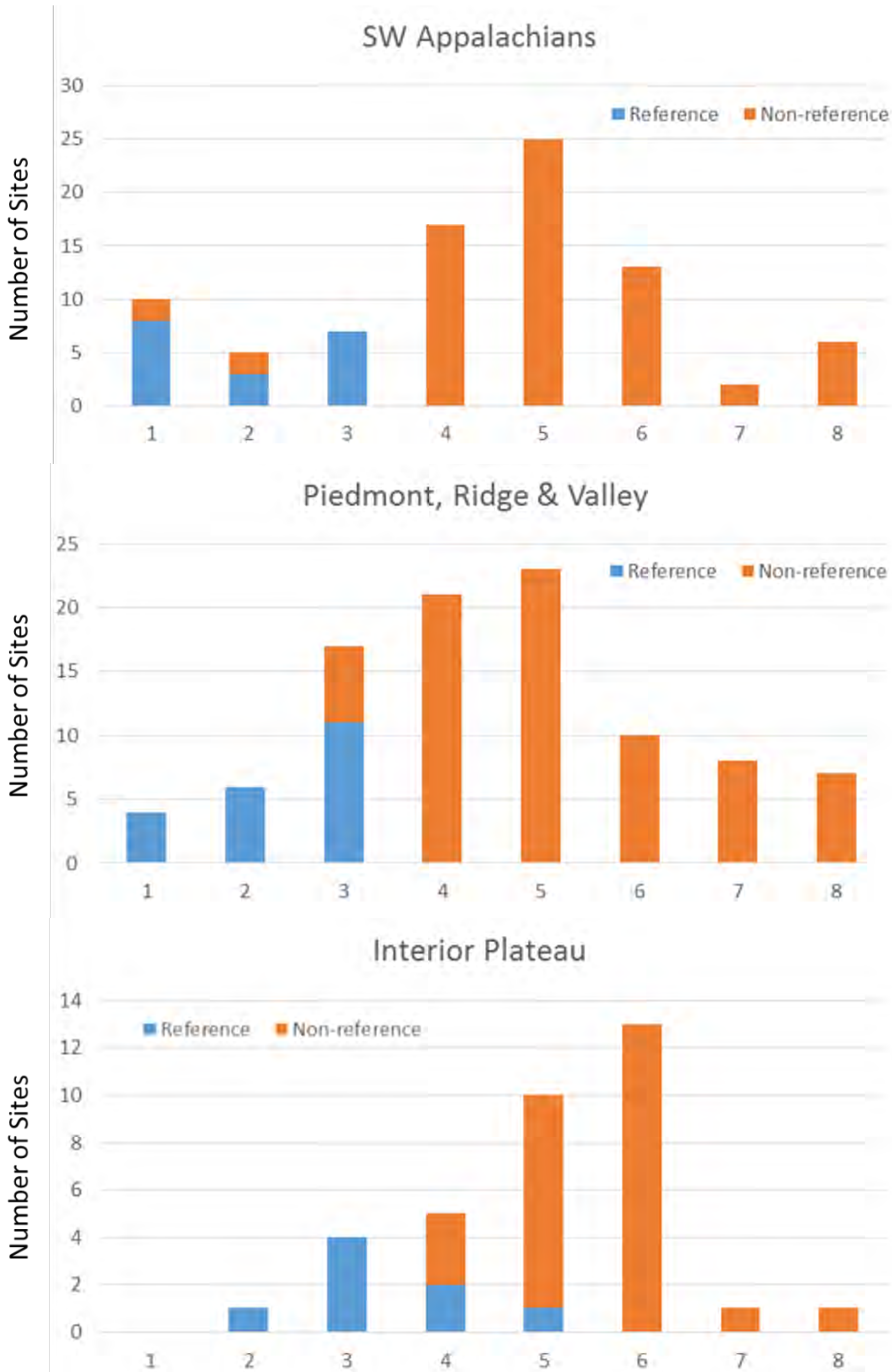


Figure 45. Frequencies of sites in ranked WDG categories (x-axis), distinguishing reference and non-reference sites in each site class. Distributions are based on sites monitored in ADEM's biological assessment program. WDG categories are numerically ranked with increased levels of stress. ADEM converted the WDG scores to ranks 1–8, with lower numbers representing less disturbance.

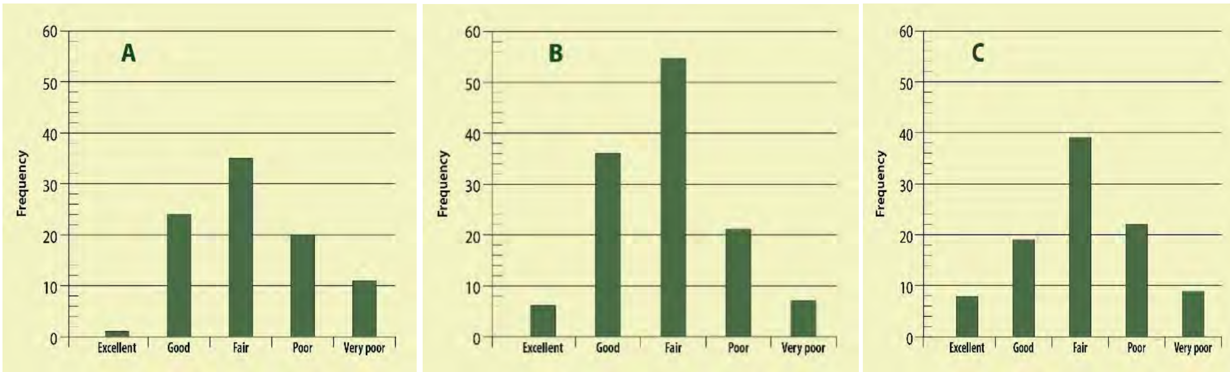


Figure 46. Frequency distribution of fish IBI condition categories for sites in the three ichthyoregions discussed in this case study: the (A) Plateau; (B) Piedmont, Ridge, and Valley; and (C) Tennessee Valley site classes. The x-axis is divided into five condition categories: excellent, good, fair, poor, and very poor.

6.3.4 The Biological Condition Gradient

In 2014, ADEM and Geological Survey of Alabama convened an expert panel of scientists from the state, outside agencies, academia, and other research organizations. The charge to the expert panel was to develop a quantitative BCG and to use the BCG to calibrate BCG-based indices for fish and macroinvertebrate assemblages for wadeable streams in Alabama. The first phase of BCG development was on wadeable streams in Northern Alabama in three ecoregions: the Interior Plateau, Southwest Appalachian, and the Piedmont Ridge Valley ecoregions. This case study reports on these results. The second phase of BCG development is underway for the coastal plain streams in central and southern Alabama.

Wadeable streams in northern Alabama are higher gradient relative to streams in the coastal plains of southern Alabama and tend to have a riffle habitat (Figure 47). Experts developed numeric decision rules to predict the BCG level of a stream based on site classes for fish and macroinvertebrates (Jessup and Gerritsen 2014). Models were then developed to replicate the expert decisions for assigning new samples to BCG levels 2–6 without having to reconvene the expert panel. There were no sites in the data set used to develop the BCG that the experts considered comparable to BCG level 1 (undisturbed), so the experts conceptually described the expected biological community for a BCG level 1. The conceptual description provided a shared, narrative starting point for assessing incremental changes from BCG level 1 to BCG level 6. The final modeled BCG levels correctly predicted the expert ratings of actual site data for BCG levels 2–6 in 94% and 96% of cases for macroinvertebrates and fish, respectively.

Figure 47. Example of range in typical northern Alabama streams with riffle-run habitat. Top: Hendriks Mill Branch; Bottom: Hatchet Creek.

As the first step in developing the BCG model for northern Alabama streams, the benthic macroinvertebrate and fish species were assigned BCG attributes corresponding to their prevalence and sensitivity to disturbance. These characteristics were analyzed using abundance of individuals and general additive models (GAMs) based on the capture probability of each taxon along the WDG scale. Experts in the workgroup used the model results and their own experience to assign attributes to each taxon. Taxa with steeply descending model slopes were sensitive to disturbance and were assigned attributes II or III (e.g., highly and intermediate pollution sensitivity) based on the slope of the response curve (e.g., capture probability) (e.g., *Acroneuria* in Figure 48). Taxa with flat slopes were found in a variety of disturbance conditions and were assigned to BCG attribute IV (taxa of intermediate tolerance). Taxa with increasing capture probabilities with increasing disturbance were assigned to BCG attribute V (tolerant taxa) (e.g., *Ferrissia* in Figure 48). In the second step of the BCG process, the experts used the attribute assignments in developing the decision rules for assigning sites to BCG levels (Table 33).

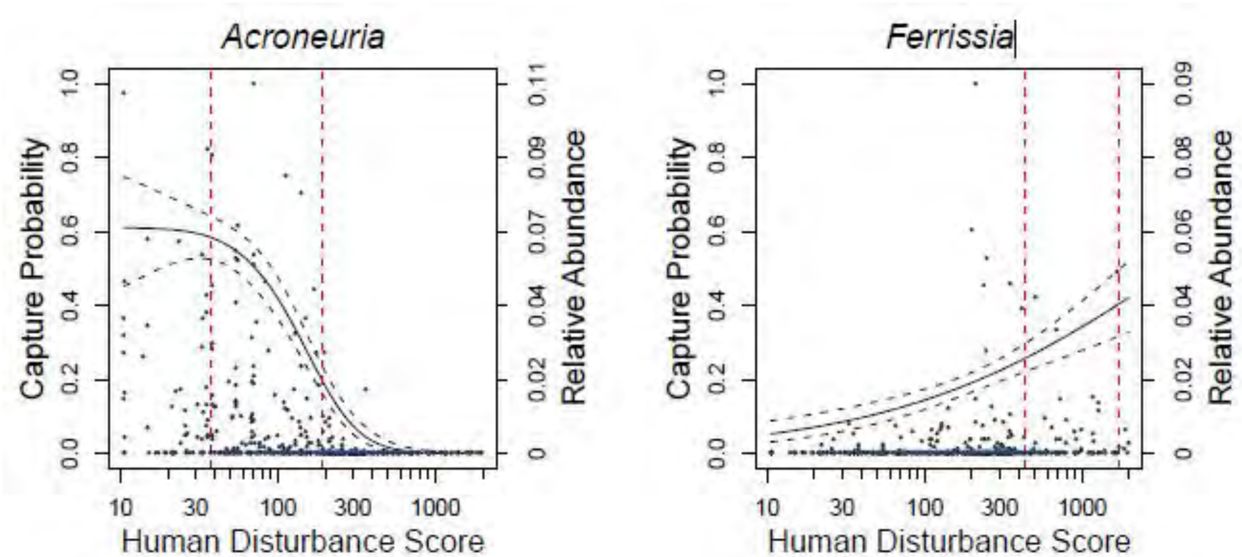


Figure 48. Taxa relative abundance and the GAM slope based on capture probabilities for *Acroneuria* (Plecoptera: Perlidae; attribute III) and *Ferrissia* (Gastropoda: Ancylidae; attribute V).

Table 33. Example of narrative and quantitative rules from Northern Alabama BCG: BCG level 2 narrative and quantitative rules for macroinvertebrates and quantitative rules for fish in northern Alabama. Macroinvertebrate rules apply in all northern Alabama streams. Fish rules are applied by site class (PLA, RVP, and TV) and stream size (Small and Large).

Narrative Macroinvertebrate Rules for BCG Level 2

The sample is considered a level 2 condition if:
The number of all taxa in the sample is greater than 50–60 taxa and
The number of highly sensitive (attribute II) taxa is greater than 6–10 taxa and
The percentage of sensitive (attribute II+III) taxa is greater than 35%–40% of all taxa and
The number of sensitive (attribute II+III) EPT taxa is greater than 10–18 taxa and
The percentage of individuals in the 5 most abundant taxa is less than 60%–70% and
The percentage of individuals in the most abundant 5 tolerant (attribute IV, V, VI) taxa is less than 45%–55% OR the number of all taxa in the sample is greater than 70–80 taxa.
If any of these rules is not met at least half-way, the sample is level 3–6, depending on rules for those levels.

Macroinvertebrates: BCG Level 2	Quantitative Rule
# Total taxa	≥ 55 (50–60)
# Attribute II taxa	≥ 8 (6–10)
% Attribute II+III taxa	≥ 40% (35–45)
# Attribute II+III EPT taxa	≥ 14 (10–18)
% individuals in the most dominant 5 taxa	≤ 65% (60–70)
% individuals in the most dominant 5 tolerant taxa	≤ 50% (45–55) or Total Taxa > 75 (70–80)

Narrative Fish Rules for BCG Level 2

The sample is considered a level 2 condition if:
The number of all taxa in the sample is greater than 10–25 taxa in the PLA and RVP and
The number of highly sensitive (attribute I+II) taxa is greater than 0–4 taxa and
The number of sensitive (attribute I+II+III) taxa is greater than 5–10 in large TV sites and
The percentage of sensitive (attribute I+II+III) taxa is greater than 10%–25% and
The percentage of sensitive (attribute I+II+III) individuals is greater than 5%–30% and
The percentage of tolerant (attribute V+Va+VI) individuals is less than 15%–30% in the PLA and RVP and
The percentage of the most abundant Va or VI individuals is less than 30%–40% in the TV.
If any of these rules is not met at least half-way, the sample is level 3–6, depending on rules for those levels.

Fish: BCG Level 2	PLA		RVP		TV	
	Small	Large	Small	Large	Small	Large
# Total taxa	≥ 15 (10–20)	≥ 20 (15–25)	≥15 (10–20)	≥ 20 (15–25)	—	
# Attribute I+II taxa	> 2 (1–4)		> 0 (0–1)	> 2 (1–4)	> 1 (0–3)	≥ 2 (1–4)
# Attribute I+II+III taxa	—		—		—	> 7 (5–10)
% Attribute I+II+III taxa	≥ 20% (15–25)		≥ 15% (10–20)		≥ 20% (15–25)	
% Attribute I+II+III individuals	≥ 25% (20–30)		≥ 20% (15–25)		≥ 10% (5–15)	
% Attribute V+Va+VI individuals	≤ 25% (20–30)		≤ 20% (15–25)		—	
% Most dominant Attribute Va or VI individuals	—		—		≤ 35% (30–40)	

6.3.5 Application of the Biological Condition Gradient to Support Aquatic Life Use Assessments

Because biotic assemblages may respond to stressors differently depending on the mechanism of action, information from two or more assemblages provides more comprehensive insight into condition of the water, possible sources of stress, and potential for improvements. For example, the presence of small dams along streams and rivers alter natural flow and in stream habitat. These barriers prevent migration of some native species from rivers into streams. Likewise, presence of large reservoirs can introduce lake species into adjacent streams. Both of these impacts could result in a lower rating of biological condition using fish community data. An assessment of the benthic macroinvertebrate community of the same stream might result in a better biological condition rating if there are no additional stressors and physical habitat "as naturally occurs." This information would indicate that habitat and food source for fish exist and inform ADEM or other state agency decision makers that the stream may be a prime candidate for restocking of native species.

The BCG can be used by ADEM to characterize and communicate the biological conditions in the "least disturbed" reference reaches, aiding the interpretation of reference site quality relative to the absolute definitions of the BCG levels. "Least disturbed" reference sites are the best observable landscape and stream sites within a region. They can differ across regions of Alabama because development can be ubiquitous across entire regions of the state. The BCG can be used to interpret biological conditions in the "least disturbed" reference sites based on expert consensus in a manner that is transparent as long as expert judgment and the resulting decision rules are documented. For example, 57% and 44% of sites from ADEM's reference data set for two macroinvertebrate site classes, the Piedmont, Ridge, and Valley and the Southwest Appalachian regions, were assigned as BCG level 2 based on the benthic macroinvertebrate decision rules with the remainder of the sites primarily assigned as BCG level 3 (Figure 49). In contrast, only 13% of reference sites in the Interior Plateau were modeled as BCG level 2 and the majority of sites were assigned to BCG level 3. The differences in BCG levels among the reference sites of the three site classes illustrates how the "least disturbed" reference condition can have different biological meaning. BCG level 2 conditions support an aquatic community comparable to what would be expected under naturally occurring conditions with no or minimal anthropogenic impacts. The biological community characteristic of BCG level 3 includes loss of some native taxa and shifts in relative abundance of taxa relative to BCG level 2. Integration of the reference information and the BCG scale can be used to more clearly communicate to the public the quality of the reference condition for each region. In addition, existing indicators could be calibrated to the BCG scale to refine attainment thresholds. Despite the differences in reference site quality within the ADEM reference data set, there is a comparable relationship with the WDG in all three regions (Figure 50). The scatter observed with increasing WDG could, in part, be attributed to confounding effects and different mechanisms of action of multiple stressors as well as mitigating influence of BMPs that have been implemented.

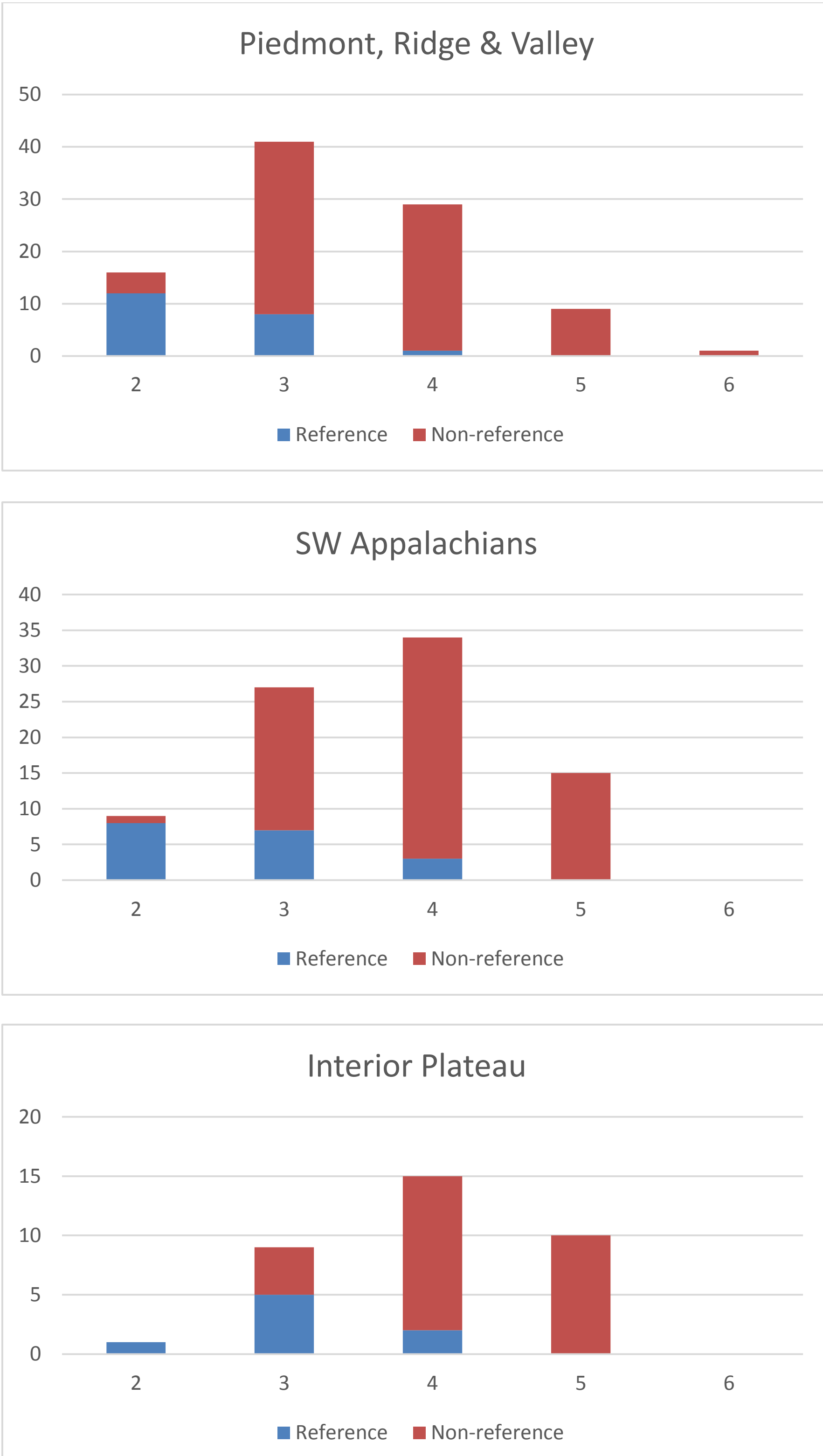


Figure 49. Frequencies of sites (y-axis) in each BCG level (x-axis) in each northern Alabama site class, showing reference sites as the blue portions of the bars. Distributions are based on sites monitored in ADEM's biological assessment program.

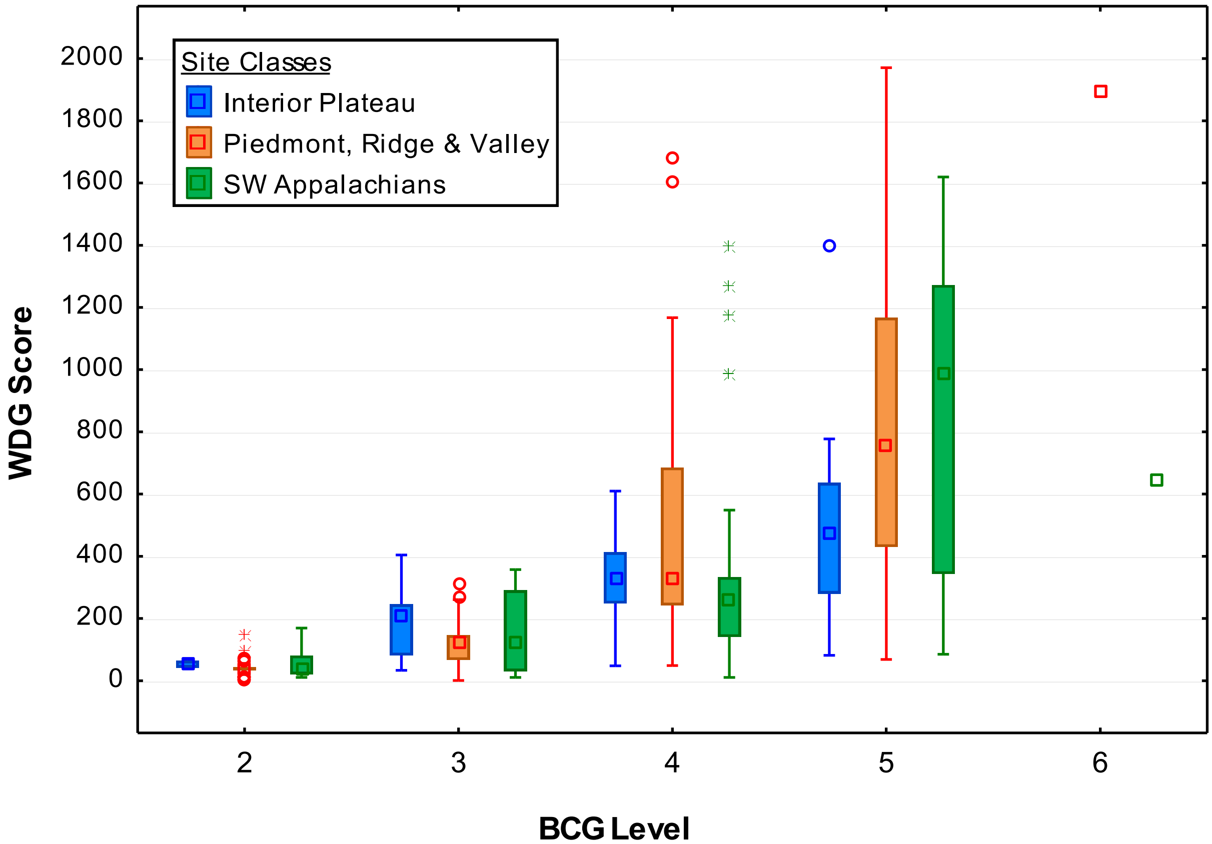


Figure 50. BCG scores and corresponding WDG scores for Northern Alabama. Distributions are based on sites monitored in ADEM's biological assessment program.

6.3.6 Future Applications

With the BCG model now available to characterize multiple levels of biological conditions, goals for protection of high quality waters and for improvements in degraded waters can be better defined. Currently, monitoring, assessment, and restoration focus on the most degraded watersheds throughout Alabama, leaving fewer resources to prevent threatened waters from degrading and becoming listed as impaired. Additionally, because success has typically been defined as a single threshold (i.e., attaining/nonattaining), incremental improvements in water quality and watershed conditions are not effectively measured and documented. Information that conditions are incrementally improving is valuable feedback to management, and stakeholders, including the public. Incremental changes can be observed with a shift in BCG levels or in index values associated with the BCG levels (Figure 51 and Figure 52).

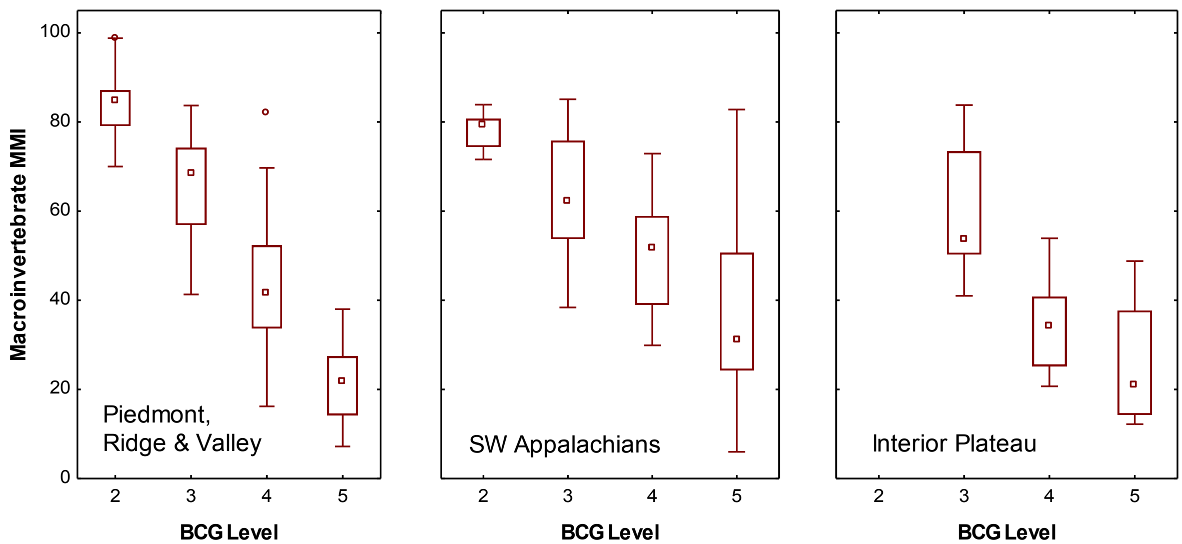


Figure 51. Alabama macroinvertebrate MMI distributions in site classes and BCG levels.

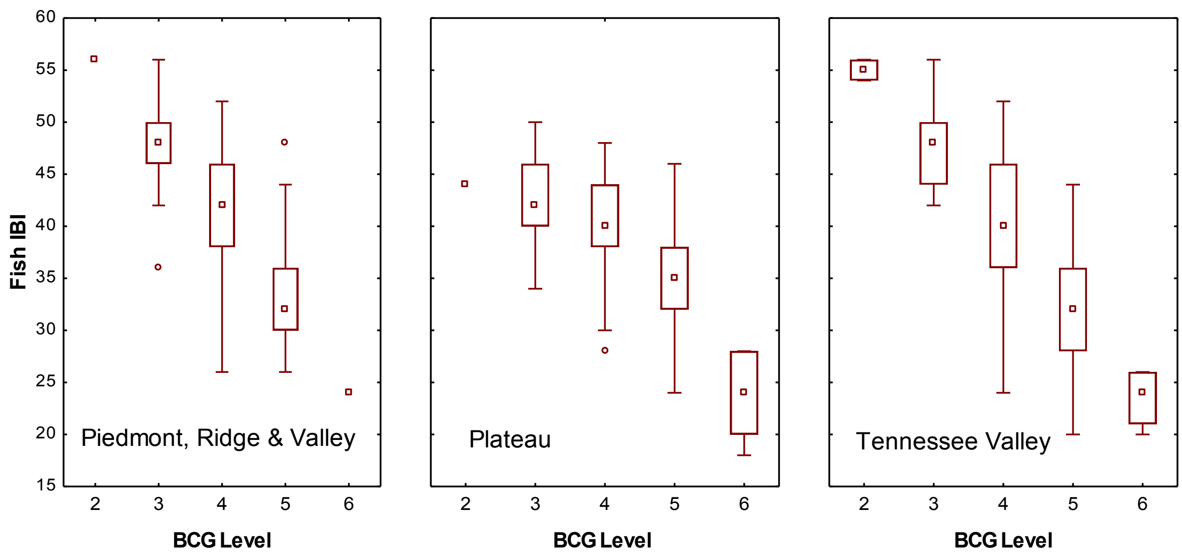


Figure 52. Alabama fish IBI distributions in site classes and BCG levels.

With the BCG, multiple condition levels can be recognized, and each can be associated with different resource status and management goals. For example, sites with BCG level 4, 5, or 6 conditions might be targeted for incremental improvements with interim milestones set based on next BCG level. Streams that score close to the next BCG level could be further prioritized for management actions. Such incremental improvements would document successful management strategies and actions and support adaptive management approaches. For sites supporting BCG level 2 conditions, the management goal might be protection so that the water body continues to support exceptional biological communities. BCG level 2 conditions could be identified using the predictive BCG models and/or the MMI and IBI scores.

As part of its Healthy Watersheds Program,[29] in 2011 EPA acknowledged the need to increase protection of U.S. waters and provided states with a framework and tools. In 2013, ADEM completed the Alabama and Mobile Bay Basin integrated assessment of watershed health (USEPA 2014b). The purpose of this project was to characterize the relative health of catchments across Alabama and the Mobile Bay Basin for the purpose of guiding future initiatives to protect healthy watersheds. The assessment synthesized disparate data sources and types to depict current landscape and aquatic ecosystem conditions throughout the Alabama/Mobile Bay Basin assessment area. The assessment included six distinct, but interrelated attributes of watersheds and the aquatic ecosystems within them, including landscape condition, habitat, hydrology, geomorphology, water quality, and biological condition. A total of 12 indicators were used to characterize the relative health of Alabama's watersheds. By integrating information on multiple ecological attributes at several spatial and temporal scales, it provided a systems perspective on watershed health. To compare the Healthy Watersheds Index (HWI) to BCG assessments, ADEM recalculated the HWI after removing the biological components from the calculation. The comparison showed a clear association between the non-biological HWI scores and the BCG scores (Figure 53). The ranges of HWI scores in each BCG level were similar among site classes, indicating that the BCG reflects differences in watershed integrity despite differences in landscape stressor intensity among site classes.

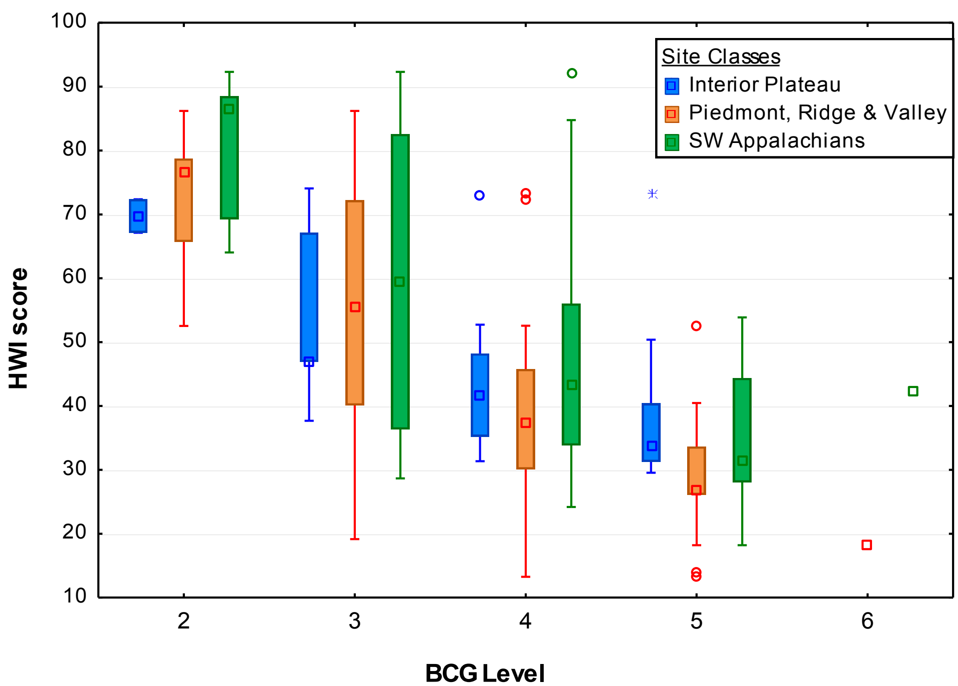


Figure 53. Distributions of Healthy Watershed Index (HWI) scores by macroinvertebrate BCG level and site class.

[29] More information on the Healthy Watersheds Program is available at: http://www.epa.gov/hwp. Accessed February 2016.

The most pervasive changes to watershed condition are predicted to come from population increase (changes in land and water use) and climate change (USEPA 2014b). Watershed vulnerability can be defined as a combination of an ecological system's exposure, sensitivity, and adaptive capacity to cope with changes in population and climate (IPCC 2007). The adaptive capacity of a watershed to cope with such changes is enhanced by connectivity of habitats and maintenance of floodplain, wetland, and other landscape features in their natural conditions to support natural hydrology and sediment supply. Vulnerability was characterized for Alabama watersheds using indicators of projected changes in precipitation, temperature, impervious cover, and water use (USEPA 2014b). Estimates of watershed health and vulnerability combined with the BCG level scores can potentially be used together to inform management decisions and priorities for protection and restoration.

6.3.7 Conclusion

ADEM developed a BCG model to expand the technical capability of its biological monitoring and assessment program, with four key results. First, ADEM has been able to use the BCG to more accurately characterize the quality of reference sites relative to natural conditions (e.g., no or minimal anthropogenic disturbance). Second, in conjunction with biological indices, ADEM has used the BCG as a tool to help identify high quality streams, evaluate recovery potential of degraded streams, propose incremental biological goals for improvements, and track improvements. Third, ADEM is better able to convey to the public and decision makers more detail about the aquatic community to assist both the public and water quality managers in prioritizing areas for protection and restoration.

Finally, ADEM has found that adding fish community assessments to its biological assessment program produces more robust and comprehensive assessments of aquatic life (USEPA 2013a). Fish assessments are the primary biological indicator used to assess the status of threatened and endangered aquatic species within the state. Macroinvertebrate and fish assessments are generally conducted at different sites to make the most of limited resources and enable ADEM and partner agencies to assess biological conditions at more sites throughout the state. The two assemblages are sensitive to different stressors because of differences in the life cycles and motility of fish and benthic macroinvertebrates. The potential for different kinds of stress, the presence of threatened and endangered species, watershed area, and depth are all factors used to determine which assemblage will be assessed at each site. The BCG provides a common interpretive framework for benthic and fish assemblage data so both sets of information could be mapped on a common assessment scale and the information used to inform management decisions.

6.4 Minnesota: More Precisely Defining Aquatic Life Uses and Developing Biological Criteria

6.4.1 Key Message

Most surface waters in Minnesota are protected for aquatic life and recreation to meet the objectives set forth in CWA section 101(a). In the state, there are two primary sub-classes of streams protected for aquatic life, including a cold water stream class (2A) and a warm water stream class (2B). While the current system of beneficial uses and WQS has served Minnesota well, advances in the fields of biological assessment have led to the recognition that among the diversity of water body types there are variable biological conditions. For example, within rivers and streams, factors such as water body size, geographic location, hydrology, water temperature, and stream gradient influence chemical, physical, and biological composition. The Minnesota Pollution Control Agency (MPCA) recognized that effective water quality management requires a more comprehensive approach in which goals for water quality protection are tailored to specific water body types and uses. In response to these challenges, MPCA is proposing to modify its beneficial use framework for aquatic life. The new framework will allow for better goal-setting processes through the application of a framework that recognizes tiers, or levels, of aquatic life-use based on a stream's type and potential. MCPA is using the BCG to describe existing biological conditions and help provide the technical basis for assigning streams to ALU classes.

6.4.2 Background

MPCA's collection of biological water quality information began in the 1960s as part of an effort to monitor the conditions of state waters and since that time the state has developed a robust biological assessment program (USEPA 2013a). Over the past two decades, MPCA has routinely monitored both fish and benthic macroinvertebrates in streams, and, in combination with assessment of chemical and physical parameters, has used this information to assess the integrity of streams (MPCA 2014b). In the mid-1990s MPCA developed IBIs for fish (F-IBI) and benthic macroinvertebrates (M-IBI) to characterize the health of biological communities, identify stressors, select management actions to protect and restore water bodies, and determine how effective management actions are in meeting those goals. The initial IBIs developed were supported by narrative statements in the state's regulatory language that identified how to calculate an IBI. In 2003 and 2004, IBIs were developed for streams in specific basins of the state, and subsequently MPCA developed IBIs that could be applied statewide (MPCA 2014c, 2014d). Both the M-IBI and F-IBI used today are calibrated for a number of stream environments (e.g., large rivers, moderate-sized streams, headwaters, low-gradient streams, and cold water streams) (MPCA 2014c, 2014d). The IBIs for different stream types minimize the effects of natural differences between streams in order to enhance the signal from anthropogenic stressors. For example, the St. Louis River, a large river in northern Minnesota, naturally has a very different fish fauna compared to a small cold water stream in southern Minnesota such as Beaver Creek (Figure 54). Because the fish communities are naturally different in these habitats, IBI models need to be specific to the stream type so that appropriate expectations for healthy communities can be established. Since 2007, MPCA has monitored the state's rivers and lakes using a 10-year rotating watershed approach.

Minnesota's WQS classify state waters according to their designated beneficial uses (e.g., aquatic life, recreation, drinking water), and the state applies chemical, physical, and biological criteria to protect designated uses. Currently, the majority of surface waters in Minnesota are classified as Class 2,

Figure 54. Left: St. Louis River; Right: Beaver Creek.

protection of aquatic life and recreation[30] (i.e., the "General Use" goal). For streams and rivers, class 2 waters are further distinguished as Class 2A (aquatic life cold water habitat) or Class 2B (aquatic life warm water habitat). Despite the application of chemical, physical, and biological criteria, state scientists determined that a single biological threshold does not reflect existing conditions in high quality waters, nor set attainable restoration goals for degraded waters. For example, the West Branch of the Little Knife River (Figure 55) in the Lake Superior drainage in Minnesota supports fish and macroinvertebrate assemblages that would be expected in environments comparable to BCG level 1 or 2. A contrasting example is Judicial Ditch 7 in southeastern Minnesota (Figure 55). Fish and macroinvertebrate assemblages in this stream do not meet the stream's current aquatic life goal, which is estimated to be comparable to BCG level 4, because it is maintained for drainage. The activities associated with maintaining this ditch for drainage remove the habitat necessary to support natural aquatic assemblages and might limit attainment of the designated ALU. A use attainment analysis (UAA) will support determination of the highest attainable use for these types of streams, and the BCG could provide the basis for setting incremental restoration targets and tracking improvements.

Figure 55. Left: West Branch Little Knife River; Right: Judicial Ditch 7.

[30] A full definition of *Class 2 water* can be found in Minnesota Administrative Rule 7050.0140, Subp. 3. https://www.revisor.leg.state.mn.us/rules/?id=7050.0140. Accessed February 2016.

6.4.3 Tiered Aquatic Life Uses and Biological Criteria Development

Over the past ten years, state scientists have sought an approach that would capitalize on the state's wealth of biological monitoring data and more specifically define the ALUs of rivers and streams in Minnesota. MPCA is revising the state WQS to more accurately designate ALUs and establish multiple levels (or goals) for aquatic life conditions in the WQS (in Minnesota this is known as the tiered aquatic life use (TALU) framework). Using this framework, Minnesota is proposing to classify rivers and streams based on the best attainable biological condition for a water body. The state is also proposing to subcategorize its designated ALU categories to best reflect a stream or river's current conditions and its ecological potential. This approach requires knowledge of the current condition of water bodies and the stressors affecting them (MPCA 2012). In order to develop TALUs and associated biological criteria, MPCA has capitalized on a variety of past work, including stream classification, IBI development, an HDS, and the BCG (MPCA 2014b). The BCG was used to interpret current conditions and set expectations for biological communities across the state. IBIs are used to determine the biological conditions of state rivers and streams and to determine which ALU best describes the highest attainable biological conditions in a specific water body.

MPCA's application of TALUs will subdivide Class 2 streams into three designated use class tiers (MPCA 2014e):

- Exceptional uses—"High quality waters with fish and invertebrate communities at or near undisturbed conditions."
- General uses—"Waters with good fish and invertebrate communities that meet minimum restoration goals."
- Modified uses—"Waters with legally altered habitat that prevents fish and invertebrate communities from meeting minimum goals."

For each designated use class tier, MPCA has developed biological criteria using biological, chemical, physical, and land use data collected during the 1995–2010 period. MPCA used a multiple lines of evidence approach that included use of the BCG and the reference condition.

In order to identify reference streams, MPCA first calculated an HDS, an index that measures the degree of human activity upstream of and within a stream. MPCA defined stream reference sites as those with an HDS score of 61 or greater; this is a defined least disturbed condition (the upper 25% of the HDS distribution). The reference streams are least influenced by stressors within the context of the current landscape condition of Minnesota (Stoddard et al. 2006), as far as practical from urban areas, point sources, feedlots, and other sources. MPCA also identified a subset of reference streams that satisfied "minimally disturbed" in the northern part of the state where widespread and long-term human disturbance is much less than in the south. MPCA compared the IBI scores for reference and non-reference sites. While MPCA identified some concerns with applicability of the reference condition approach in southern Minnesota due to widespread, high levels of land use and development, the agency determined that reference data sets were sufficient to develop biological criteria in the northern regions and in cold water classes (MPCA 2014b). Reference conditions for the southern region might require an alternate approach to more precisely characterize least disturbed conditions.

During 2009–2012, expert panels were assembled to develop BCG models for both macroinvertebrate and fish assemblages (Gerritsen et al. 2013). The conceptual BCG model (Davies and Jackson 2006) was calibrated by these expert panels using regional data for each of the two assemblages. The narrative descriptions for the different BCG condition levels were used by MPCA to describe each of the three designated use class tiers proposed in the revision to its WQS regulation:[31]

- Exceptional Use—"Evident changes in structure due to loss of some rare native taxa; shifts in relative abundance; ecosystem level functions fully maintained."
- General Use—"Overall balanced distribution of all expected major groups; ecosystem functions largely maintained through redundant attributes."
- Modified Use—"Sensitive taxa markedly diminished; conspicuously unbalanced distribution of major taxonomic groups; ecosystem function shows reduced complexity & redundancy."

The MPCA expert panels characterized and calibrated the BCG for both benthic macroinvertebrates and fish for seven classes of warm water streams and two classes of cold and coolwater streams. A summary of the narrative rules includes:

- Taxa richness declined from BCG level 1 to level 6. All level 1 sites were large water bodies (rivers), and might be more influenced by size than by condition
- Attribute I taxa were characteristic of BCG level 1, occurred occasionally in BCG level 2, and were generally absent in levels 3–6
- All sensitive taxa (attributes I, II, and III combined) are common and abundant in levels 1 and 2, somewhat reduced in level 3, decline markedly in level 4, and have almost disappeared from levels 5 and 6.
- Intermediate taxa (attribute IV) are nearly constant throughout the gradient, but are reduced in level 6.
- MPCA divided the tolerant fish category into two: tolerant taxa (attribute V), and highly tolerant taxa (attribute V-a), as well as highly tolerant nonnative (attribute VI-a). The highly tolerant subgroups increased in abundance, dominance and variability at BCG levels 4 to 6, although the natives are represented at all levels.

An example of quantitative BCG rules derived for fish in the two river classes is shown in Table 34.

[31] Information about Minnesota's WQS process is available at: http://www.pca.state.mn.us/index.php/water/water-permits-and-rules/water-quality-standards.html. Accessed February 2016.

Table 34. Decision rules for fish assemblages in two classes of Minnesota rivers. Rules show the ranges of fuzzy membership functions. N indicates the number of sites for a given BCG level and stream class in the calibration data set.

Metric	Prairie Rivers	Northern Forest Rivers	
BCG Level 1	N=2	N=3	
Total taxa	> 25–35	> 16–24	
Endemic taxa (Att I)	Present	Present	
Att I+II taxa	> 2–5	> 1–2	
Att I+II+III % taxa	> 45%–55%	> 35%–45%	
Att I+II+III % ind	> 25%–35%	> 45%–55%	
Att Va or VIa Dominance		< 7%–13%	
Tolerant % ind (V + Va + VIa)	< 3%–7%		
Highly tol % ind (Va + VIa)		< 7%–13%	
BCG Level 2	N=6	N=15	
Total taxa	> 16–24	> 6–10	
Att I+II taxa	Present	-	
Att I+II+III % taxa	> 35%–45%	> 25%–35%	
Att I+II+III % Ind	> 15%–25%	> 25%–35%	
Att Va or VIa Dominance		< 7%–13%	
Highly tol % ind (Va + VIa)	< 7%–13%	< 7%–13%	
BCG Level 3	N=25	N=11	
Total taxa	> 11–16	> 6–10	
Att I+II+III % taxa	> 15%–25%	> 15%–25%	
Att I+II+III % Ind	> 7%–13%	> 7%–13%	
Tol % ind (V + Va + VIa)	-	< 25%–35%	
Att Va or VIa Dominance	< 7%–13%	< 10%–20%	
Highly tol % ind (Va + VIa)	< 25%–35%	-	
BCG Level 4	N=31	N=16	
		Alt 1	**Alt 2**
Total taxa	> 11–16	> 6–10	= alt 1[1]
Att I+II+III % taxa	10%–20%	> 15%–25%	> 7%–13%
Att I+ II+III % Ind	0%–1%	> 3%–7%	present
I+II+III+IV % Ind			
Att Va or VIa Dominance	< 35%–45%	< 25%–35%	= alt 1[1]
Tol % ind (V + Va + VIa)		n/a	< 30%–40%
Highly Tol % ind (Va + VIa)	< 45%–55%	< 35%–45%	= alt 1[1]
BCG Level 5	N=12	N=2	
Total taxa	> 11–16	6–10	
Att I+II+III+4 % Taxa			
Att Va or VIa Dominance	< 65%–75%	< 35%–45%	
Highly tol % ind (Va + VIa)		< 55%–65%	
BCG Level 6 (no rules)	N=1	N=0	

[1] "= alt 1" the rule is the same as given under Alt 1 for this metric

MPCA then calibrated the BCG with the state's index for biological assessment of Minnesota's warm water and cold water streams for both the fish and macroinvertebrate assemblages (Figure 56). MPCA has used this information to develop draft numeric biological criteria that would be applied to each designated use class tier—thus directly linking the ALU goal with the state's assessment method (Figure 57). In December 2015, MPCA held a formal public comment period on a proposed revision to the state WQS that would include TALUs.

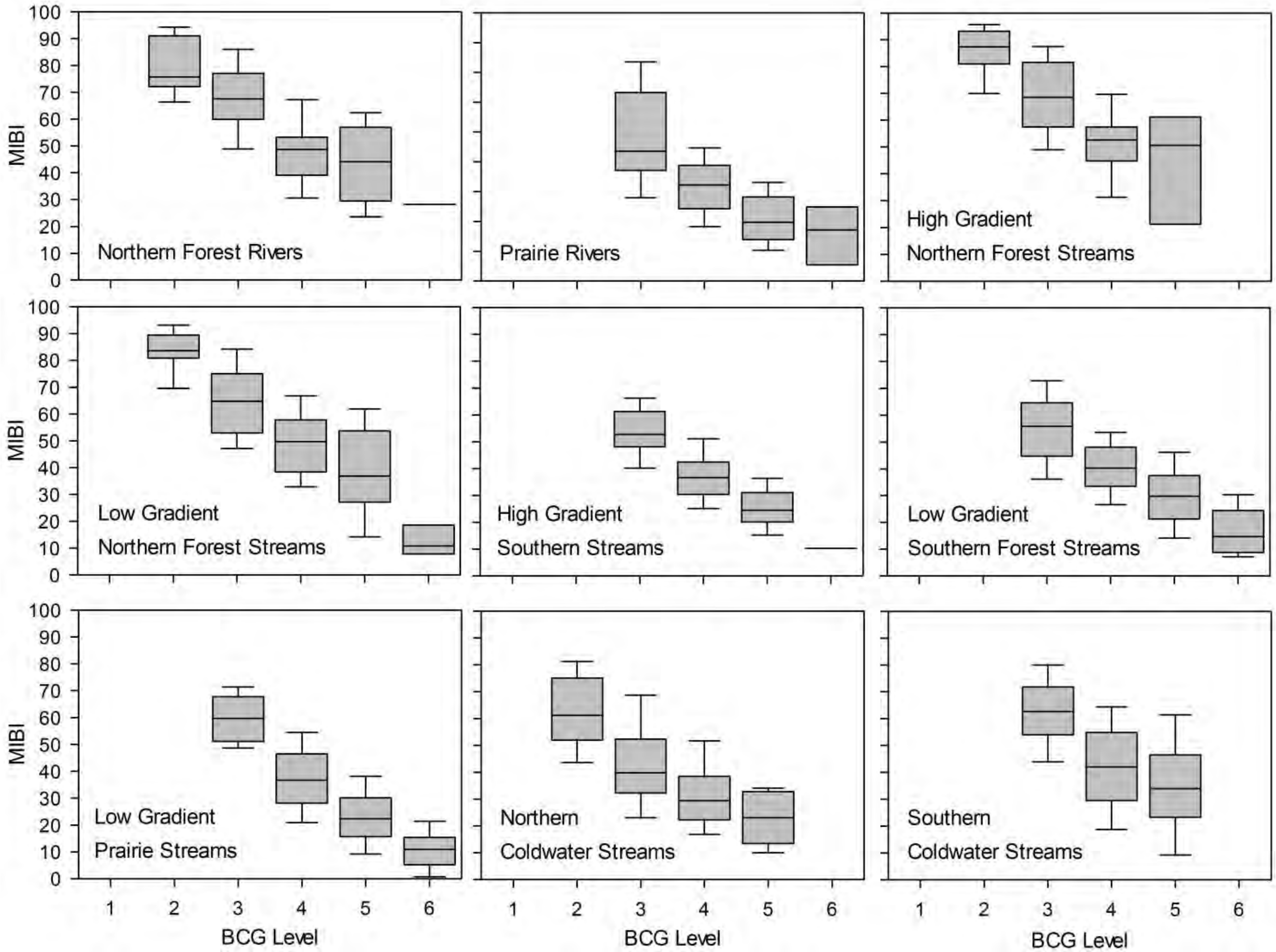


Figure 56. Frequency distributions of IBI scores by BCG level for macroinvertebrate stream types using data from natural channel streams sampled 1996–2011. Symbols: upper and lower bounds of box = 75th and 25th percentiles, middle bar in box = 50th percentile, upper and lower whisker caps = 90th and 10th percentiles. MPCA also did a calibration of fish index scores with BCG levels assigned to sites.

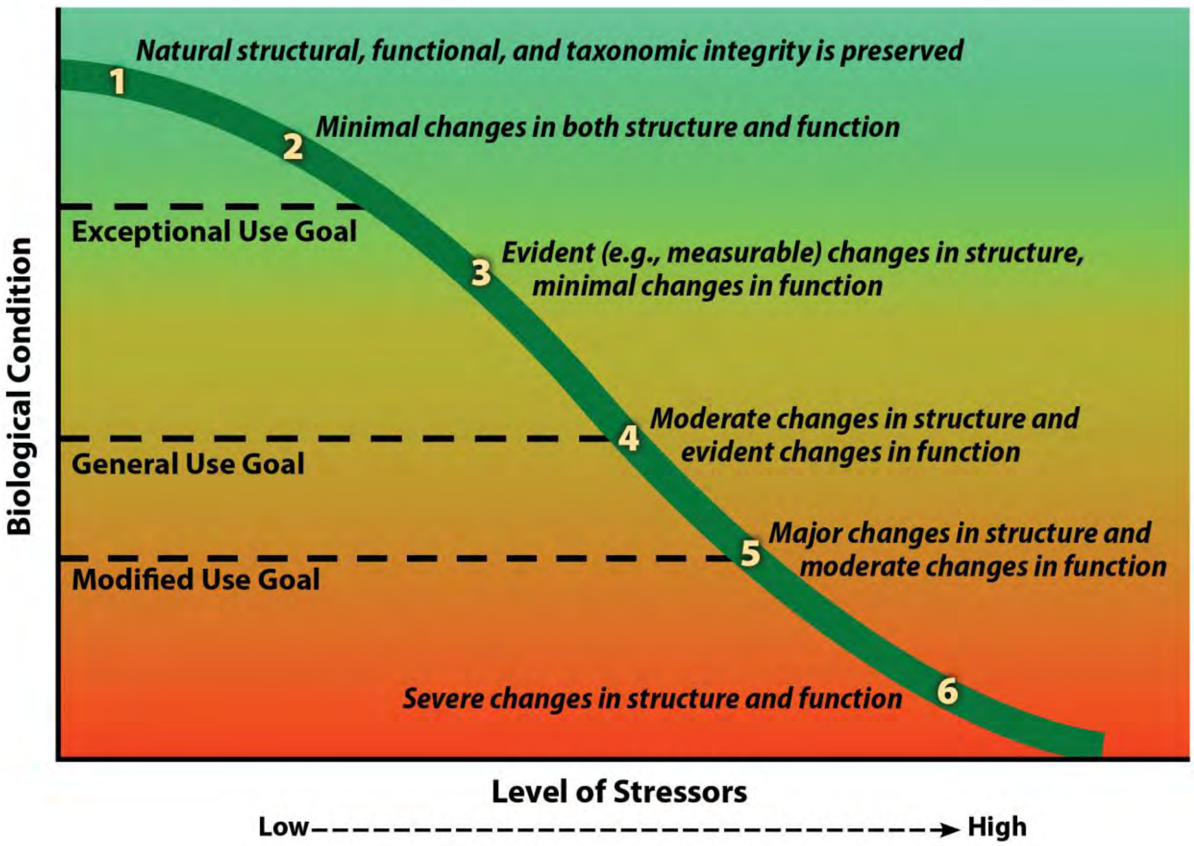


Figure 57. BCG illustrating the location of proposed biological criteria (black dotted line) for protection of Minnesota's TALU goals (Exceptional, General, Modified) (Source: MPCA 2014b).

6.4.4 Benefits of the Biological Condition Gradient

Because the BCG provides a common framework to interpret changes in biological condition regardless of geography or water resource type, Minnesota will be able to make more accurate determinations and classifications of its aquatic resources on a statewide basis. The state will be in position to make decisions on aquatic life designations based on robust and detailed ecological data and information. Another advantage of the BCG is that it provides a means to communicate with the public about existing conditions and potential for improvement for specific water bodies. BCGs were developed for each of Minnesota's aquatic resource classes for streams (e.g., cold water and warm water streams). The development of warm water BCG models involved input from biological experts familiar with biological communities in Minnesota from the MPCA and Minnesota Department of Natural Resources. BCG models were developed for fish and macroinvertebrates for each of the seven warm water stream classes. A cold water BCG involved experts from Minnesota, Wisconsin, Michigan, and several tribes located in those states. In Minnesota this effort included two classes each for fish and macroinvertebrates. Model development for each class involved reviewing biological community data from monitoring sites and then assigning that community to a BCG level. A sufficient number of samples were assessed to develop a model that can duplicate the panel's BCG level assignments. Using the BCG and reference conditions permits MPCA to provide more detailed descriptions of the expected biota for each ALU and to develop biological criteria that are protective, consistent, and attainable across the state (MPCA 2012). These accomplishments will help Minnesota achieve several key goals described below.

Refinement of Biological Standards

Numeric water quality criteria that are codified in the Minnesota WQS are currently based on chemical and physical criteria such as DO, temperature, and pH. These criteria do not directly measure the condition of biological communities that include fish, insects, mussels, aquatic plants, and algae. Biological communities can be monitored as a direct measure of the response of the biota to a wide range of physical and chemical stressors and provide a quantitative measure of the cumulative and synergistic impacts of multiple stressors over time. A major goal of Minnesota's water quality management program is to protect the fish, invertebrates, and other aquatic organisms in the state's waters. Therefore, it is sensible that a direct measurement of these communities is used to monitor their condition.

Ability to Address Natural Variation

One of the strengths of Minnesota's approach is the ability to address the natural variation in water resources across the state. Minnesota's diverse water resources mean that refined biological monitoring tools are needed to reduce errors in assessment and management. For example, streams along the shore of Lake Superior in northern Minnesota are very different from streams in southern Minnesota such that, under natural conditions, the biological communities in streams in each location are expected to be different. The Minnesota BCG framework takes into account these natural differences and requires that comparisons be made between streams with naturally similar biological communities. As the state's database is built through long term monitoring, Minnesota will be able to define current, or baseline, conditions and be in a better position to discern shifts in species composition and structure due to climate change impacts.

Identification of Reference Condition Quality

The biological monitoring program in Minnesota relies on BCG models and the reference condition approach to set expectations for water bodies. The BCG provides a common "yardstick" of biological condition that is rooted in the natural condition. As a result, the BCG can be used to develop biological criteria that are consistent across regions and stream types in Minnesota—particularly important for a state where the range of existing quality is regionally distinct and extreme (i.e., undisturbed to highly disturbed conditions). The reference condition approach identifies water bodies that are least disturbed and uses them to establish the reference condition. Once this reference condition has been established, water bodies with unknown condition can be compared to this baseline. If the condition of the water body is lower than that of the reference condition, it would be considered impacted or stressed. The use of a reference condition relies on the development of accurate expectations for least disturbed sites. The BCG provides a framework for assessing the quality of reference sites relative to undisturbed conditions and can be used to interpret the quality of reference sites, including reference sites in regions where the least disturbed conditions include sites with moderate to higher levels of stress. In these regions, such as in southern Minnesota, the BCG was used to help develop protective ALU goals (MPCA 2014b, 2014e).

Protection of High Quality Water Resources

Minnesota's classification framework and BCGs will be applied in conjunction with another element of states' antidegradation policy. This policy requires:

- Maintenance of existing uses;
- Prevention of degradation of water quality that exceeds levels necessary to support the protection and propagation of aquatic life and recreation unless the state finds that lowering of

water quality is necessary to accommodate important economic or social development (Tier 2 protection); and

- Maintenance of water quality needed to protect outstanding resource waters (Tier 3 protection).

Minnesota is planning to propose a higher tier of ALU (i.e., exceptional use goal) to protect high quality biological communities. Once it has been established that a water body is meeting the requirements associated with an exceptional water resource, the resource needs to be protected to maintain that status. The BCG provides a framework with which to identify candidate high quality streams and rivers for designation as exceptional resources.

Setting Expectations for Modified Water Resources

There are water resources in Minnesota that will not in the near future meet the CWA interim goals due to historical or legacy impacts. These legacy impacts include streams under drainage maintenance or other irreversible hydromodification that preclude attainment of water body goals (e.g., channelized streams and ditches). The BCG provides a framework to monitor and help set realistic expectations for waters that are unlikely to meet ALU goals due to legacy impacts and have been designated as modified water resources. Additionally, as conditions improve, the BCG provides a framework to document and acknowledge these improvements to reflect existing conditions.

6.4.5 Conclusion

In conjunction with numeric biological indices developed for macroinvertebrates, the BCG allows Minnesota to set consistent and protective ALU goals and numeric biological criteria across the state despite the heterogeneity of its water bodies. This heterogeneity is due both to natural conditions and human disturbance, and the BCG provides a framework to characterize and communicate these differences. The BCG described in this case study is applicable to streams and wadeable rivers. Minnesota is currently developing a BCG and biological criteria for lakes using fish assemblage information.

6.5 Maine: Development of Condition Classes and Biological Criteria to Support Water Quality Management Decision Making

6.5.1 Key Message

Clear, technically rigorous goal statements have provided Maine with an effective framework to improve biological condition of streams and rivers. Maine has established four ALU classes (Classes AA/A/B/C) with different ecological expectations. The classes span the range from Maine's interpretation of the CWA interim goal to the ultimate CWA objective "to restore and maintain chemical, physical and biological integrity" (Class AA/A). All rivers and streams in Maine are assigned to one of the four classes in Maine's WQS for planning and management purposes. These TALUs and numeric biological criteria have enabled Maine to inject critical biological information into all aspects of water quality management. Along with the practical experience and scientific advancements demonstrated by other states with strong biological assessment programs, Maine's approach to classification and biological criteria development provided the template for the conceptual BCG (Davies and Jackson 2006). In turn, Maine continues to strengthen and develop its biological assessment program to address other water bodies and include measures of the algal communities in its assessments. The BCG is being incorporated as part of its "toolbox" to accomplish these tasks.

6.5.2 Background

Since the 1960s, prior to adoption of the CWA, Maine water quality law has had a tiered structure based on observations of gradients of water quality conditions. In 1986, Maine revised its water classification law and added TALUs to maintain and restore the structure, function, and biological integrity of aquatic life communities. Maine's TALUs were based on concepts of John Cairns, H.T. Odum, and others who observed declines in biological condition in response to gradients of increasing stressors (Ballentine and Guarraia 1977; Odum et al. 1979, Cairns et al. 1993; Karr and Chu 2000). The four narrative TALU standards in Maine's water classification law describe conditions across a biological gradient ranging from "as naturally occurs" (Classes AA and A) to "maintenance of structure and function" (Class C). Class C is the lowest ALU designation allowed in the state and consistent with Maine's interpretation of the CWA fishable/swimmable interim goal (Table 35; M.R.S.A Title 38 Article 4-A § 464-466). Maine's TALUs for fresh surface waters apply to streams, rivers, and wetlands. Maine has similar TALUs for coastal marine waters (SA, SB, SC). Maine has established a single class for lakes that is equivalent to Class A. Maine's TALUs are based on tiers of biological condition along observed human disturbance gradients. Such stressor-response relationships are also the foundation of the later development of the BCG.

Maine's TALUs are supported by ecologically-based definitions in the law. The narrative definitions in Maine law establish the biological characteristics that are required to attain the standards of each class (Table 35). Class AA and Class A have the same "*as naturally occurs*" aquatic life goals and will hereafter be referred to as Class AA/A; Class AA is more restrictive in allowable permitted activities. For example, no dams or discharges are allowed in Class AA waters. Maine's assessed streams and rivers are predominantly classified as either Class AA/A or B waters, 48.6% and 51%, respectively. Class A/AA waters have been interpreted by Maine as comparable to BCG levels 1 and 2 and class B waters are equivalent to BCG level 3. Less than 1% of Maine's streams and rivers are classified as Class C waters, which have been deemed as comparable to BCG level 4. These waters are primarily in urbanizing areas or downstream of significant point sources. Figure 58 summarizes relationships between Maine's narrative biological, chemical, and physical standards and shows Maine's TALUs in relation to the BCG.

Table 35. Criteria for Maine river and stream classifications and relationship to antidegradation policy

Class	DO criteria	Bacteria criteria	Habitat narrative criteria	Aquatic life narrative criteria*** and management limitations/restrictions	2012 Percentage of Maine waters designated in class ****	Corresponding federal antidegradation policy tiers
AA	As naturally occurs	As naturally occurs	Free-flowing and natural	As naturally occurs**; no direct discharge of pollutants; no dams or other flow obstructions.	3.6%	3 (Outstanding National Resource Water [ONRW])
A	7 ppm; 75% saturation	As naturally occurs	Natural**	Discharges permitted only if the discharged effluent is of equal to or better quality than the existing quality of the receiving water; before issuing a discharge permit the Department shall require the applicant to objectively demonstrate to the department's satisfaction that the discharge is necessary and that there are no reasonable alternatives available. Discharges into waters of this class licensed before 1/1/1986 are allowed to continue only until practical alternatives exist.	45%	2 ½
B	7 ppm; 75% saturation	64/100 mg (g.m.) or 236/100 ml (inst.)*	Unimpaired**	Discharges shall not cause adverse impact to aquatic life** in that the receiving waters shall be of sufficient quality to support all aquatic species indigenous** to the receiving water without detrimental changes to the resident biological community.**	51%	2 to 2 ½
C	5 ppm; 60% saturation; and 6.5 ppm (monthly avg.) when temperature is ≤ 24 °C	125/100 mg (g.m.) or 236/100 (inst.)*	Habitat for fish and other aquatic life	Discharges may cause some changes to aquatic life**, provided that the receiving waters shall be of sufficient quality to support all species of fish indigenous** to the receiving waters and maintain the structure** and function** of the resident biological community. **	0.4%	1 to 2

Source: Maine DEP (modified). http://www.maine.gov/dep/water/monitoring/classification/index.html. Accessed February 2016.
Notes:
* g.m. = geometric mean; inst. = instantaneous level.
** Terms are defined by statute (Maine Revised Statutes Title 38, §466).
*** Numeric biological criteria in Maine regulation Chapter 579, Classification Attainment Evaluation Using Biological Criteria for Rivers and Streams http://www.maine.gov/dep/water/rules/index.html. Accessed February 2016.
**** Source: 2012 Maine Integrated Water Quality Report, http://www.maine.gov/dep/water/monitoring/305b/2012/report-final.pdf. Accessed February 2016.

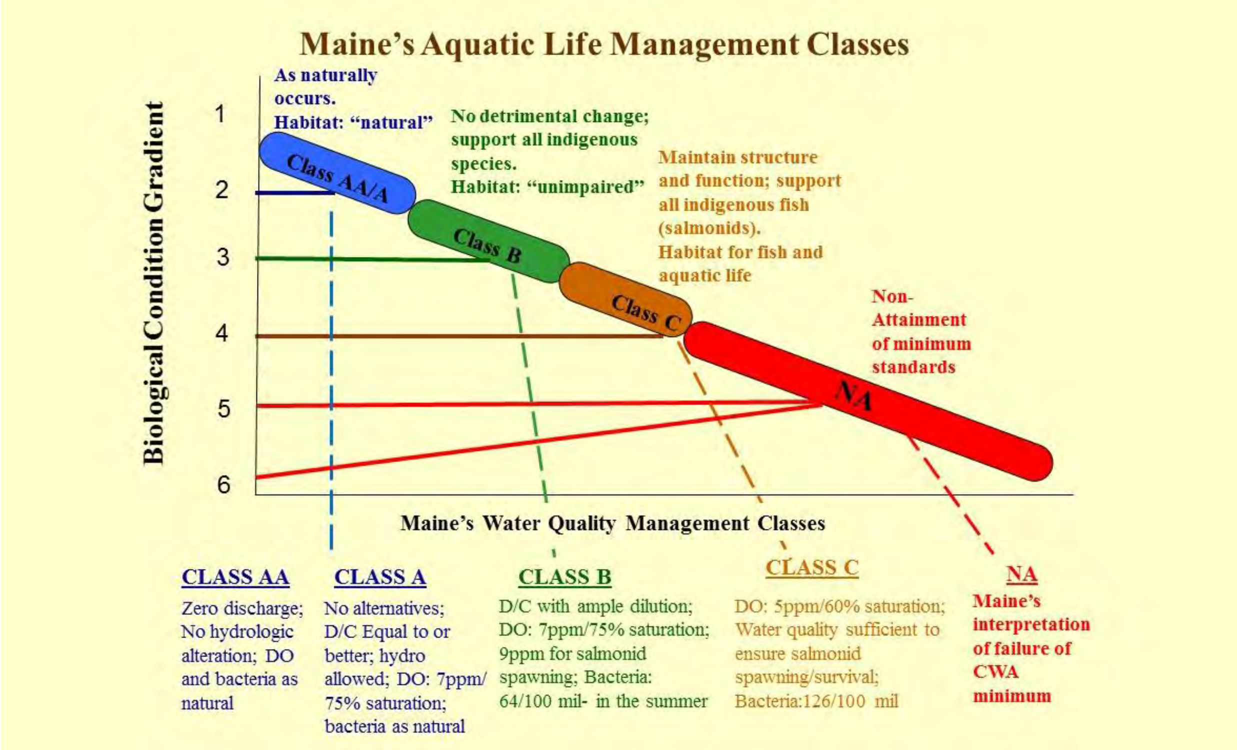


Figure 58. Relation between Maine TALUs, the BCG, and Maine's other water quality standards and criteria. Class AA/A is approximately equivalent to BCG levels 1 and 2. Classes B and C approximate BCG levels 3 and 4, respectively. Non-attainment conditions below Class C are approximately equivalent to BCG levels 5 and 6.

6.5.3 Maine's Numeric Biological Criteria and Tiered Aquatic Life Uses

In 2003, Maine adopted numeric biological criteria in rule for rivers and streams, based on assessment of benthic macroinvertebrates (State of Maine 2003; Shelton and Blocksom 2004; Davies et al. In press). Technical details describing development of the statistical biological criteria models are found in Chapter 4 of this document and in Davies et al. (In press). In short, MEDEP utilized expert consensus to establish four *a priori* groups corresponding to Maine's TALUs, and developed and tested a linear discriminant model (LDM) to predict the probability of a sample attaining ALU goal conditions (Class AA/A, Class B, and Class C). The fourth group, termed "non-attainment" (NA) represents samples that are in poorer condition than Class C. The LDM and accompanying provisions for application are codified in rule and constitute Maine's numeric biological criteria.[32] When confirmed (e.g., by re-sampling and review of data results) that a stream reach fails to attain its assigned water quality goal, the water body segment is listed as impaired on the state's 303(d) list (Table 36). State law requires that water bodies be considered for upgrade to a higher class if they are found to be consistently attaining the standards of that higher classification.

[32] http://www.maine.gov/dep/water/rules/index.html. Accessed February 2016.

Table 36. Examples of how numeric biological criteria results determine whether or not a water body attains designated ALUs in Maine

Legislative Class	Monitoring Result	Attains Class?	Next Step
A	A	Yes	--
C	B	Yes	Review for upgrade
A	B	No	303(d) list as impaired if confirmed
B	NA	No	303(d) list as impaired if confirmed

MEDEP also conducts biological assessments of stream algal, wetland macroinvertebrate, and wetland phytoplankton and epiphytic algal assemblages (Danielson et al. 2011, 2012). MDEP used Maine's narrative biological criteria and the BCG as the foundation of biological assessment models for stream algae and wetland macroinvertebrates. A first step in model-building was to empirically compute tolerance values for algal and macroinvertebrate species that had been collected in Maine's monitoring program. After computing tolerance values, the species were grouped into the BCG framework's sensitive, intermediate, and tolerant attribute groups. MEDEP then modified the BCG framework for stream macroinvertebrates for stream algae and wetland macroinvertebrates, describing how those assemblages empirically respond to anthropogenic stressor gradients. MEDEP used the BCG and tolerance metrics along with the narrative biological criteria and other metrics to build predictive biological assessment models for the additional assemblages. MEDEP has completed LDM statistical models to predict TALU attainment for both stream algal and wetland macroinvertebrate community data. These models currently are used to help interpret narrative biological criteria. Following adequate testing and standard public review protocols, MEDEP intends to amend the Maine Biological Criteria Rule[33] to include the stream algal and wetland macroinvertebrate models as numeric biological criteria.

In summary, numeric biological assessment models, when codified in the MEDEP biological criteria rule (as for stream macroinvertebrates), or when used as an objective corroboration of expert judgment (as for stream algae and wetlands), provide a transparent and standardized quantitative means for determining attainment of TALUs in Maine WQS. Numeric biological criteria have enabled Maine to use biological information to support multiple water quality management information needs and decision making. Examples of applications follow.

6.5.4 Goal-based Management Planning to Optimize Aquatic Life Conditions

As described in section 6.5.2, the Maine State Legislature revised Maine's WQS and classification law in 1986 (M.R.S.A Title 38 Article 4-A § 464-466) establishing narrative biological criteria for four ALU classes for rivers and streams. This law set in motion a process involving the public, the state environmental agency, and the Maine legislature to assign all Maine waters to an appropriate goal classification. All available monitoring data and information about then-current biological and/or water quality conditions were used to initially propose the statutory classes for stream and river segments for the 1986 law. Many waters that lacked current monitoring data retained their previous water quality goals (generally Class B, except for some urban or industrialized areas, which were Class C) until monitoring data or other evidence was found to recommend a different (and in most cases higher) class.

[33] See Code of Maine Rules, MEDEP, Chapter 579, http://www.maine.gov/dep/water/rules/index.html. Accessed February 2016.

Maps spanning the period between 1987 (Figure 59) and 2012 (Figure 60) show the past and present distribution of water quality classifications. Approximately 99% of Maine's rivers and streams have been designated for classes of protection equal to or higher than Maine's interpretation of the CWA Interim Goal (i.e., Class C). Reclassification upgrades have been implemented with strong public and legislative support. The state has designated water bodies into higher classes to protect waters currently demonstrating high quality and to retain improvements in lower quality waters that had been restored to higher conditions due to wastewater treatment successes. During the nearly three decades since 1987, the Maine State Legislature has assigned 13,955 river and stream miles to a Class A or Class AA management goal, an increase of 25.5%[34]. Numeric biological criteria and articulation of the gradient of aquatic life management classes facilitated the recognition of both the presence of high quality waters and improvements in condition due to remediation. As shown in Figures 21 and 22, these classification upgrades have mostly been drawn from Class B and Class C waters where biological monitoring data demonstrated either the potential, or the actual achievement of the standards of Class A or Class AA. Without their ALU classification approach, TALUs, and criteria, these gains in condition would likely have gone un-detected and unprotected. Additionally, the state's ecologically descriptive condition classes have enhanced public understanding of existing conditions, problems, and restorable target conditions. They provide an important tool in building public and stakeholder support for the often substantial investment that is required to restore aquatic resources.

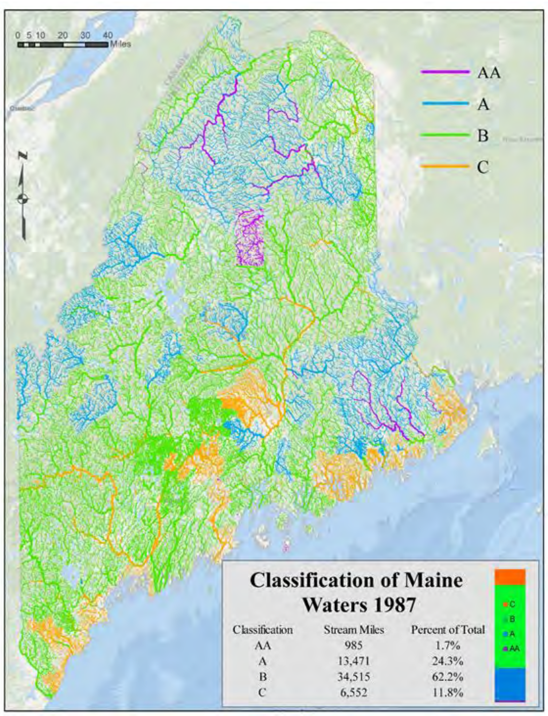


Figure 59. Distribution of Maine water quality classifications in 1987 prior to WQS revisions.

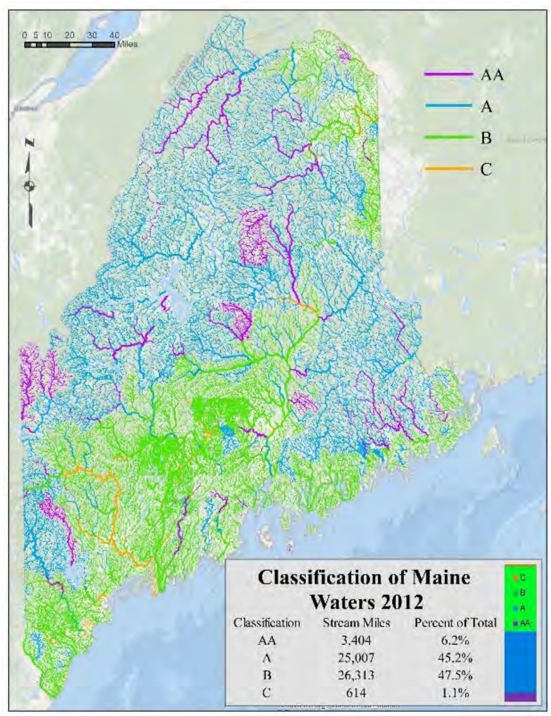


Figure 60. Distribution of Maine water quality classifications in 2012 following 25 years of water quality improvements and classification upgrades.

[34] See State of Maine Water Quality Standards Docket, http://www.maine.gov/dep/water/wqs/docket/index.html (Accessed February 2016) and USEPA, State Tribal and Territorial Standards http://water.epa.gov/scitech/swguidance/standards/wqslibrary/me_index.cfm (Accessed February 2016).

6.5.5 Early Detection and Management of an Emerging Problem

When Maine's Biological Monitoring Program was initiated, a primary concern was management of point source discharges. Implementation of Best Available Technology for point sources eliminated many of these causes of biological impairment with the result that the aquatic life in receiving waters throughout the State rebounded to significantly improved conditions (Davies et al. 1999; Davies et al. In press). More recently, however, biological assessment of smaller streams has revealed impairment caused by changes in physical stream conditions (e.g., increased impervious surfaces in the watershed, hydrologic and stream channel shape alteration). Chemical assessments in these smaller streams have documented increased nutrients and toxic constituent concentrations, salt runoff, increased temperature, and decreased DO.

In 2006, Maine became one of the first states to issue TMDLs based on the percent of a stream watershed covered by impervious surfaces such as roads and parking lots (% IC) (Meidel and MEDEP 2006a, 2006b). Narrative and numeric biological criteria in Maine's WQS were used as the TMDL end point, goal, and ultimate numeric water quality compliance measure for the impaired portions of the streams in order to address non-attainment of ALUs. The restoration pathway described in the TMDL focused on realistic approaches to minimizing the biological, physical, and chemical *effects* of impervious cover, rather than direct elimination of IC. Expanding on the success of the 2006 % IC TMDL, in 2012, MEDEP completed a statewide % IC TMDL for 30 urban impaired streams and 5 associated wetlands (MEDEP 2012). As in 2006, the 2012 TMDL also included aquatic life restoration targets based on the relationship of % IC in the stream watersheds and target improvements in macroinvertebrate community condition.

In 2015, MEDEP conducted a fine-scale geospatial analysis of % IC in watersheds upstream of algal and macroinvertebrate biological assessment sites and determined attainment of TALU for each assemblage at those sites (Danielson et al. In press). Watershed % IC estimates were computed in ArcMap with 1-meter, high-resolution spatial data from 2004 and 2007. Results, shown in Figure 61, revealed that in general, streams become vulnerable to no longer attaining Class AA/A biological criteria when % IC in upstream watersheds is in the range of 1%–3% IC. The risk of not attaining Class B biological criteria increases in the range of 3%–6% IC. Finally, the transition from low risk to high risk of attaining Class C criteria is in the range of 10%–15% IC.

The % IC study revealed that small streams are at risk of impairment at lower levels of watershed % IC than previously recognized. Recognizing the difficulty, expense, and extended lag times associated with urban stream restoration, environmental managers and urban planners in Maine increasingly realize the importance and cost-effectiveness of *preventing* impairment of urban streams. TALU and BCG concepts, along with rigorous biological assessment data, helped MDEP raise awareness about the vulnerability of biological assemblages to urbanization and other human-caused stressors. This information is used in Maine at both the state and local level to inform water quality management decisions and local land use planning and design of development.

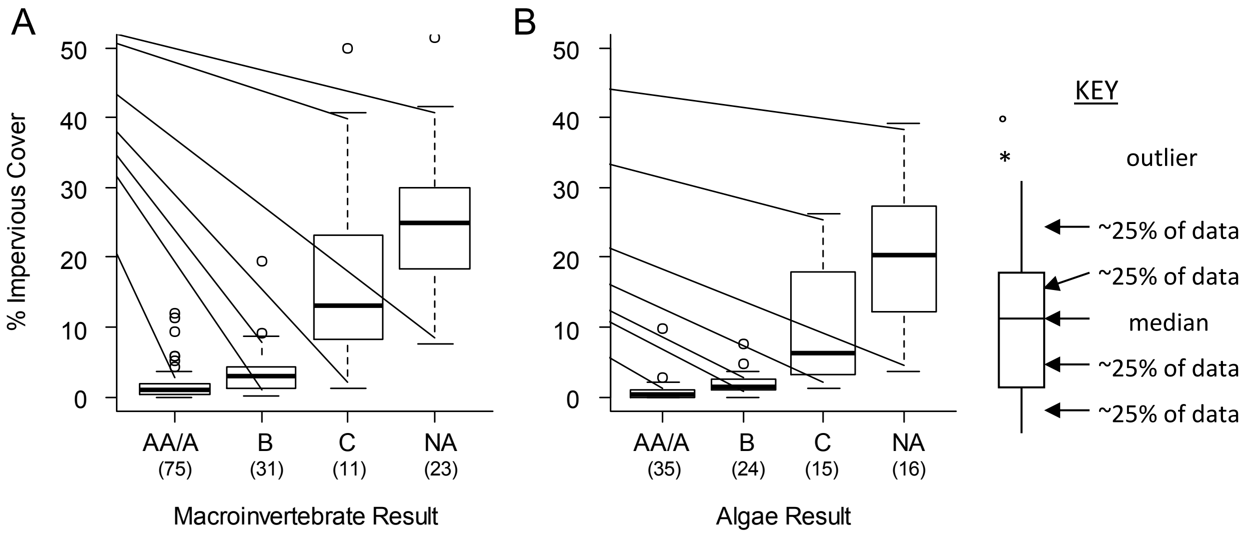
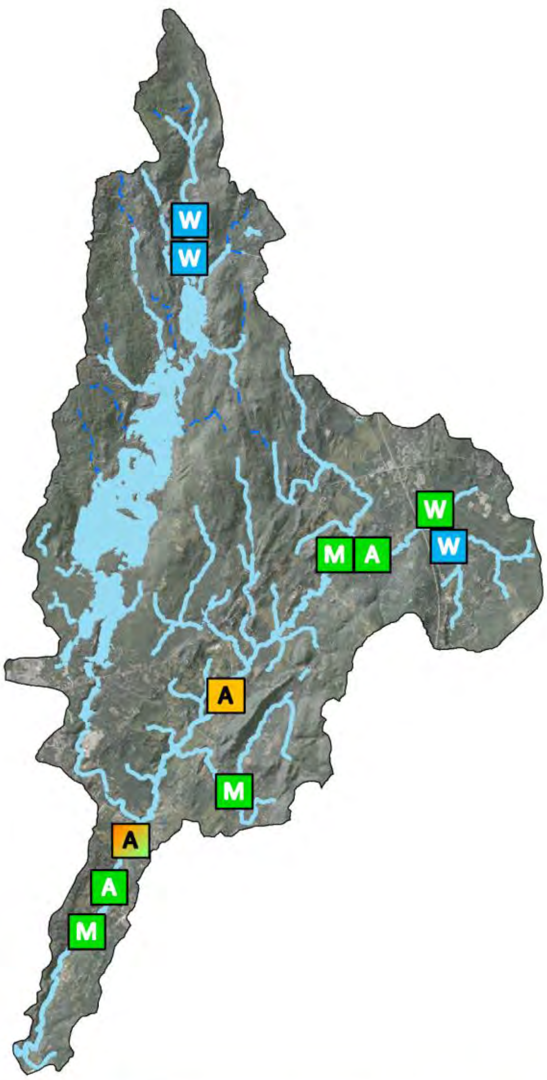


Figure 61. Box-and-whisker plot of % IC of samples grouped by biological assessment results for (A) macroinvertebrates and (B) algae with number of samples in parentheses. The NA group includes samples that do not attain biological criteria for Classes AA/A, B, or C (Source: Danielson et al. In press).

6.5.6 Monitoring and Assessment to Determine Current Condition: Using Biological Condition Gradient Concepts to Integrate Biological Information from Multiple Assemblages and Water Body Types



	WATERBODY	ASSEMBLAGE	CLASS	BCG LEVEL
W	WETLAND	MACROINVERTEBRATE	A	2
W	WETLAND	MACROINVERTEBRATE	B	3
M	STREAM	MACROINVERTEBRATE	B	3
A	STREAM	ALGAE	B	3
A	STREAM	ALGAE	B/C	3/4
A	STREAM	ALGAE	C	4

Figure 62. Pleasant River sites with attained water quality class and BCG level for different assemblages and water body types.

BCG concepts provide Maine with a common assessment framework for comparing biological integrity among different types of water bodies (wetlands, rivers, and streams), regardless of the assemblage assessed or the sampling methods used. This enables MEDEP to evaluate condition and threats to aquatic resources on a watershed basis. The integrated assessment also contributes important information for design of remediation activities, even in the absence of formally promulgated numeric biological criteria. For example, MEDEP evaluated the condition of the Pleasant River watershed using multiple biological assessment models, water quality class attainment, expert judgment, the BCG, and supporting chemical and physical information. Located in southern Maine, the Pleasant River watershed is primarily forested with some agriculture, as well as increasing amounts of urbanization in the downstream portions of the watershed. The Pleasant River has a TALU goal of Class B. MEDEP sampled algae and macroinvertebrates in several locations on the Pleasant River and sampled macroinvertebrates in several headwater wetlands (MEDEP 2006, 2009, 2014; Danielson et al. 2011). Biological assessment showed that the headwater stream and wetland samples attained Class A or B biological criteria using macroinvertebrate data (Figure 62).

However, further downstream, the stream macroinvertebrate samples attained Class B biological criteria, but stream algal samples were mixed, attaining Class B or C. MEDEP used water chemistry data, habitat evaluations, diagnostic algal and macroinvertebrate metrics, expert judgment, and the BCG concept to determine that nutrient pollution was the probable stressor to which the algal community was responding. A watershed survey identified potential sources of nutrients in the lower part of the watershed. The combination of biological assessments for two water body types and taxonomic groups allowed MEDEP to complete a more holistic and meaningful evaluation of the Pleasant River watershed than what could have been accomplished with only one biological assessment method. MEDEP now has a tool to detect early signals of nutrient pollution before the full aquatic community is detrimentally impacted.

Findings from biological assessments of multiple assemblages and water body types have also been used to improve and strengthen Maine's statewide impervious cover TMDL report.[35] For example, in Maine's 2010 Integrated Water Quality Report, Capisic Brook in Portland and Westbrook, Maine was 303(d)-listed for stream benthic macroinvertebrate impairment based on MEDEP's numeric biological criteria rule. Although numeric biological criteria for Maine wetlands had not yet been formally promulgated, Capisic Pond was also listed for wetland macroinvertebrate impairments based on interpretation of quantitative data showing that narrative ALUs were not attained. The state's multivariate biological assessment models for wetland macroinvertebrates and stream algae enabled results to be compared to Maine's TALU classes and macroinvertebrate numeric biological criteria. Stream algal and wetland macroinvertebrate biological assessments helped biologists determine that Capisic Pond and Capisic Brook were not attaining narrative biological criteria, resulting in biological impairment listing for multiple causes.

6.5.7 Using Maine's Tiered Aquatic Life Uses and Biological Assessment Methods to Evaluate Wetland Condition

The MEDEP Biological Monitoring Program assesses the health of inundated emergent and aquatic bed freshwater wetlands. Samples consist of aquatic macroinvertebrates, planktonic and epiphytic algae, and physical and chemical data related to trophic state and habitat condition (MEDEP 2006; MEDEP 2009). Sampling typically occurs in freshwater marshes and fringing wetlands associated with rivers, streams, lakes, and ponds. The biological assessment statistical model for wetlands provides an objective means of assessing condition.

Maine has found that wetland biological assessment provides a complementary approach to assessments of wetland function and value. Under the definitions established by the USEPA *Wetland Core Elements of an Effective State and Tribal Wetlands Program*[36] Maine conducts a "level 3" biological assessment of wetlands. According to EPA, "level 3 or intensive site assessments provide a more thorough and rigorous measure of wetland condition by gathering direct and detailed measurements of biological taxa and/or hydro-geomorphic functions." Maine's wetland macroinvertebrate biological assessment program can detect incremental differences in aquatic resource condition utilizing a locally calibrated statistical model consistent with the BCG concepts (MDEP 2006; MDEP 2009). Additional applications of wetland biological assessments include determining whether wetlands attain designated ALUs, tracking trends over time, and, in conjunction with chemical and physical assessments, diagnosing stressors, and assessing impacts or threats related to land use practices (e.g., point source discharges, toxic contaminants, hydropower, and water withdrawal projects).

In 2013, the MEDEP Biological Monitoring Program evaluated the biological condition of wetland compensatory mitigation projects using wetland biological assessment methods (DiFranco et al. 2013).

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35 See http://www.maine.gov/dep/water/monitoring/tmdl/tmdl2.html. Accessed February 2016.

36 See http://water.epa.gov/grants_funding/wetlands/cefintro.cfm. Accessed February 2016.

Mitigating adverse environmental impacts of development is an integral part of Maine's Natural Resources Protection Act,[37] a state law regulating land use activities and administered by MEDEP. The State of Maine or federal agencies administering resource protection regulations might require appropriate and practicable compensatory mitigation as a condition of granting a permit to alter or destroy wetlands. Compensation is defined in the NRPA as "replacement of a lost or degraded wetland function with a function of equal or greater value." If ecologically appropriate compensation is not available or otherwise practicable, a permit applicant may request to pay an *in-lieu* compensation fee to be used for the purpose of restoring, enhancing, creating or preserving other resource functions or values that are environmentally equal or preferable to the functions and values being lost. Upon authorization the In-Lieu Fee is placed in a "Natural Resource Mitigation Fund" administered by The Nature Conservancy's (TNC's) Maine office.

For this study, MEDEP wanted to determine whether compensatory mitigation projects supported aquatic life communities comparable to minimally disturbed reference sites. The MEDEP Biological Monitoring Program evaluated quantitative biological data, biological assessment model results, expert judgment, and the BCG, to compare the biological condition of 9 wetland compensation sites to that of 51 minimally disturbed reference sites. The mitigation sites in the study represented a cross section of available Maine "permittee-responsible" compensation projects that used restoration, creation, enhancement, and preservation techniques, and were completed between 1995 and 2007. The compensation projects varied in age and encompassed a range of freshwater wetland types, including forested, scrub-shrub, emergent, wet meadow, aquatic bed, and open water marsh.

Figure 63 illustrates comparisons of reference and mitigation sites for sensitive versus tolerant taxa metrics using box and whisker plots and quantile (cumulative distribution) plots. In general, mitigation sites had fewer numbers and types of sensitive taxa and a higher proportion of eurytopic taxa (i.e., taxa that are adapted to a wide range of environmental conditions). Table 37 shows estimated BCG condition based on data analysis, expert judgment and the provisional wetland biological assessment model (DiFranco et al. 2013). Results of this study indicated that community structure is significantly different between a set of 51 reference wetlands and nine mitigation wetlands based on taxa tolerance metrics and BCG level. This type of information can improve monitoring and assessment of mitigation sites.

[37] See NRPA, http://www.maine.gov/dep/land/nrpa/index.html (Accessed February 2016), 38 M.R.S.A. § 480 A–BB.

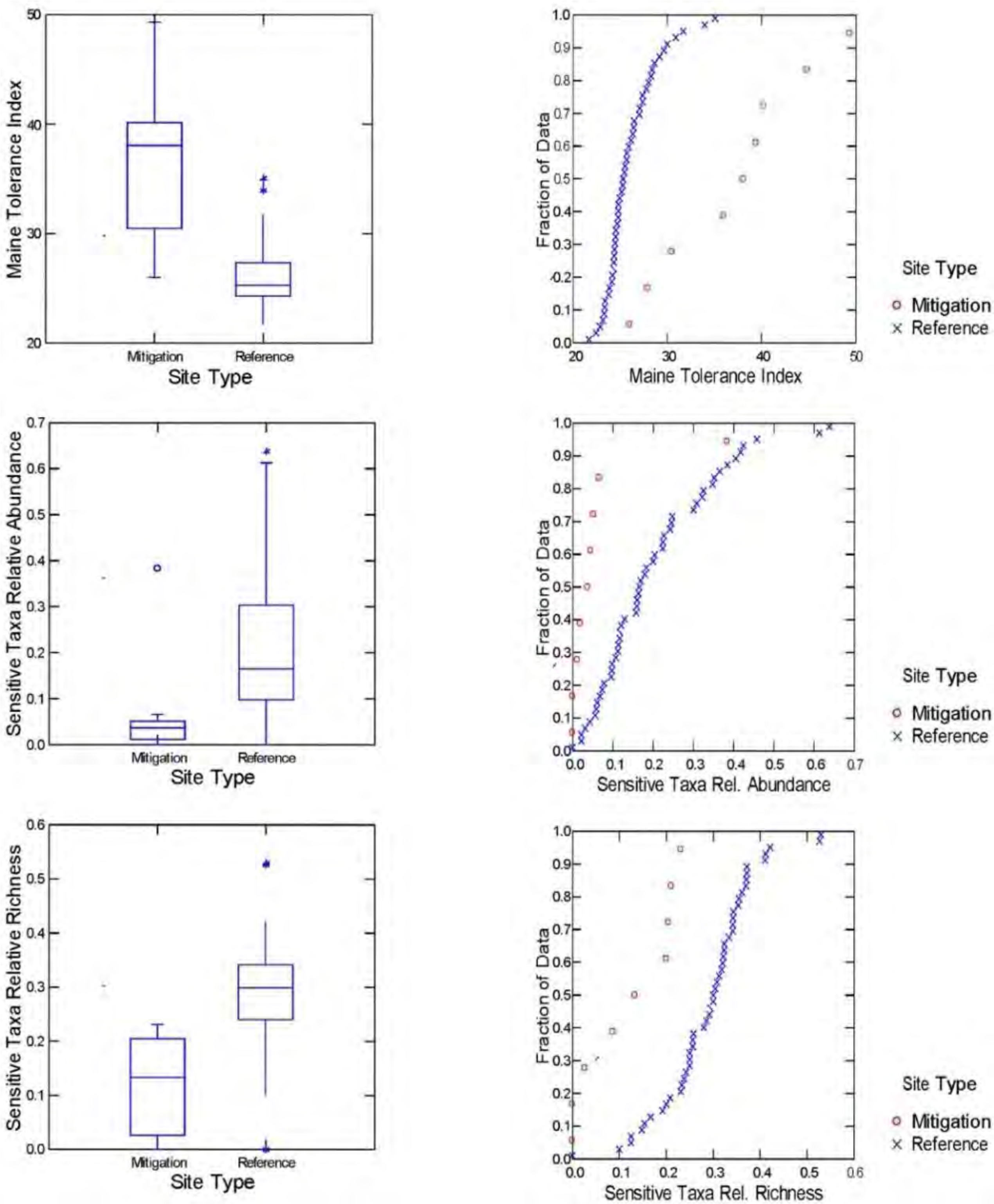


Figure 63. Comparison of reference and mitigation sites for the Maine Tolerance Index and sensitive/tolerant taxa metrics (reference site N=51; mitigation site N=9) (DiFranco et al. 2013).

Table 37. Measured values of chemical and watershed stressors, attained water quality classes, and corresponding BCG levels of reference wetlands and mitigation wetlands (DiFranco et al. 2013)

Mitigation Site Station Number	Specific Conductance µS/cm	Total Phosphorus (mg/L)	MEDEP Human Disturbance Score	% Watershed Alteration	Assigned Legislative Class	BCG Level
Reference site range	**9–95**	**.005–.097**	**1–10**	**0–5.5**		**2.5–4.5**
Reference site mean	**30.6**	**.017**	**5**	**1.9**		**2.8**
W-171	98	0.15	26	24.1	B	5.2[3]
W-173	141	0.22	20	74.7	B	5.5
W-174	57	0.071	10	37.6	C	4.2
W-175	25	0.013	23	16.7	B	4.2
W-179	265	0.051	23	84.0	B	5.5
W-180	76	0.032	22	21.9	B	4.2
W-181	163	0.091	24	39.9	C	4.8
W-182	1120	0.069	40	100	B	4.5
W-184	234	0.027	22	73.3	B	4.5

[1] Reference site classification attainment: Class AA/A or Class B: 78%; Class C: 8%; Non-attainment: 0

[2] Non-attainment of Class C (i.e., lower than the lowest Maine ALU standards)

[3] MEDEP assigns BCG scores utilizing digits to the right of the decimal point to indicate the strength of association, e.g., level 3.2 means "Leans toward level 2"; level 3.5 means "Solid level 3", level 3.8 means "Leans toward level 4".

6.5.8 *Conclusion*

For Maine, their approach to classifying waters based on current ecological condition provides a direct linkage to CWA biological integrity objectives and ALU goals. This direct linkage facilitates effective communication with stakeholders and water quality management decision makers on current conditions and the likelihood for improvements. As sustained and significant improvements in biological condition were observed based on systematic monitoring of streams, these improvements were documented and class assignments for specific streams were upgraded (e.g., Class C to B; Class B to A as appropriate). As Maine further develops and applies biological assessment tools and data to water bodies other than streams (e.g., wetlands, estuaries, lakes, large rivers), the BCG is included as part of their toolbox.

6.6 Ohio: Use of Biological Gradient to Support Water Quality Management

6.6.1 Key Message

Ohio has used biological assessment information in conjunction with chemical water quality and physical habitat assessments to support water quality management decisions since the late 1970s. While the Ohio ALU classification framework pre-dated the BCG by 25 years, it is based on concepts that are parallel to the BCG, highlighting the relationship between biology, habitat, and the potential for water quality improvements. Ohio's ecological based approach contributed both technical and implementation "lessons learned" to conceptualization of the BCG (Davies and Jackson 2006). The state's biological monitoring and assessment program has provided timely information about the status of individual water bodies and the data to support water quality management program information needs for more than 35 years. This includes when biological conditions improve and when revisions of designated uses are warranted. A systematic process to determine which use(s) is (are) appropriate and attainable for a stream or river has been and remains the key first step in using biological assessment data to support water quality management.

6.6.2 Background

A major aspect of the development of the Ohio biological assessment program and tiered ALU framework is the experience gained through the sustained development of systematic biological assessments beginning in the late 1970s and through the 1980s. This is where the methods, concepts, and theories were tested, applied, and refined, resulting in a tractable system for measuring biological quality at appropriate spatial scales and through time. Qualitative, narrative guidelines were initially used to assess biological status via systematic watershed monitoring and assessment. The data and experiences gained in this early assessment process provided the raw materials for incorporating the concepts of biological integrity that emerged later. Further refinements were also made to the biological assessment tools and the tiered uses including how they are assigned and assessed. Keys to the success of this approach were the initial decisions about indicator assemblages and methods. These have remained stable through time with no major modifications that could have resulted in disconnections within the statewide database that is more than 35 years old.

Ohio EPA formally adopted numeric biological criteria into the Ohio Water Quality Standards (Ohio WQS; Ohio Administrative Code 3745-1) in 1990. The biological criteria have been used to guide and enhance water quality management programs and assess their environmental outcomes. As a result, the state refined definitions of some ALUs, adopted new ones, and added numerical biological criteria to support a tiered approach to water quality management within the Ohio WQS (Table 38). The numeric biological criteria are an outgrowth of an existing framework of TALUs and narrative biological assessment criteria that had been in place since the late 1970s (Table 39 and Table 40). Ohio's approach to biological assessment evolved from an initial reliance on best professional judgment guided by the narrative biological criteria for determining the quality of fish and macroinvertebrate assemblages to a more quantitative and independent approach based on calibrated indices and numeric biological criteria. While the early narrative descriptions of four levels of quality ranging from excellent to poor (Table 39 and Table 40) predated the BCG, the narrative attributes and the rating of multiple levels of condition are consistent with the attributes and scaling of the current BCG. These concepts were retained and further refined with the development of the fish IBI and invertebrate community integrity index (ICI) and the derivation of numeric biological criteria for the current Ohio TALUs (Figure 64) which were initially mapped to the BCG as part of the early BCG development workshops hosted by EPA (Figure 65).

Table 38. Descriptive summary of Ohio's tiered aquatic life use designations

Aquatic Life Use	Key Attributes	Why a Water body Would Be Designated	Practical Impacts (compared to a baseline of WWH)
Warmwater Habitat (WWH)	Balanced assemblages of fish/invertebrates comparable to least impacted *regional* reference condition	Either supports biota consistent with numeric biological criteria for that ecoregion **or** exhibits the habitat potential to support recovery of the aquatic fauna	Baseline regulatory requirements consistent with the CWA "fishable" and "protection & propagation" goals; criteria consistent with EPA guidance with state/regional modifications as appropriate
Exceptional Warmwater Habitat (EWH)	Unique and/or diverse assemblages; comparable to upper quartile of *statewide* reference condition	Attainment of the EWH biological criteria demonstrated by both organism groups	More stringent criteria for DO, temperature, ammonia, and nutrient targets; more stringent restrictions on dissolved metals translators; restrictions on nationwide dredge & fill permits; may result in more stringent wastewater treatment requirements
Coldwater Habitat (CWH)	Sustained presence of Salmonid or non-salmonid coldwater aquatic organisms; bonafide trout fishery	Biological assessment reveals coldwater species as defined by Ohio EPA (2014); put-and-take trout fishery managed by Ohio Department of Natural Resources	Same as above except that common metals criteria are more stringent; may result in more stringent wastewater treatment requirements
Modified Warmwater Habitat (MWH)	Warmwater assemblage dominated by species tolerant of low DO, excessive nutrients, siltation, and/or habitat modifications	Impairment of the WWH biological criteria; existence and/or maintenance of hydrological modifications that cannot or will not be reversed or abated In the foreseeable future so that WWH biological criteria can be attained; a UAA is required	Less stringent criteria for DO, ammonia, and nutrient targets; less restrictive applications of dissolved metals translators; Nationwide permits apply without restrictions or exception; may result in less restrictive wastewater treatment requirements
Limited Resource Waters (LRW)	Highly degraded assemblages dominated exclusively by tolerant species; *should not* reflect acutely toxic conditions	Extensive physical and hydrological modifications that cannot be reversed, are essentially irretrievable and which preclude attainment of higher uses; a UAA is required	Chemical criteria are based on the prevention of acutely lethal conditions; may result in less restrictive wastewater treatment requirements

Table 39. Narrative biological criteria (fish) for determining ALU designations and attainment of CWA goals (November, 1980; after Ohio EPA 1981)

Evaluation Class Category	"Exceptional" Class I (EWH)	"Good" Class II (WWH)	"Fair" Class III	"Poor" Class IV
1.	Exceptional or unusual assemblage of species	Usual association of expected species	Some expected species absent, or in very low abundance	Most expected species absent
2.	Sensitive species abundant	Sensitive species present	Sensitive species absent, or in very low abundance	Sensitive species absent
3.	Exceptionally high diversity	High diversity	Declining diversity	Low diversity
4.	Composite index > 9.0–9.5	Composite index > 7.0–7.5; < 9.0–9.5	Composite index > 4.5–5.0; < 7.0–7.5	Composite index < 4.0–4.5
5.	Outstanding recreational Fishery		Tolerant species increasing, beginning to dominate	Tolerant species dominate
6.	Rare, endangered, or threatened species present			

Conditions: Categories 1, 2, 3, and 4 (if data are available) must be met and 5 or 6 must also be met in order to be

Table 40. Narrative biological criteria (macroinvertebrates) for determining ALU designations and attainment of CWA goals (November 1980; after Ohio EPA 1981)

Evaluation Class Category	"Exceptional" Class I (EWH)	"Good" Class II (WWH)	"Fair" Class III	"Poor" Class IV designated in a particular class.
1.	Pollution sensitive species abundant	Pollution sensitive species present in moderate numbers	Pollution sensitive species present in low numbers	Pollution sensitive species absent
2.	Intermediate species present in low numbers	Intermediate species present in moderate numbers	Intermediate species abundant	Intermediate species present in low numbers or absent
3.	Tolerant species present in low numbers	Tolerant species present in low numbers	Tolerant species present in moderate numbers	Tolerant species abundant (all types may be absent if extreme toxic conditions exist)
4.	Number of taxa > 30[1]	Number of taxa 25–30	Number of taxa 20–25	Number of taxa < 20
5.	Exceptional diversity Shannon index < 3.5	High diversity Shannon index 2.9–3.5	Moderate diversity Shannon index 2.3–2.9	Low diversity Shannon index < 2.3

[1]Number of quantitative taxa from artificial substrates.

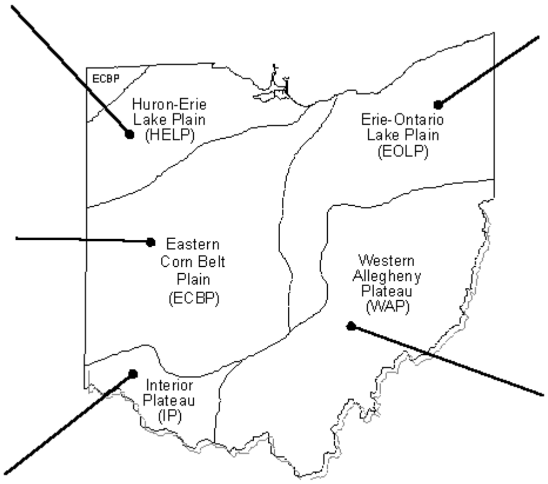
Ohio Biological Criteria: Adopted May 1990 (OAC 3745-1-07; Table 7-14)

Huron Erie Lake Plain (HELP)

Use	Size	IBI	MIwb	ICI
WWH	H	28	NA	34
	W	32	7.3	34
	B	34	8.6	34
MWH-C	H	20	NA	22
	W	22	5.6	22
	B	20	5.7	22
MWH-I	B	30	5.7	NA

Erie Ontario Lake Plain (EOLP)

Use	Size	IBI	MIwb	ICI
WWH	H	40	NA	34
	W	38	7.9	34
	B	40	8.7	34
MWH-C	H	24	NA	22
	W	24	6.2	22
	B	24	5.8	22
MWH-I	B	30	6.6	NA



Eastern Corn Belt Plains (ECBP)

Use	Size	IBI	MIwb	ICI
WWH	H	40	NA	36
	W	40	8.3	36
	B	42	8.5	36
MWH-C	H	24	NA	22
	W	24	6.2	22
	B	24	5.8	22
MWH-I	B	30	6.6	NA

Western Allegheny Plateau (WAP)

Use	Size	IBI	MIwb	ICI
WWH	H	44	NA	34
	W	44	8.4	34
	B	40	8.6	34
MWH-C	H	24	NA	22
	W	24	6.2	22
	B	24	5.8	22
MWH-A	H	24	NA	30
	W	24	5.5	30
	B	24	5.5	30
MWH-I	B	30	6.6	NA

Interior Plateau (IP)

Use	Size	IBI	MIwb	ICI
WWH	H	40	NA	30
	W	40	8.1	30
	B	38	8.7	30
MWH-C	H	24	NA	22
	W	24	6.2	22
	B	24	5.8	22
MWH-I	B	30	6.6	NA

Statewide Exceptional Criteria

Use	Size	IBI	MIwb	ICI
EWH	H	50	NA	46
	W	50	9.4	46
	B	48	9.6	46

Figure 64. Numeric biological criteria adopted by Ohio EPA in 1990, showing stratification of biological criteria by biological assemblage, index, site type, ecoregion for warmwater and modified warmwater habitat (WWH and MWH, respectively), and statewide for the exceptional warmwater habitat (EWH) use designations.

Developed and adopted by Ohio EPA in 1978, the original tiered aquatic life use narratives represented a major revision to a general use framework that was adopted in 1974. Ohio's tiered uses recognized the different types of warmwater aquatic assemblages that corresponded to the mosaic of natural features of the landscape and nearly two centuries of human-induced changes. The eventual development of more refined tiered uses and numeric biological criteria that are in place today was the result of sustained state support to develop a biological monitoring and assessment program with technical capability to discriminate incremental changes in biological condition with increasing stress. The empirical evidence used to develop the initial concepts for tiered uses can be found in comprehensive works on the natural history and zoogeography of the Midwest such as *Fishes of Ohio* (Trautman 1957, 1981). This and other natural history texts documented the natural and human-caused variations in the distribution, composition, and abundance of biological assemblages over space and through time including before and after European settlement. Trautman (1957) not only provides a detailed narrative of Ohio's natural history, but describes the biological evidence that was used to formulate the initial concepts about biological integrity that emerged in the late 1970s and early 1980s and which were later incorporated in the BCG. Such works also described the key features of the landscape that influence and determine the potential aquatic fauna of water bodies and were the forerunners of the regionalization frameworks that appeared soon after. As an alternative to a "one-size-fits-all" approach, these provided an important foundation for the development of Ohio's tiered uses. The articulation of a practical definition of biological integrity by Karr and Dudley (1981) provided a theoretical framework for the development of Ohio's numeric biological criteria (Figure 65). Key components of this framework are: (1) using biological assemblages as a direct measure of ALU attainment status (Herricks and Schaeffer 1985; Karr et al. 1986), (2) the development and use of IBIs as assessment tools (Karr 1981; Karr et al. 1986), (3) derivation of regional reference condition to determine appropriate and attainable ALU goals and assessment endpoints (Hughes et al. 1986), and (4) systematic monitoring and assessment of the state's rivers and streams using a pollution survey design. These represented a major advancement over previous attempts (Ballantine and Guarria 1975) to define and develop a workable framework to address the concept of biological integrity. Embedded in this framework is the recognition that water quality management must be approached from an ecological perspective that is grounded in sound ecological theory *and* which is validated by empirical observation. This means developing monitoring and assessment and WQS to encompass the five factors that determine the integrity of a water resource Figure 22; Karr et al. 1986).

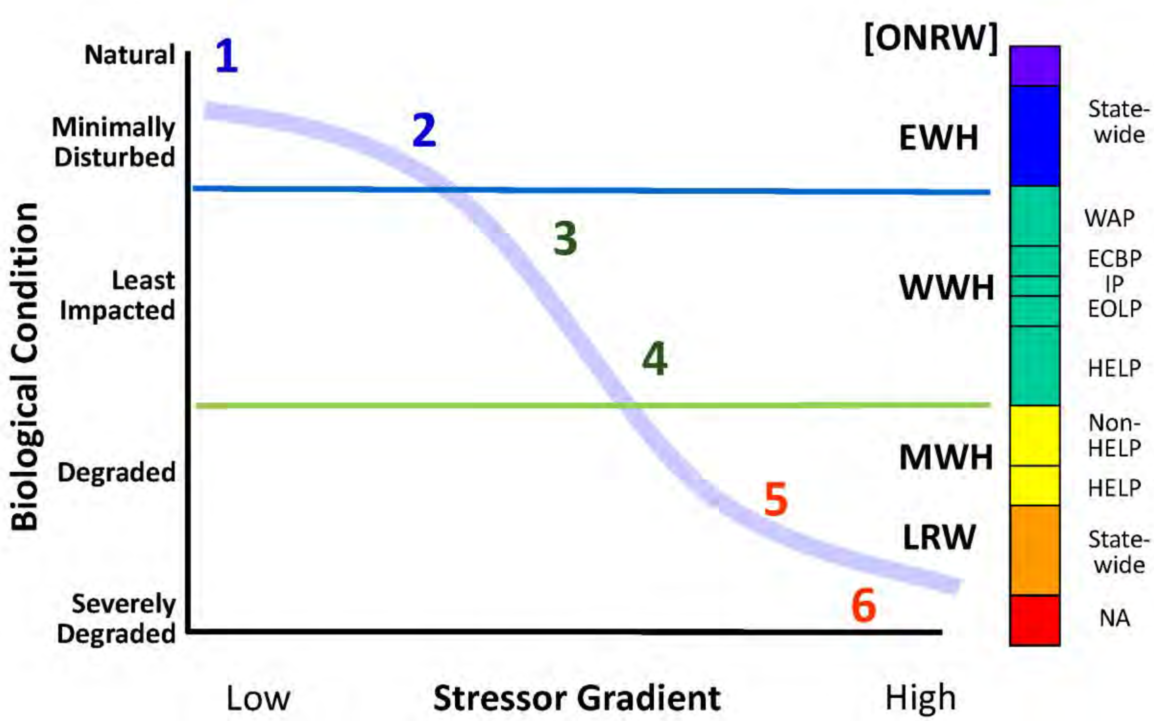
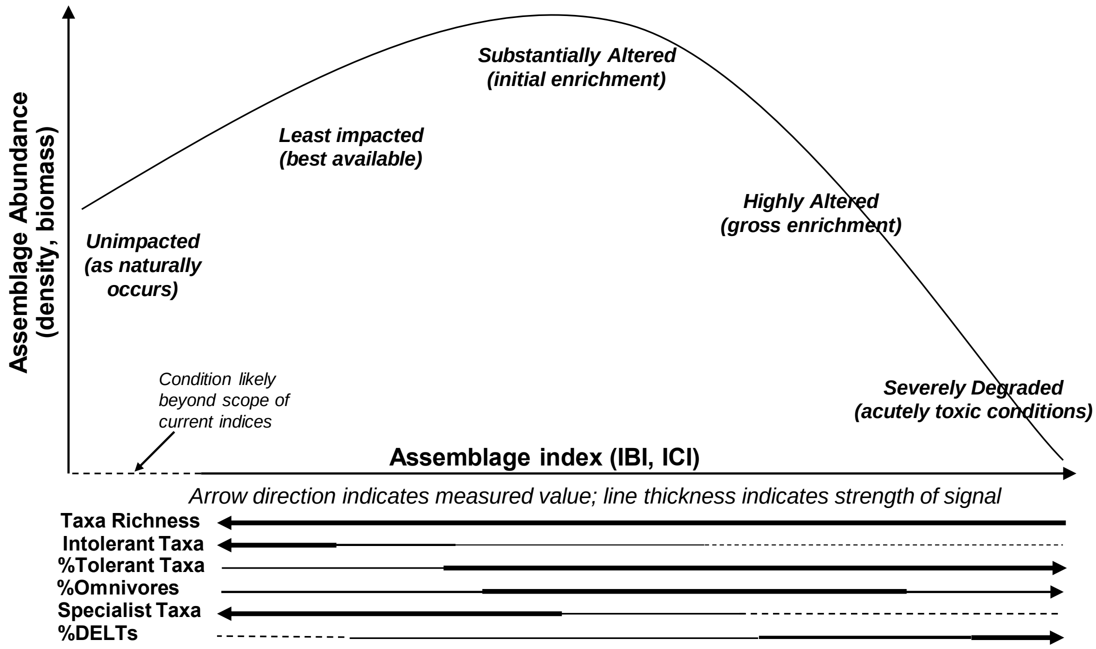


Figure 65. An initial mapping of the Ohio TALUs to the BCG relating descriptions of condition along the y1-axis and ranges of condition encompassed by the numerical biological criteria for each of four tiered use subcategories and the highest antidegradation tier (ONRW) along the y2-axis. ONRW – Outstanding National Resource Waters; EWH – Exceptional Warmwater Habitat; WWH – Warmwater Habitat; MWH – Modified Warmwater Habitat; LRW – Limited Resource Waters.

The understanding of fish and macroinvertebrate assemblage responses to stressor gradients ranging from minimally disturbed to severely altered conditions was affirmed by repeated empirical observations of assemblage responses which are depicted in Figure 66. This graphic represents measured assemblage abundance (y-axis) against assemblage indices (fish IBI, macroinvertebrate ICI; x-axis) with the response of selected metrics and other assemblage attributes at increments along what



Biological and Stressor Gradient Descriptors

"As Naturally Occurs" ***(Pristine)***	**"Least Impacted"** ***(Exceptional)***	**"Initial Enrichment"** ***(Good)***	**"Moderate Enrichment"** ***(Fair)***	**"Gross Enrichment"** ***(Poor)***	**"Severely Degraded"** ***(Very Poor)***
Assemblage Characteristics					
Native assemblages; no symptoms of stress	"Best of what's left" assemblages; high richness; intolerants, specialists predominate	"Typical" assemblages; good richness; emerging symptoms of stress in selected metrics	"Impaired" assemblages; tolerants & generalists predominate numbers/bio-mass; loss of intolerants	"Degraded"; highly tolerant taxa pre-dominate; reduced abundance; anomalies increasing	"Severely degraded"; very low numbers; few taxa; very high % anomalies; toxic signatures
Chemical Water Quality Conditions					
As natural; no human-made compounds present	"Best reference" quality; toxics < detection; high D.O., low nutrients	"Background reference" quality; toxics < chronic; adequate D.O., nutrients = reference	"Enriched" quality; toxics < chronic; marginal D.O. regime, nutrients > reference	"Degraded" quality; toxics > chronic; low D.O., nutrients >> reference	"Extremely poor" quality; toxics ≥ acute; very low D.O., nutrients >> reference; contaminated sediments
Physical Habitat & Flow Regime					
Natural habitat and flow regime; no human-made modifications	Excellent quality habitat & flow regime; recovered from human-made modifications	Good quality habitat & flow regime; *de minimis* human modifications	Fair quality habitat & flow regime; active human modifi-cations; incomplete recovery	Poor quality habitat & flow regime; active human modifi-cations; no recovery	Severe modifi-cations; ephemeral flows; active human modifications; no recovery potential
Examples of Sources and Activities					
No effects of human activity are evident	Point sources present, do not dominate flows; NPS impacts buffered by extensive riparian system	Point sources may dominate flows; NPS impacts buffered by good riparian zones	PS/NPS enrich-ment impacts; NPS unbuffered; channel modifi-cations; im-poundments	Gross PS/NPS enrichment impacts inc. CSOs; NPS unbufferd; chan-nel modifications; urbanization	Severe PS/NPS toxic impacts; extreme channel modifications; urbanization; acid mine drainage, severe thermal

Figure 66. Descriptive model of the response of fish and macroinvertebrate assemblage metrics and characteristics to a quality gradient and different levels of impact from stressors in Midwestern U.S. warmwater rivers and streams (modified from Ohio EPA 1987 and Yoder and Rankin 1995b).

is in reality a continuum. Biological descriptions correspond to the six levels of the then emerging BCG model and include descriptions of key assemblage characteristics, chemical water quality conditions, physical habitat and flow regime, and sources of stress that are typically associated with each. This was modified from the original conceptual model of Ohio EPA (1987a) and Yoder and Rankin (1995b), and it includes the probable upper limits of Ohio's fish and macroinvertebrate indices. It demonstrates that understanding the relationship between assemblage responses and stressors is a fundamental aspect of using biological assessments to support condition assessments *and* water quality management programs. It also demonstrates the pre-BCG concepts that eventually merged in the formal development and description of the current BCG.

6.6.3 Determining Appropriate Levels of Protection

By merging the ALU framework with systematic monitoring and assessment, Ohio has been able to determine attainable levels of condition for streams and rivers and also to set protection levels for high quality waters. This framework is consistently applied within a rotating basin sequence of "biological surveys" that address the following questions:

1) Is the current designated ALU appropriate and attainable and if not, what is the appropriate use for a water body?
2) Are the biological criteria for the most appropriate and attainable use tier attained?
3) Have there been any changes through time and what do they portend for water quality management?

The scale of monitoring and assessment is sufficiently detailed so that designations of individual water bodies or segments of a water body can be made based on scientific information and data. Getting this task done correctly affects everything that follows including assessments of condition and which WQS will guide water quality management actions such as permitting and TMDLs. The data gathered by a biological survey is processed, evaluated, and synthesized in a biological and water quality report. The report serves as the rationale for justifying recommended changes to a currently assigned ALU. The report also identifies sources of pollutants and/or pollution contributing to impairment(s) of the recommended designated uses. The recommendations for use designation revisions are a direct output of the biological and water quality assessment. Recommended revisions to the WQS are based on a UAA framework that emphasizes the demonstrated *potential* to attain a particular use tier based on the following information (and in order of importance):

1) Attainment of the numeric biological criteria for WWH[38] or EWH results in designation of that use; or,
2) If the WWH biological criteria are not attained, the habitat determined by the Qualitative Habitat Evaluation Index (QHEI; Rankin 1995) based on an assessment of habitat attributes is used to determine the *potential* to attain WWH.

[38] WWH – Warmwater Habitat is the minimum condition that meets the 101[a][2] goal of the Clean Water Act under the Ohio WQS. A UAA is required to designate a river or stream to a lower use (e.g., MWH or LRW).

For uses below WWH (i.e., MWH or LRW), a UAA is performed and includes consideration of the restorability of the water body and of the factors that may preclude WWH attainment. This process requires the following information:

1) The current attainment status of the water body based on a biological assessment performed in accordance with the requirements of the biological criteria, the Ohio WQS, and the Five-Year Monitoring Strategy;
2) A habitat assessment to evaluate the potential to attain WWH; and,
3) A reasonable relationship between the impaired status and the precluding human-caused activities based on an assessment of multiple indicators used in their most appropriate indicator roles and a demonstration consistent with 40 CFR Part 131.10[g].

Since 1978 Ohio EPA has used a consistent process to validate and, if necessary, revise uses in the Ohio WQS. The codified uses for approximately 2,000 streams and rivers have been revised using this process (Figure 67) and information from a biological and water quality assessment. This became a routine practice once the assessment criteria and decision making process for UAAs were established in the mid-1980s. It required the parallel development of reliable tools, particularly for determining status, assessing habitat, and determining causal associations, all of which is part of the developmental process described in several documents and publications (Ohio EPA 1987; 2006; Rankin 1989; 1995; Yoder 1995). The terms "upgrade" and "downgrade" are used only as descriptions of the direction of change from the current codified use to that derived from systematic monitoring and assessment. The vast majority of these changes are from the baseline of original designations that were made in 1978 without the benefit of systematic monitoring and assessment data, numerical biological criteria, and refinements in the process that occurred in the mid-1980s. Hence, these original designations are merely being replaced by the most appropriate use designation based on consistently applied criteria and assessments. Undesignated streams are almost always smaller watersheds of < 5–10 mi^2 drainage area that were missed by the default stream naming format that was employed when stream and river specific designations were originally adopted in 1985. Prior to that time, smaller tributaries were "automatically" assigned the use tier of the parent mainstem river or stream, a practice that resulted in numerous erroneous use designations. The more frequent monitoring of these smaller streams and watersheds in the 1990s and 2000s was partially the result of a shift in emphasis to watershed based TMDLs which resulted in numerous undesignated streams being monitored and hence designated for the first time. A detailed fact sheet is prepared for each use designation rulemaking to communicate the types of proposed changes to the WQS, the rationale for the changes, and which rivers and streams are affected by the proposed changes. When use designation rulemakings are underway, fact sheets specific to affected river basins can be found on Ohio EPA's website.[39]

[39] See http://epa.ohio.gov/dsw/dswrules.aspx#120473212-early-stakeholder-outreach. Accessed February 2016.

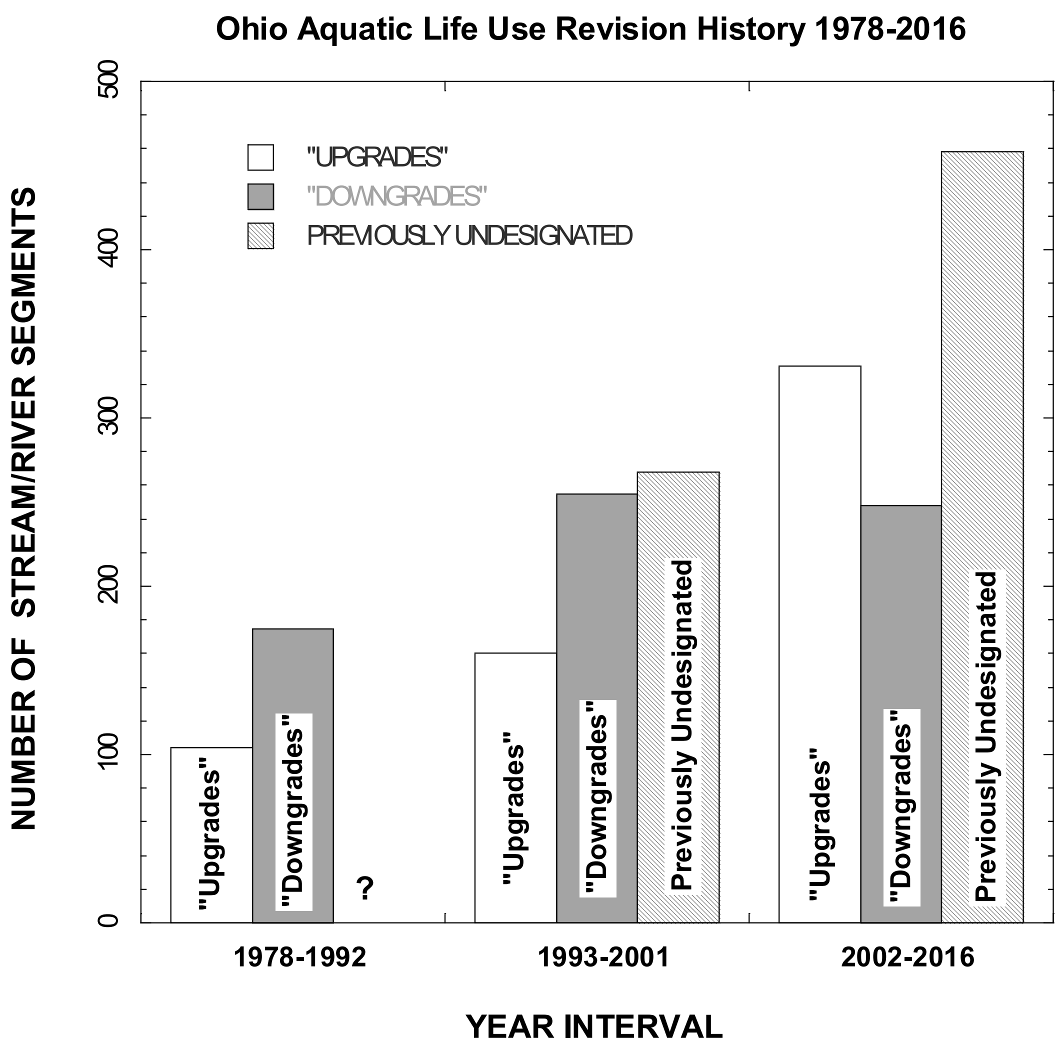


Figure 67. The number of individual stream and river segments in which ALU designations were revised during 1978–1992, 1993–2001, and 2002–2016. Cases where the use was revised to a higher use are termed "upgrades" and cases where a lower use was assigned are termed "downgrades." Previously undesignated refers to streams that were not listed in the 1985 WQS, but which were added as each was designated as a result of systematic monitoring and assessment. The number of waters previously undesignated in the first interval is unknown.

The Ohio tiered use and biological criteria framework and their application to Ohio rivers and streams were first tested in the Ohio court system in 1989 and were validated by a lower court and upheld in appeals up to, and including, the Ohio Supreme Court (NEORSD vs. Shank No. 89-1554, Supreme Court of Ohio, Feb. 27, 1991). The application of the biological criteria to justify additional pollution controls in response to a biological impairment was likewise validated by a lower court and upheld in subsequent appeals (City of Salem vs. Korleski No. 09AP-620, Tenth District Court of Appeals, March 23, 2010; Ohio Supreme Court 2010-0818; appeal not accepted, August 25, 2010).

6.6.4 Setting Attainable Goals for Improvements

Ecologically-based tiered uses, a systematic approach to monitoring and assessment, and a tractable UAA process can provide substantial benefits for water quality management programs related to guiding efforts to improve conditions and assessing the effectiveness of those efforts in protecting and restoring an ALU. The identification of the recovery potential for aquatic life in a water body using a systematic approach can help set attainable goals for improvements and support evaluation of environmental risks. The Ohio case example illustrates the role of tiered ALUs using a BCG approach for interpretation of conditions, systematic monitoring and assessment, and a consistent process for conducting UAAs in support of TMDLs. The UAA process is routinely applied as a result of the systematic monitoring and assessment of Ohio rivers and streams (Figure 68). The data are used to support recommendations for revisions to the Ohio WQS on an annual basis.

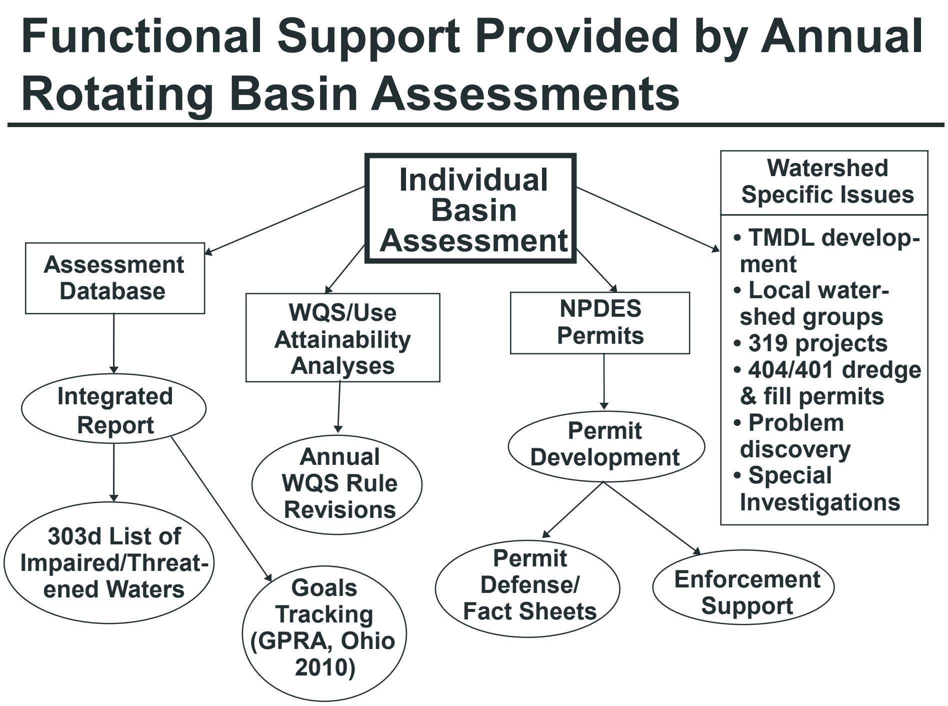


Figure 68. The flow of information from biological and water quality assessments to support for major water quality management programs in Ohio.

Ohio's tiered ALU designation procedures were incorporated into the TMDL process beginning in 1999 (Figure 69; Ohio EPA 1999). Figure 69 illustrates the steps for validating the most appropriate tiered ALU and then basing a TMDL on the criteria embodied by that use tier and the attendant assessment of the receiving streams and rivers. It also illustrates the delineation of the severity and extent of impairments, the most probable causes of the impairments, and follow-up assessments to validate TMDL effectiveness. Because the Ohio EPA monitoring and assessment strategy includes chemical, physical, and biological indicators which are used in their most appropriate roles as indicators of stress, exposure, and response (Yoder and Rankin 1998), support for the development of TMDLs can go beyond addressing singular pollutants to addressing the combination of pollution and pollutants that impair an ALU.

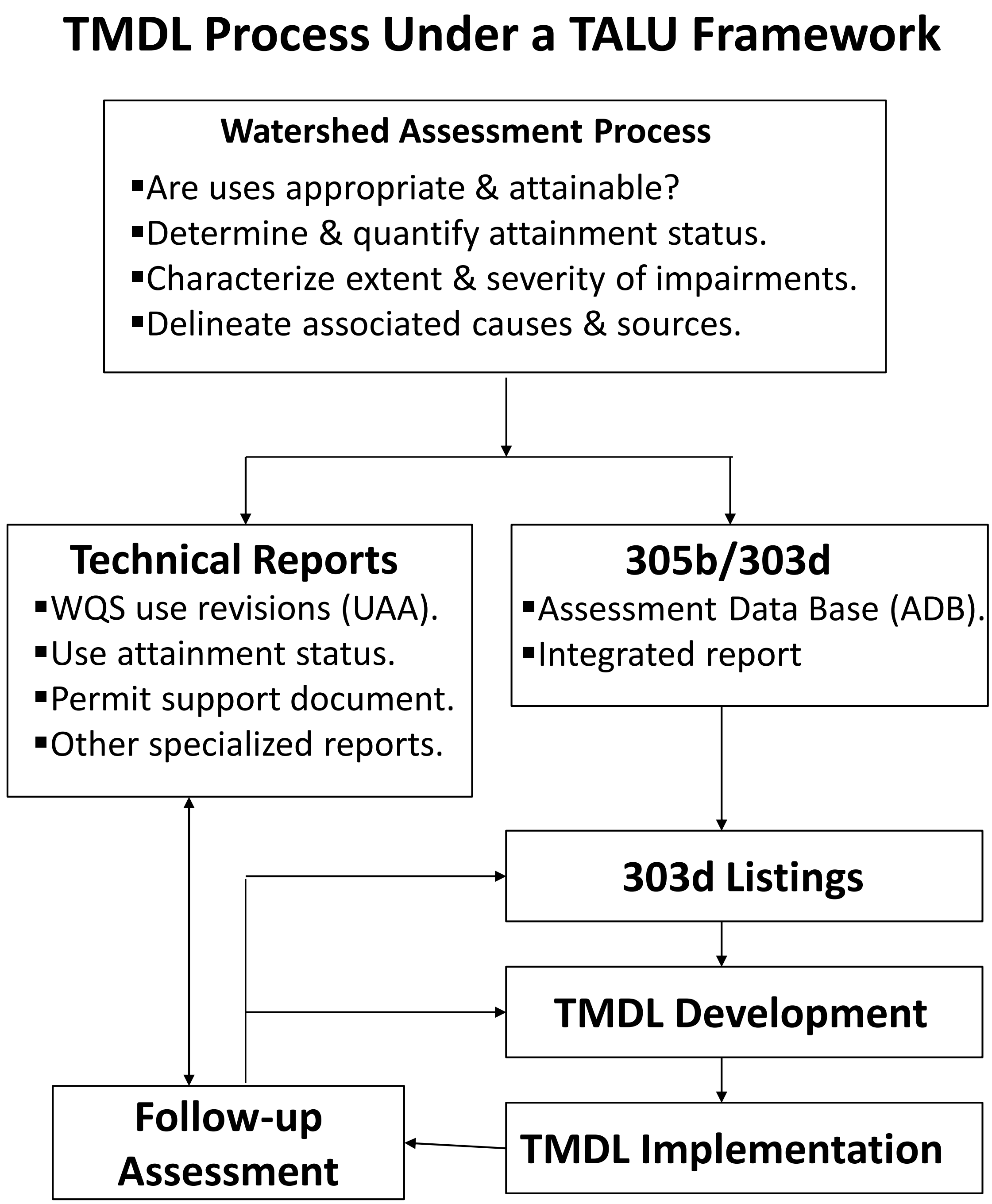


Figure 69. Key steps showing how a TALU based framework can be used to organize and guide a TMDL development and implementation process.

6.6.5 Protecting High Quality Water Bodies

Ohio's antidegradation rule (Ohio Administrative Code 3745-1-05) incorporates levels of protection between the minimum required under the CWA and the maximum protection afforded by federal regulations. The most stringent application of antidegradation is to disallow any lowering of water quality in waters listed as ONRWs. The minimum requirement allows for a lowering of water quality to the minimum WQS applicable to the water body if a determination is made that lowering water quality is necessary to accommodate important social and economic development. However, lowering of water quality below that which is necessary to protect an existing use is prohibited. Ohio has two intermediate levels of protection for certain ecologically important water bodies that permanently reserve a portion of the unused pollutant assimilative capacity, thereby assuring maintenance of a water quality that is better than that prescribed by the prevailing designated use tier. The two intermediate levels are: (1) Outstanding State Water (OSW; Figure 70), and (2) Superior High Quality Water (SHQW) which fall in between ONRW and General High Quality Waters (GHQWs; Figure 71). High quality water bodies are valued public resources because of their ecological and human benefits. Their biological components act as an early warning system that can indicate potential threats to human health, degradation of aesthetic values, reductions in the quality and quantity of recreational opportunities, and other ecosystem

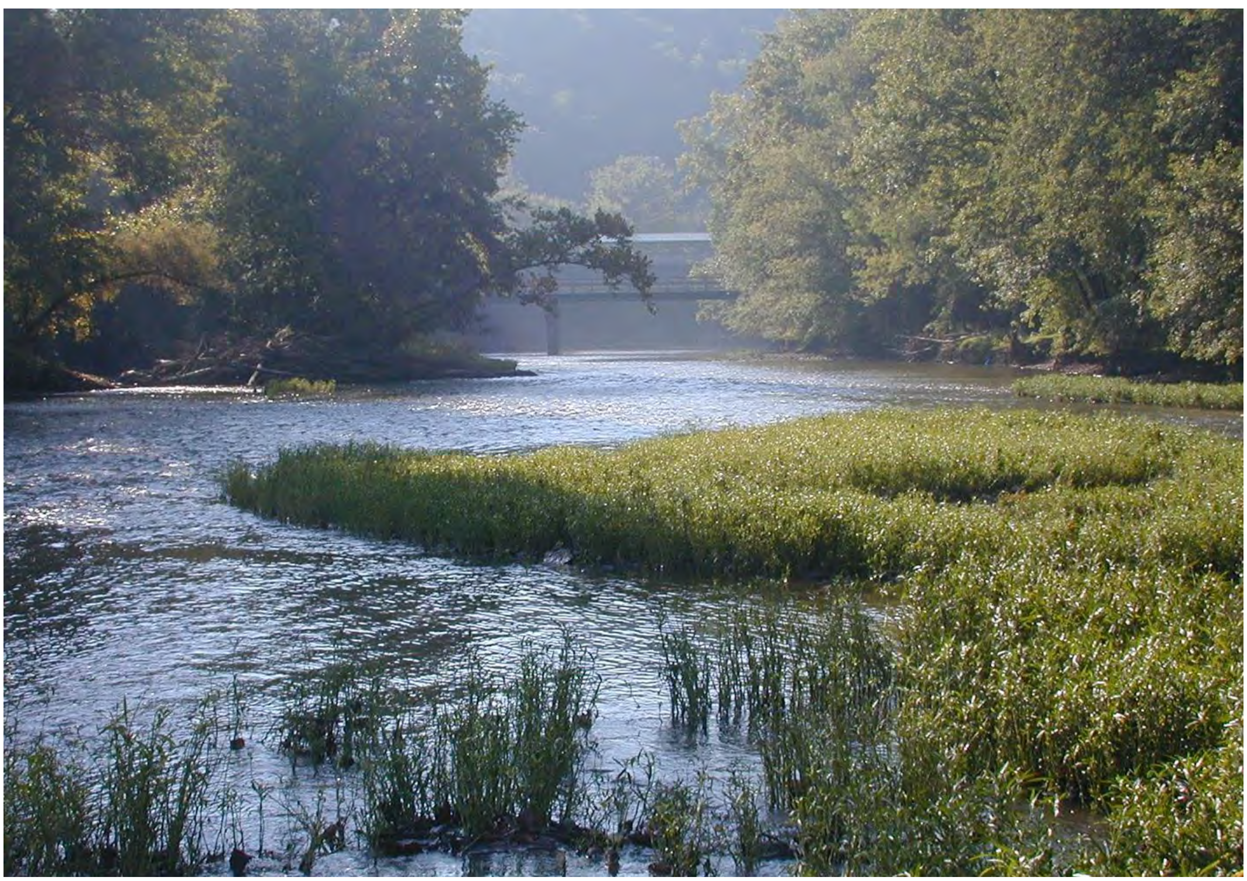


Figure 70. The Mohican River in northeastern Ohio—a candidate for OSW classification because of its high quality ecological and recreational attributes.

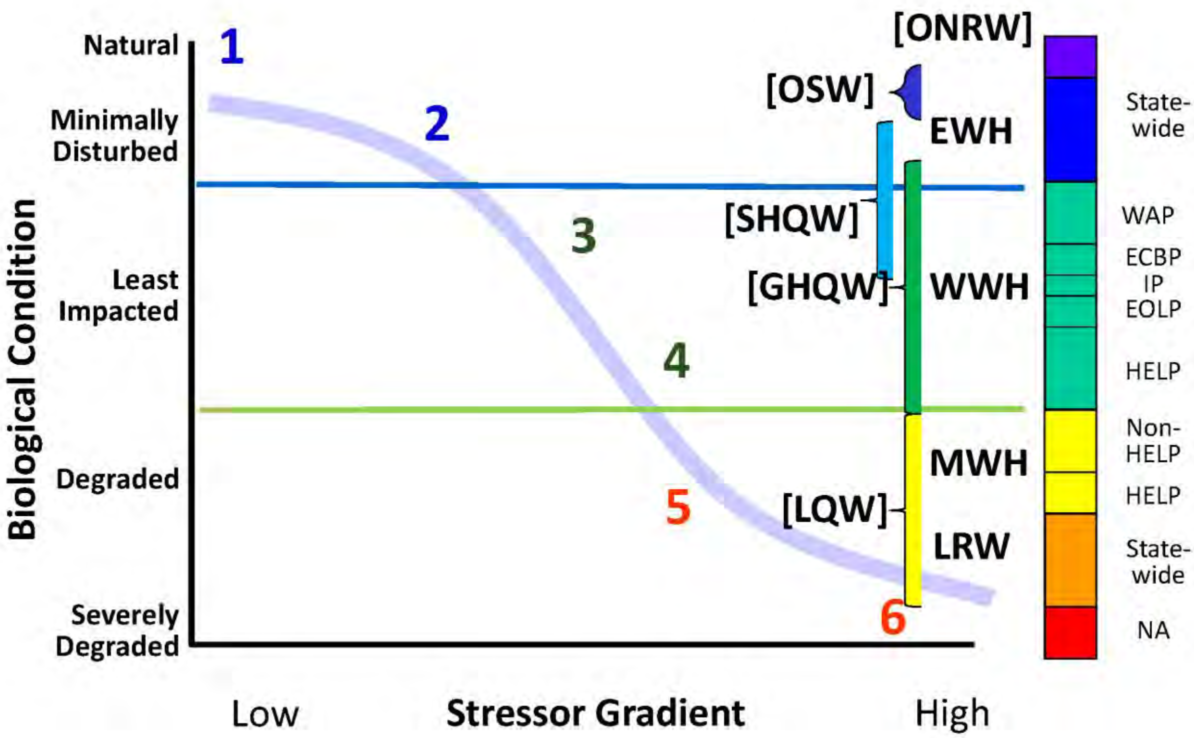


Figure 71. Mapping the Ohio antidegradation tiers to the BCG relating descriptions of condition along the y1-axis and ranges of condition encompassed by the numerical biological criteria for each of four tiered use subcategories and the four antidegradation tiers along the y2-axis. ONRW – Outstanding National Resource Waters; OSW – Outstanding State Waters; SHQW – Superior High Quality Waters; GHQW – Generally High Quality Waters; LQW – Low Quality Waters; EWH – Exceptional Warmwater Habitat; WWH – Warmwater Habitat; MWH – Modified Warmwater Habitat; LRW – Limited Resource Waters.

benefits, or services. The ability of streams and rivers to provide these beneficial services and to act as environmental sentinels is reduced whenever their integrity is degraded. Under the Ohio antidegradation rule, a portion of the remaining assimilative capacity is reserved for water bodies classified as OSW or SHQW in order to preserve an already existing high quality.

Ohio uses a number of biological and physical attributes to place river and stream segments into the OSW, SHQW, and GHQW antidegradation tiers (Table 41). Included are the presence of state or federally listed endangered and threatened species, declining fish species (as defined in the antidegradation rules), the fish and macroinvertebrate assemblage indices (IBI and ICI), the QHEI, the vulnerability of the river or stream to increased stressors, the relative abundance of fish species sensitive to pollution and habitat destruction, and the accumulation of multiple attributes. Adjustments are also made for the Lake Erie drainage to account for the fewer endemic fish and mussel species. Additional considerations include other designations, such as state and national scenic river status, outstanding biodiversity among all aquatic assemblages, exceptionally high quality habitat, and the presence of unique landforms along geological and geomorphological boundaries.

Table 41. General guidelines for nominating OSW, SHQW, and GHQW categories in Ohio. Attributes are considered both singly and in the aggregate

Attribute	OSW	SHQW	GHQW

Attribute	OSW	SHQW	GHQW
Endangered & Threatened Species	Multiple species; large populations; include the most vulnerable species	Present, smaller populations; may include less vulnerable species	Absent or, if present, small populations or of low vulnerability
Declining Fish Species	> 4 declining fish species/segment; large populations	2–4 declining fish species/segment; moderate populations	< 2 declining fish species/segment; typically small populations
IBI and ICI	High mean scores; very high max scores (> 56)	Lower mean scores; fewer high max scores or, if more high scores, few other attributes	Lower mean scores; few or no very high max scores
QHEI	High percentage of QHEI scores ≥ 80	Fewer QHEI scores ≥ 80, many above 70	Few or no QHEI scores ≥ 80, fewer above 70
Vulnerability	Little wastewater effluent; high vulnerability	May be more wastewater effluent; moderate vulnerability	Lower vulnerability; for vulnerable components, antidegradation application may still be denied
Relative Abundance of Fish Species Sensitive to Pollution and Habitat Destruction	Relative abundance is ≥ 3 standard deviations compared to statewide collections of similar sized streams	Relative abundance is ≥ 2 standard deviations compared to statewide collections of similar sized streams	Relative abundance is < 2 standard deviations compared to statewide collections of similar sized streams
Multiple Attributes	High co-occurrence of above attributes	Lower co-occurrence of above attributes or individual attributes more marginal	Little co-occurrence of above attributes, individual attributes often marginal if present

6.6.6 Conclusion

The Ohio approach to classifying waters based on current ecological condition and potential for improvement provides a direct linkage to the CWA biological Integrity objective and ALU goals. This direct linkage enables more effective communication with stakeholders and water quality management decision makers on current conditions and likelihood for improvements. The BCG-like approach enables Ohio EPA to account for biological expectations relative to ecoregion and drainage area and provides a numeric value that synthesizes everything that is being experienced by the biota that can be tracked, monitored, and compared over time to determine if conditions are improving, stabilizing, or deteriorating. As chemical, physical, and biological monitoring has been coordinated and the database expanded, critical information for investigating cause and source of biological impairments has been built and has enabled water quality managers to target sources of stressors and their mechanism of action on the aquatic ecosystem. Because of this database, the state has been able to develop water quality goals for some parameters less well-suited to the classic dose-response relationship for DO and many toxicants. Ohio's ecologically-based approach to classifying waters combined with a robust monitoring program has provided a scientifically defensible method to categorize waters into designated uses and antidegradation tiers. The process has generated UAAs and justification documents as an accepted and routine rulemaking process, primarily resulting in incremental upgrades as controls and BMPs were implemented and improvements observed.

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Glossary

aquatic assemblage	An association of interacting populations of organisms in a given water body; for example, fish assemblage or a benthic macroinvertebrate assemblage.
aquatic community	An association of interacting assemblages in a water body, the biotic component of an ecosystem.
aquatic life use	A beneficial use designation in which the water body provides, for example, suitable habitat for survival and reproduction of desirable fish, shellfish, and other aquatic organisms.
attribute	The measurable part or process of a biological system.
benthic macroinvertebrates or benthos	Animals without backbones, living in or on the sediments, of a size large enough to be seen by the unaided eye and which can be retained by a U.S. Standard no. 30 sieve (28 meshes per inch, 0.595-mm openings); also referred to as benthos, infauna, or macrobenthos.
best management practice	An engineered structure or management activity, or combination of those, that eliminates or reduces an adverse environmental effect of a pollutant.
biological assessment or bioassessment	An evaluation of the biological condition of a water body using surveys of the structure and function of a community of resident biota.
biological criteria or biocriteria	Narrative expressions or numeric values of the biological characteristics of aquatic communities based on appropriate reference conditions; as such, biological criteria serve as an index of aquatic community health.
biological indicator or bioindicator	An organism, species, assemblage, or community characteristic of a particular habitat, or indicative of a particular set of environmental conditions.
biological integrity	The ability of an aquatic ecosystem to support and maintain a balanced, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitats in a region.
biological monitoring or biomonitoring	Use of a biological entity as a detector and its response as a measure to determine environmental conditions; ambient biological surveys and toxicity tests are common biological monitoring methods.
biological survey or biosurvey	Collecting, processing, and analyzing a representative portion of the resident aquatic community to determine its structural and/or functional characteristics.

biotope	An area that is relatively uniform in physical structure and that is identified by a dominant biota.
catchment	An incremental watershed that drains directly into a stream reach and excludes upstream areas.
Clean Water Act	The act passed by the U.S. Congress to control water pollution (formally referred to as the Federal Water Pollution Control Act of 1972). Public Law 92-500, as amended. 33 U.S.C. 1251 *et seq*.
Clean Water Act section 303(d)	This section of the act requires states, territories, and authorized tribes to develop lists of impaired waters for which applicable WQS are not being met, even after point sources of pollution have installed the minimum required levels of pollution control technology. The law requires that the jurisdictions establish priority rankings for waters on the lists and develop TMDLs for the waters. States, territories, and authorized tribes are to submit their lists of waters on April 1 in every even-numbered year.
Clean Water Act section 305(b)	Biennial reporting requires description of the quality of the nation's surface waters, evaluation of progress made in maintaining and restoring water quality, and description of the extent of remaining problems.
Clean Water Act section 304(a) criteria	EPA-published, recommended water quality criteria that consist of scientific information regarding concentrations of specific chemicals or levels of parameters in water that protect aquatic life and human health. The States may use these contents as the basis for developing enforceable water quality standards.
criteria	Elements of state water quality standards, expressed as constituent concentrations, levels, or narrative statements, representing a quality of water that supports a particular use. When criteria are met, water quality will generally protect the designated use.
designated uses	Those uses specified in WQS for each water body or segment whether or not they are being attained.
disturbance	Human activity that alters the natural state and can occur at or across many spatial and temporal scales.
ecological integrity	The condition of an unimpaired ecosystem as measured by combined chemical, physical (including physical habitat), and biological attributes. Ecosystems have integrity when they have their native components (plants, animals and other organisms) and processes (such as growth and reproduction) intact.

ecoregion	A relatively homogeneous ecological area defined by similarity of climate, landform, soil, potential natural vegetation, hydrology, or other ecologically relevant variables.
function	Processes required for normal performance of a biological system (may be applied to any level of biological organization).
guild	A group of organisms that exhibit similar habitat requirements and that respond in a similar way to changes in their environment.
historical data	Data sets from previous studies, which can range from handwritten field notes to published journal articles.
index of biological/biotic integrity	An integrative expression of site condition across multiple metrics; an IBI is often composed of at least seven metrics.
invasive species	A species whose presence in the environment causes economic or environmental harm or harm to human health. Native species or nonnative species can show invasive traits, although that is rare for native species and relatively common for nonnative species. (Note that this term is not included in the biological condition gradient [BCG].)
least disturbed condition	The best available existing conditions with regard to physical, chemical, and biological characteristics or attributes of a water body within a class or region. Such waters have the least amount of human disturbance in comparison to others in the water body class, region, or basin. Least disturbed conditions can be readily found but can depart significantly from natural, undisturbed conditions or minimally disturbed conditions. Least disturbed condition can change significantly over time as human disturbances change.
maintenance of populations	Sustained population persistence; associated with locally successful reproduction and growth.
metric	A calculated term or enumeration that represents some aspect of biological assemblage, function, or other measurable aspect and is a characteristic of the biota that changes in some predictable way with increased human influence.
minimally disturbed condition	The physical, chemical, and biological conditions of a water body with very limited, or minimal, human disturbance.
multimetric index	An index that combines indicators, or metrics, into a single index value. Each metric is tested and calibrated to a scale and transformed into a unitless score before being aggregated into a multimetric index. Both the index and metrics are useful in assessing and diagnosing ecological condition. See **index of biological/biotic integrity (IBI).**

narrative biological criteria	Written statements describing the structure and function of aquatic communities in a water body that support a designated aquatic life use.
native	An original or indigenous inhabitant of a region; naturally present.
nonnative or intentionally introduced species	With respect to an ecosystem, any species that is not found in that ecosystem; species introduced or spread from one region of the United States to another outside their normal range are nonnative or non-indigenous, as are species introduced from other continents.
numeric biological criteria	Specific quantitative measures of the structure and function of aquatic communities in a water body necessary to protect a designated aquatic life use.
periphyton	A broad organismal assemblage composed of attached algae, bacteria, their secretions, associated detritus, and various species of microinvertebrates.
rapid bioassessment protocols	Cost-effective techniques used to survey and evaluate the aquatic community to detect aquatic life impairments and their relative severity.
rebuttable presumption	In the context of water quality standards, the concept that the CWA 101(a)(2) uses are attainable and therefore must be assigned to a water body, unless a State or Tribe affirmatively demonstrates, with appropriate documentation, that such uses are not attainable.
recovery potential	In the context of water quality management, the likelihood that an impaired water body can be restored so that it ultimately meets water quality standards. Consideration of ecological, stressor, and social factors are involved in the consideration of recovery potential.

reference condition (biological integrity)	The condition that approximates natural, unaffected conditions (biological, chemical, physical, and such) for a water body. Reference condition (biological integrity) is best determined by collecting measurements at a number of sites in a similar water body class or region undisturbed by human activity, if they exist. Because undisturbed conditions can be difficult or impossible to find, minimally or least disturbed conditions, combined with historical information, models, or other methods can be used to approximate reference condition as long as the departure from natural or ideal is understood. Reference condition is used as a benchmark to determine how much other water bodies depart from this condition because of human disturbance. See definitions for minimally and least disturbed condition
reference site	A site selected for comparison with sites being assessed. The type of site selected and the types of comparative measures used will vary with the purpose of the comparisons. For the purposes of assessing the ecological condition of sites, a reference site is a specific locality on a water body that is undisturbed or minimally disturbed and is representative of the expected ecological integrity of other localities on the same water body or nearby water bodies.
refugia	Accessible microhabitats or regions in a stream reach or watershed where adequate conditions for organism survival are maintained during circumstances that threaten survival; for example, drought, flood, temperature extremes, increased chemical stressors, habitat disturbance.
sensitive taxa	Taxa intolerant to a given anthropogenic stress; first species affected by the specific stressor to which they are *sensitive* and the last to recover following restoration.
sensitive or regionally endemic taxa	Taxa with restricted, geographically isolated distribution patterns (occurring only in a locale as opposed to a region), often because of unique life history requirements. Can be long-lived, late-maturing, low-fecundity, limited-mobility, or require mutualist relation with other species. Can be among listed endangered/threatened or special concern species. Predictability of occurrence often low; therefore, requires documented observation. Recorded occurrence can be highly dependent on sample methods, site selection, and level of effort.

sensitive-rare taxa Taxa that naturally occur in low numbers relative to total population density but can make up large relative proportion of richness. Can be ubiquitous in occurrence or can be restricted to certain micro-habitats, but because of low density, recorded occurrence is dependent on sample effort. Often stenothermic (having a narrow range of thermal tolerance) or coldwater obligates; commonly K-strategists (populations maintained at a fairly constant level; slower development; longer life span). Can have specialized food resource needs or feeding strategies. Generally intolerant to significant alteration of the physical or chemical environment; are often the first taxa observed to be lost from a community.

sensitive-ubiquitous taxa Taxa ordinarily common and abundant in natural communities when conventional sample methods are used. Often having a broader range of thermal tolerance than sensitive or rare taxa. These are taxa that constitute a substantial portion of natural communities and that often exhibit negative response (loss of population, richness) at mild pollution loads or habitat alteration.

stressors Physical, chemical, and biological factors that adversely affect aquatic organisms.

structure Taxonomic and quantitative attributes of an assemblage or community, including species richness and relative abundance structurally and functionally redundant attributes of the system and characteristics, qualities, or processes that are represented or performed by more than one entity in a biological system.

taxa A grouping of organisms given a formal taxonomic name such as species, genus, family, and the like.

taxa of intermediate tolerance Taxa that compose a substantial portion of natural communities; can be r-strategists (early colonizers with rapid turnover times; boom/bust population characteristics). Can be eurythermal (having a broad thermal tolerance range). Can have generalist or facultative feeding strategies enabling utilization of relatively more diversified food types. Readily collected with conventional sample methods. Can increase in number in waters with moderately increased organic resources and reduced competition but are intolerant of excessive pollution loads or habitat alteration.

tolerant taxa Taxa that compose a small proportion of natural communities. They are often tolerant of a broader range of environmental conditions and are thus resistant to a variety of pollution- or habitat-induced stresses. They can increase in number (sometimes greatly) in the absence of competition. Commonly r-strategists (early colonizers with rapid turnover times; boom/bust population characteristics), able to capitalize when stress conditions occur; last survivors.

total maximum daily load The sum of the allowable loads of a single pollutant from all contributing point and nonpoint sources; the calculated maximum amount of a pollutant a water body can receive and still meet WQS and an allocation of that amount to the pollutant's source.

water quality management (nonregulatory) Decisions on management activities relevant to a water resource, such as problem identification, need for and placement of best management practices, pollution abatement actions, and effectiveness of program activity.

water quality standard A law or regulation that consists of the designated use or uses of a water body, the narrative or numerical water quality criteria (including biological criteria) that are necessary to protect the use or uses of that water body, and antidegradation requirements.

whole effluent toxicity The aggregate toxic effect of an aqueous sample (e.g., whole effluent wastewater discharge) as measured by an organism's response after exposure to the sample (e.g., lethality, impaired growth or reproduction); WET tests replicate the total effect and actual environmental exposure of aquatic life to toxic pollutants in an effluent without requiring the identification of the specific pollutants.

Abbreviations and Acronyms

ADEM	Alabama Department of Environmental Management
AIS	aquatic invasive species
ALAWADR	Alabama Water-Quality Assessment and Monitoring Data Repository
ALU	aquatic life use
ANOVA	univariate analysis of variance
aRPD	apparent redox potential discontinuity
ATtiLA	Analytical Tools Interface for Landscape Assessments
AUSRIVAS	AUStralian RIVer Assessment System
BCG	biological condition gradient
BEAST	BEnthic Assessment of SedimenT
BMP	best management practice
BT	brook trout
CADDIS	Causal Analysis/Diagnosis Decision Information System
CART	classification and regression tree (statistical analysis)
CBP	Chesapeake Bay Program
CCA	Canonical Correspondence Analysis
CFR	*Code of Federal Regulations*
CIBI	Continuous Index of Biological Integrity
CNMI	Commonwealth of the Northern Mariana Islands
CRW	Coral Reef Watch, NOAA
CT DEEP	Connecticut Department of Energy and Environmental Protection
Cu	copper
CWA	Clean Water Act
CWH	coldwater habitat
DELT	deformities, erosion, lesions, and tumors
D-IBI	diadromous index of biotic integrity
DO	dissolved oxygen
EDAS	Environmental Data Acquisition System
EMAP	Environmental Monitoring and Assessment Program
EPA	U.S. Environmental Protection Agency
EPT	ephemeroptera, plecoptera, trichoptera taxa
ESD	environmental site design
E/T	endangered/threatened
EV	exceptional value
FACI	Fish Assessment Community Index
F-IBI	fish index of biological/biotic integrity
GAM	general additive model
GHQW	General High Quality Water

GLEI	Great Lakes Environmental Indicators
GRE	Great Rivers Evaluation
GRFIn	Great River Fish Index
GSA	generalized stress axis
HDG	human disturbance gradient
HDS	human disturbance score
HQ	high-quality
HUC	hydrologic unit code
HWI	Healthy Watershed Index
IBI	index of biological/biotic integrity
IC	impervious cover
ICI	invertebrate community integrity index
LDI	landscape development intensity index
LDM	linear discriminant model
LRBOI	Little River Band of Ottawa Indians
LRW	limited resource water
LWD	large, woody debris
MANOVA	multivariate analysis of variance
MCDEP	Montgomery County Department of Environmental Protection
MEDEP	Maine Department of Environmental Protection
M-IBI	macroinvertebrate index of biological/biotic integrity
mIBI	modified index of biological integrity
MIwb	modified index of well-being
MMI	multimetric index
M-NCPPC	Maryland-National Capital Park and Planning Commission
MPCA	Minnesota Pollution Control Agency
MWH	modified warmwater habitat
NA	non-attainment
NBEP	Narragansett Bay Estuary Program
NCRMP	National Coral Reef Monitoring Program
NELP	New England large rivers
NHD	National Hydrography Dataset
NIH	National Institutes of Health
NJ DEP	New Jersey Department of Environmental Protection
NLCD	National Land Cover Database
NMDS	non-metric multidimensional scaling
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRC	National Research Council
O/E	observed over expected
OM	organic matter

ONRW	Outstanding National Resource Water
OSI	Organism-Sediment Index
OSW	Outstanding State Water
PA DEP	Pennsylvania Department of Environmental Protection
PAR	photosynthetic active radiation
PCA	Principal Component Analysis
QHEI	qualitative habitat evaluation index
POM	particulate organic matter
REMAP	Regional Environmental Monitoring and Assessment Program
RIDEM	Rhode Island Department of Environmental Management
RIVPACS	River Invertebrate Prediction and Classification System
RM	river mile
RPS	Recovery Potential Screening
SHQW	Superior High Quality Water
SPI	sediment profile imagery
SST	sea surface temperature
STORET	STOrage and RETrieval
TALU	tiered aquatic life use
TBEP	Tampa Bay Estuary Program
TITAN	Threshold Indicator Taxa ANalysis
TIV	Tolerance Indicator Value
TMC	Ten Mile Creek
TMDL	Total Maximum Daily Load
TNC	The Nature Conservancy
UAA	use attainability analysis
UMRBA	Upper Mississippi River Basin Association
UMR	Upper Mississippi River
USVI	U.S. Virgin Islands
WDG	watershed disturbance gradient
WSIO	Watershed Index Online
WQS	water quality standards
WQTF	Water Quality Task Force
WQV	Weighted Stressor Value
WWH	warmwater habitat
WWTF	wastewater treatment facility

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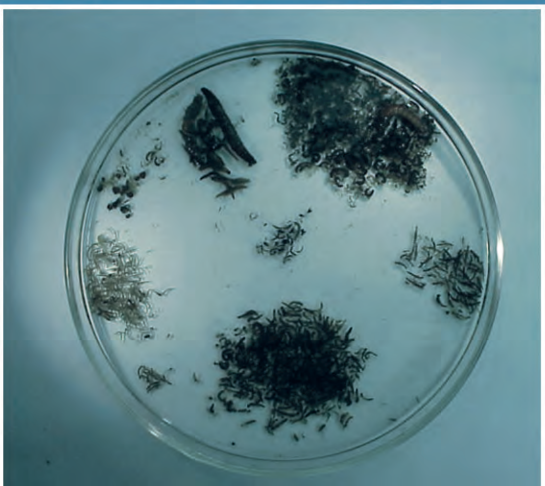
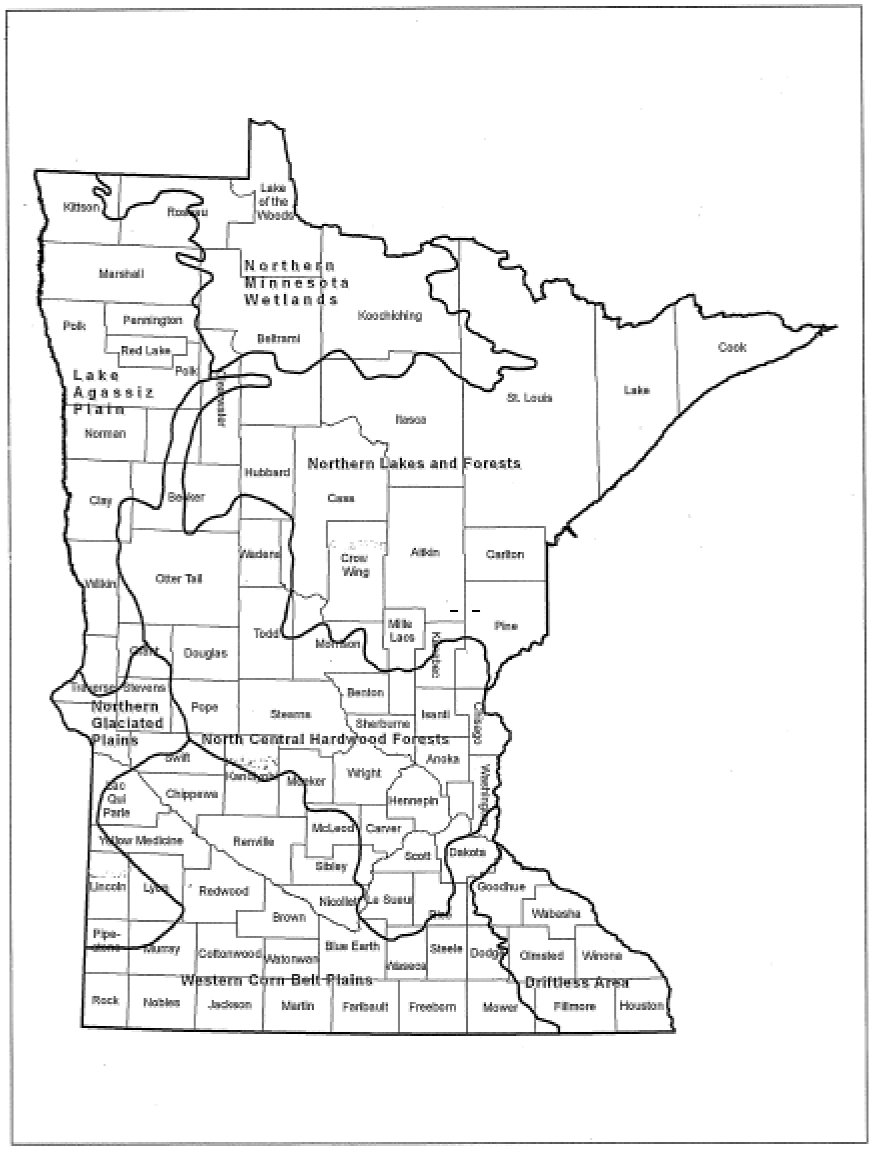



7050.0468 MAP: MINNESOTA ECOREGIONS.



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7050.0150 DETERMINATION OF WATER QUALITY, BIOLOGICAL AND PHYSICAL CONDITIONS, AND COMPLIANCE WITH STANDARDS.

Subpart 1. **Policy and scope.** The intent of the state is to protect and maintain surface waters in a condition which allows for the maintenance of all existing beneficial uses. The condition of a surface water body is determined by its physical, chemical, and biological qualities. The agency shall determine an exceedance of water quality standards or an impaired condition based on pollution of the waters of the state from point and nonpoint sources that has resulted in degradation of the physical, chemical, or biological qualities of the water body to the extent that attainable or previously existing beneficial uses are actually or potentially lost.

The narrative water quality standards in subpart 3 prescribe the qualities or properties of surface waters that are necessary for the protection of designated public uses and benefits. If the narrative standards in this part are exceeded, it is considered indicative of a polluted condition which is actually or potentially deleterious, harmful, detrimental, or injurious with respect to the designated uses of the waters of the state.

Subparts 5 to 7 list factors the commissioner will use to determine if surface waters are in compliance with applicable narrative standards in subpart 3. Determination of compliance with the narrative standards will be made for individual water bodies on a case-by-case basis.

Subp. 2. **Other standards preserved.** The requirements of this part are in addition to the application of other narrative or numeric water quality standards in this chapter. If the requirements of this part conflict with any other narrative or numeric standard in this chapter, the more stringent standard applies.

Subp. 3. **Narrative standards.** For all Class 2 waters, the aquatic habitat, which includes the waters of the state and stream bed, shall not be degraded in any material manner, there shall be no material increase in undesirable slime growths or aquatic plants, including algae, nor shall there be any significant increase in harmful pesticide or other residues in the waters, sediments, and aquatic flora and fauna; the normal fishery and lower aquatic biota upon which it is dependent and the use thereof shall not be seriously impaired or endangered, the species composition shall not be altered materially, and the propagation or migration of the fish and other biota normally present shall not be prevented or hindered by the discharge of any sewage, industrial waste, or other wastes to the waters.

Subp. 4. **Definitions.** For the purposes of this chapter and chapter 7053, the following terms have the meanings given them.

A. "122-day ten-year low flow" or "$122Q_{10}$" means the lowest average 122-day flow with a once in ten-year recurrence interval. A $122Q_{10}$ is derived using the same methods used to derive a $7Q_{10}$, and the guidelines regarding period of record for flow data and estimating a $7Q_{10}$ apply equally to determining a $122Q_{10}$, as described in part 7050.0130, subpart 3.

B. "Altered materially," "material increase," "material manner," "seriously impaired," and "significant increase," as used in subparts 3, 5, and 6, mean that pollution of the waters of the state has resulted in degradation of the physical, chemical, or biological qualities of the water body to the extent that attainable or previously existing beneficial uses are actually or potentially lost.

C. "BOD_5" or "five-day biochemical oxygen demand" means the amount of dissolved oxygen needed by aerobic biological organisms to break down organic material present in a given water sample at a certain temperature over a five-day period.

D. "Chlorophyll-a" means a pigment in green plants including algae. The concentration of chlorophyll-a, expressed in weight per unit volume of water, is a measurement of the abundance of algae.

E. "Diel flux" means the daily change in a constituent, such as dissolved oxygen or pH, when there is a distinct daily cycle in the measurement. Diel dissolved oxygen flux means the difference between the maximum daily dissolved oxygen concentration and the minimum daily dissolved oxygen concentration.

F. "Ecoregion" means an area of relative homogeneity in ecological systems based on similar soils, land use, land surface form, and potential natural vegetation. Minnesota ecoregions are shown on the map in part 7050.0468.

G. "Eutrophication" means the increased productivity of the biological community in water bodies in response to increased nutrient loading. Eutrophication is characterized by increased growth and abundance of algae and other aquatic plants, reduced water transparency, reduction or loss of dissolved oxygen, and other chemical and biological changes. The acceleration of eutrophication due to excess nutrient loading from human sources and activities, called cultural eutrophication, causes a degradation of water quality and possible loss of beneficial uses.

H. "Eutrophication standard" means the combination of indicators of enrichment and indicators of response as described in subpart 5. The indicators upon which the eutrophication standard for specific water bodies are based are as provided under subparts 5a to 5c.

I. "Fish and other biota" and "lower aquatic biota" mean the aquatic community including, but not limited to, game and nongame fish, minnows and other small fish, mollusks, insects, crustaceans and other invertebrates, submerged or emergent rooted vegetation, suspended or floating algae, substrate-attached algae, and microscopic organisms. "Other biota" includes aquatic or semiaquatic organisms that depend on aquatic systems for food or habitat such as amphibians and certain wildlife species.

J. "Hydraulic residence time" means the time water resides in a basin or, alternately, the time it would take to fill the basin if it were empty.

K. "Impaired water" or "impaired condition" means a water body that does not meet applicable water quality standards or fully support applicable beneficial uses, due in whole or in part to water pollution from point or nonpoint sources, or any combination thereof.

L. "Index of biological integrity" or "IBI" means an index developed by measuring attributes of an aquatic community that change in quantifiable and predictable ways in response to human disturbance, representing the health of that community.

M. "Lake" means an enclosed basin filled or partially filled with standing fresh water with a maximum depth greater than 15 feet. Lakes may have no inlet or outlet, an inlet or outlet, or both an inlet and outlet.

N. "Lake morphometry" means the physical characteristics of the lake basin that are reasonably necessary to determine the shape of a lake, such as maximum length and width, maximum and mean depth, area, volume, and shoreline configuration.

O. "Mixing status" means the frequency of complete mixing of the lake water from surface to bottom, which is determined by whether temperature gradients are established and maintained in the water column during the summer season.

P. "Measurable increase" or "measurable impact" means a change in trophic status that can be discerned above the normal variability in water quality data using a weight of evidence approach. The change in trophic status does not require a demonstration of statistical significance to be considered measurable. Mathematical models may be used as a tool in the data analysis to help predict changes in trophic status.

Q. "Natural causes" means the multiplicity of factors that determine the physical, chemical, or biological conditions that would exist in a water body in the absence of measurable impacts from human activity or influence.

R. "Normal fishery" and "normally present" mean the fishery and other aquatic biota expected to be present in the water body in the absence of pollution of the water, consistent with any variability due to natural hydrological, substrate, habitat, or other physical and chemical characteristics. Expected presence is based on comparing the aquatic community in the water body of interest to the aquatic community in representative reference water bodies.

S. "Nuisance algae bloom" means an excessive population of algae that is characterized by obvious green or blue-green pigmentation in the water, floating mats of algae, reduced light transparency, aesthetic degradation, loss of recreational use, possible harm to the aquatic community, or possible toxicity to animals and humans. Algae blooms are measured through tests for chlorophyll-a, observations of Secchi disk transparency, and observations of impaired recreational and aesthetic conditions by the users of the water body, or any other reliable data that identifies the population of algae in an aquatic community.

T. "Periphyton" means algae on the bottom of a water body. In rivers or streams, these forms are typically found attached to logs, rocks, or other substrates, but when dislodged the algae will become part of the seston.

U. "Readily available and reliable data and information" means chemical, biological, and physical data and information determined by the commissioner to meet the quality assurance and quality control requirements in subpart 8, that are not more than ten years old from the time they are used for the assessment. A subset of data in the ten-year period, or data more than ten years old can be used if credible scientific evidence shows that these data are representative of current conditions.

V. "Reference water body" means a water body least impacted by point or nonpoint sources of pollution that is representative of water bodies in the same ecoregion or watershed. Reference water bodies are used as a base for comparing the quality of similar water bodies in the same ecoregion or watershed.

W. "Reservoir" means a body of water in a natural or artificial basin or watercourse where the outlet or flow is artificially controlled by a structure such as a dam. Reservoirs are distinguished from river systems by having a hydraulic residence time of at least 14 days. For purposes of this item, residence time is determined using a flow equal to the $122Q_{10}$ for the months of June through September.

X. "River nutrient region" means the geographic basis for regionalizing the river eutrophication criteria as described in Heiskary, S. and K. Parson, Regionalization of Minnesota's Rivers for Application of River Nutrient Criteria, Minnesota Pollution Control Agency (2013), which is incorporated by reference. The document is not subject to frequent change and is available through the Minitex interlibrary loan system.

Y. "Secchi disk" means a tool that is used to measure the transparency of lake water. A Secchi disk is an eight-inch weighted disk on a calibrated rope, either white or with quadrants of black and white. To measure water transparency with a Secchi disk, the disk is viewed from the shaded side of a boat. The depth of the water at the point where the disk reappears upon raising it after it has been lowered beyond visibility is recorded.

Z. "Secchi disk transparency" means the transparency of water as measured by either a Secchi disk, a Secchi tube, or a transparency tube.

AA. "Secchi tube" means a tool that is used to measure the transparency of stream or river water. A Secchi tube is a clear plastic tube, one meter in length and 1-3/4 inch in diameter, with a mini-Secchi disk on a string. To measure water transparency, the tube is filled with water collected from a stream or river and, looking into the tube from the top, the weighted Secchi disk is lowered into the tube by a string until it disappears and then raised until it reappears, allowing the user to raise and lower the disk within the same water sample numerous times. The depth of the water at the midpoint between disappearance and reappearance of the disk is recorded in centimeters, which are marked on the side of the tube. If the Secchi disk is visible when it is lowered to the bottom of the tube, the transparency reading is recorded as "greater than 100 centimeters."

BB. "Seston" means particulate matter suspended in water bodies and includes plankton and organic and inorganic matter.

CC. "Shallow lake" means an enclosed basin filled or partially filled with standing fresh water with a maximum depth of 15 feet or less or with 80 percent or more of the lake area shallow enough to support emergent and submerged rooted aquatic plants (the littoral zone). It is uncommon for shallow lakes to thermally stratify during the summer. The quality of shallow lakes will permit the propagation and maintenance of a healthy indigenous aquatic community and they will be suitable for boating and other forms of aquatic recreation for which they may be usable. Shallow lakes are differentiated from wetlands and lakes on a case-by-case basis. Wetlands are defined in part 7050.0186, subpart 1a.

DD. "Summer-average" means a representative average of concentrations or measurements of nutrient enrichment factors, taken over one summer season.

EE. "Summer season" means a period annually from June 1 through September 30.

FF. "Transparency tube" means a tool that is used to measure the transparency of stream or river water. A transparency tube is a graduated clear plastic tube, 24 inches or more in length by 1-1/2 inches in diameter, with a stopper at the bottom end. The inside surface of the stopper is painted black and white. To measure water transparency, the tube is filled with water from a surface water; the water is released through a valve at the bottom end until the painted surface of the stopper is just visible through the water column when viewed from the top of the tube. The depth, in centimeters, is noted. More water is released until the screw in the middle of the painted symbol on the stopper is clearly visible; this depth is noted. The two observed depths are averaged to obtain a transparency measurement.

GG. "Trophic status or condition" means the productivity of a lake as measured by the phosphorus content, algae abundance, and depth of light penetration.

HH. "Water body" means a lake, reservoir, wetland, or a geographically defined portion of a river or stream.

Subp. 5. **Impairment of waters due to excess algae or plant growth.** In evaluating whether the narrative standards in subpart 3, which prohibit any material increase in undesirable slime growths or aquatic plants including algae, are being met, the commissioner will use all readily available and reliable data and information for the following factors of use impairment:

A. representative summer-average concentrations of total phosphorus and total nitrogen measured in the water body;

B. representative summer-average concentrations of chlorophyll-a seston measured in the water body;

C. representative summer-average measurements of Secchi disk transparency in the water body;

D. representative summer-average concentrations of five-day biochemical oxygen demand measured in rivers and streams;

E. representative diel dissolved oxygen flux measurements in rivers and streams as averaged over a minimum of four consecutive days during the summer season;

F. representative measurements of pH in the water body during the summer season;

G. representative measurements of chlorophyll-a (periphyton) on substrates on the beds of rivers and streams during the summer season; and

H. any other scientifically objective, credible, and supportable factor.

Subp. 5a. **Impaired condition; lakes, shallow lakes, and reservoirs.**

A. For lakes, shallow lakes, and reservoirs, a finding of an impaired condition must be supported by data showing:

(1) elevated levels of nutrients under subpart 5, item A; and

(2) at least one factor showing impaired conditions resulting from nutrient overenrichment under subpart 5, items B and C.

B. The trophic status data described in subpart 5, items A to C and H, must be assessed in light of the magnitude, duration, and frequency of nuisance algae blooms in the water body; and documented impaired recreational and aesthetic conditions observed by the users of the water body due to excess algae or plant growth, reduced transparency, or other deleterious conditions caused by nutrient overenrichment.

C. Assessment of trophic status and the response of a given water body to nutrient enrichment will take into account the trophic status of reference water bodies; and all relevant factors that affect the trophic status of the given water body appropriate for its geographic region, such as the temperature, morphometry, hydraulic residence time, mixing status, watershed size, and location.

Subp. 5b. **Impaired condition; rivers and streams.** For rivers and streams, a finding of an impaired condition must be supported by data showing:

A. elevated levels of nutrients under subpart 5, item A, and at least one factor showing impaired conditions resulting from nutrient overenrichment under subpart 5, item B, D, E, F, or H; or

B. elevated levels of chlorophyll-a (periphyton) under subpart 5, item G.

Subp. 5c. **Impaired condition; navigational pools.** For navigational pools, a finding of impaired condition must be supported by data showing:

A. elevated levels of nutrients under subpart 5, item A; and

B. impaired conditions resulting from nutrient overenrichment under subpart 5, item B.

Subp. 6. **Impairment of biological community and aquatic habitat.** In evaluating whether the narrative standards in subpart 3, which prohibit serious impairment of the normal fisheries and lower aquatic biota upon which they are dependent and the use thereof, material alteration of the species composition, material degradation of stream beds, and the prevention or hindrance of the propagation and migration of fish and other biota normally present, are being met, the commissioner will consider all readily available and reliable data and information for the following factors of use impairment:

A. an index of biological integrity calculated from measurements of attributes of the resident fish community, including measurements of:

(1) species diversity and composition;

(2) feeding and reproduction characteristics; and

(3) fish abundance and condition;

B. an index of biological integrity calculated from measurements of attributes of the resident aquatic invertebrate community, including measurements of:

(1) species diversity and composition;

(2) feeding characteristics; and

(3) species abundance and condition;

C. an index of biological integrity calculated from measurements of attributes of the resident aquatic plant community, including measurements of:

(1) species diversity and composition, including algae; and

(2) species abundance and condition;

D. a quantitative or qualitative assessment of habitat quality, determined by an assessment of:

(1) stream morphological features that provide spawning, nursery, and refuge areas for fish and invertebrates;

(2) bottom substrate size and variety;

(3) variations in water depth;

(4) sinuosity of the stream course;

(5) physical or hydrological alterations of the stream bed including excessive sedimentation;

(6) types of land use in the watershed; and

(7) other scientifically accepted and valid factors of habitat quality; and

E. any other scientifically objective, credible, and supportable factors.

A finding of an impaired condition must be supported by data for the factors listed in at least one of items A to C. The biological quality of any given surface water body will be assessed by comparison to the biological conditions determined for a set of reference water bodies which best represents the most natural condition for that surface water body type within a geographic region.

Subp. 7. **Impairment of waters relating to fish for human consumption.**

A. In evaluating whether the narrative standards in subpart 3, which prevent harmful pesticide or other toxic pollutant residues in aquatic flora or fauna, are being met, the commissioner must use the methods in:

(1) parts 7050.0218 and 7050.0219 for site-specific fish tissue-based chronic criterion (CC_{ft}); or

(2) parts 7050.0222 and 7052.0100 for fish tissue-based chronic standard (CS_{ft}).

B. If CS_{ft} has not been established for a pollutant with chronic standards (CS) applicable in water (CS_{dfr}, CS_{dev}, or CS_{fr}, as defined in parts 7050.0218, subpart 3, item Q, and 7050.0219, subpart 13, item B), the residue levels in fish muscle tissue established by the Minnesota Department of Health must be used to identify surface waters supporting fish for which the Minnesota Department of Health recommends a reduced frequency of fish consumption for the protection of public health. A water body will be considered impaired when the recommended consumption frequency is less than one meal per week, such as one meal per month, for any member of the population. That is, a water body will not be considered impaired if the recommended consumption frequency is one meal per week, or any less restrictive recommendation such as two meals per week, for all members of the population. The impaired condition must be supported with measured data on the contaminant levels in the resident fish.

C. When making impairment determinations in an individual water body for a pollutant with both a fish tissue-based CC_{ft} or CS_{ft} and a CS applicable in water, comparison of fish tissue data to the CC_{ft} or CS_{ft} must be the basis for the final impairment determination.

Subp. 8. **Determination of compliance.** In making tests or analyses of the waters of the state, sewage, industrial wastes, or other wastes to determine compliance with the standards and water quality condition, samples shall be collected in a manner and place, and of such type, number, and frequency as may be considered necessary by the agency from the viewpoint of adequately reflecting the condition of the waters, the composition of the effluents, and the effects of the pollutants upon the specified uses. The samples shall be collected, preserved, and analyzed following accepted quality control and quality assurance methods, and according to the procedures in Code of Federal Regulations, title 40, part 136. The agency may accept or may develop other methods, procedures, guidelines, or criteria for collecting and analyzing samples and measuring water quality characteristics. The commissioner will retain a record of all impairment decisions using the factors in this part, including all supporting data, for a minimum of eight years.

Statutory Authority: *MS s 115.03; 115.44; L 2005 1Sp1 art 2 s 151*

History: *9 SR 913; 15 SR 1057; 18 SR 2195; 27 SR 1217; 31 SR 1168; 32 SR 1699; 39 SR 154; 39 SR 1344*

Published Electronically: *March 24, 2015*

7050.0170 NATURAL WATER QUALITY.

The waters of the state may, in a natural condition, have water quality characteristics or chemical concentrations approaching or exceeding the water quality standards. Natural conditions exist where there is no discernible impact from point or nonpoint source pollutants attributable to human activity or from a physical alteration of wetlands. Natural background levels are defined by water quality monitoring. Where water quality monitoring data are not available, background levels can be predicted based on data from a watershed with similar characteristics.

Where natural background levels do not exceed applicable standards, the addition of pollutants from human activity and resulting point or nonpoint source discharges shall be limited such that, in total, the natural background levels and the additions from human activity shall not exceed the standards. When reasonable justification exists to preserve the higher natural quality of a water resource, the commissioner may use the natural background levels that are lower than the applicable site-specific standards to control the addition of the same pollutants from human activity. The reasonable justification must meet the requirements under parts 7050.0180 and 7050.0185.

Where background levels exceed applicable standards, the background levels may be used as the standards for controlling the addition of the same pollutants from point or nonpoint source discharges in place of the standards.

In the adoption of standards for individual waters of the state, the agency will be guided by the standards herein but may make reasonable modifications of the same on the basis of evidence brought forth at a public hearing if it is shown to be desirable and in the public interest to do so in order to encourage the best use of the waters of the state or the lands bordering such waters.

Statutory Authority: *MS s 115.03; 115.44*

History: *9 SR 913; 12 SR 1810; 18 SR 2195*

Published Electronically: *April 1, 2008* among State agencies and with local and Federal agencies.

(v) Procedures for program management and administration including provision of program financing, training and technical assistance, public participation, and emergency management.

(d) *Indian Tribes*. An Indian Tribe is eligible for the purposes of this rule and the Clean Water Act assistance programs under 40 CFR part 35, subparts A and H if:

(1) The Indian Tribe has a governing body carrying out substantial governmental duties and powers;

(2) The functions to be exercised by the Indian Tribe pertain to the management and protection of water resources which are held by an Indian Tribe, held by the United States in trust for Indians, held by a member of an Indian Tribe if such property interest is subject to a trust restriction on alienation, or otherwise within the borders of an Indian reservation; and

(3) The Indian Tribe is reasonably expected to be capable, in the Regional Administrator's judgment, of carrying out the functions to be exercised in a manner consistent with the terms and purposes of the Clean Water Act and applicable regulations.

(e) *Update and certification*. State and/or areawide agency WQM plans shall be updated as needed to reflect changing water quality conditions, results of implementation actions, new requirements or to remove conditions in prior conditional or partial plan approvals. Regional Administrators may require that State WQM plans be updated as needed. State Continuing Planning Processes (CPPs) shall specify the process and schedule used to revise WQM plans. The State shall ensure that State and areawide WQM plans together include all necessary plan elements and that such plans are consistent with one another. The Governor or the Governor's designee shall certify by letter to the Regional Administrator for EPA approval that WQM plan updates are consistent with all other parts of the plan. The certification may be contained in the annual State work program.

(f) *Consistency*. Construction grant and permit decisions must be made in accordance with certified and approved WQM plans as described in §§ 130.12(a) and 130.12(b).

[50 FR 1779, Jan. 11, 1985, as amended at 54 FR 14360, Apr. 11, 1989; 59 FR 13818, Mar. 23, 1994]

§ 130.7 Total maximum daily loads (TMDL) and individual water quality-based effluent limitations.

(a) *General*. The process for identifying water quality limited segments still requiring wasteload allocations, load allocations and total maximum daily loads (WLAs/LAs and TMDLs), setting priorities for developing these loads; establishing these loads for segments identified, including water quality monitoring, modeling, data analysis, calculation methods, and list of pollutants to be regulated; submitting the State's list of segments identified, priority ranking, and loads established (WLAs/LAs/TMDLs) to EPA for approval; incorporating the approved loads into the State's WQM plans and NPDES permits; and involving the public, affected dischargers, designated areawide agencies, and local governments in this process shall be clearly described in the State Continuing Planning Process (CPP).

(b) Identification and priority setting for water quality-limited segments still requiring TMDLs.

(1) Each State shall identify those water quality-limited segments still requiring TMDLs within its boundaries for which:

(i) Technology-based effluent limitations required by sections 301(b), 306, 307, or other sections of the Act;

(ii) More stringent effluent limitations (including prohibitions) required by either State or local authority preserved by section 510 of the Act, or Federal authority (law, regulation, or treaty); and

(iii) Other pollution control requirements (e.g., best management practices) required by local, State, or Federal authority are not stringent enough to implement any water quality standards (WQS) applicable to such waters.

(2) Each State shall also identify on the same list developed under paragraph (b)(1) of this section those water

quality-limited segments still requiring TMDLs or parts thereof within its boundaries for which controls on thermal discharges under section 301 or State or local requirements are not stringent enough to assure protection and propagation of a balanced indigenous population of shellfish, fish and wildlife.

(3) For the purposes of listing waters under §130.7(b), the term "water quality standard applicable to such waters" and "applicable water quality standards" refer to those water quality standards established under section 303 of the Act, including numeric criteria, narrative criteria, waterbody uses, and antidegradation requirements.

(4) The list required under §§130.7(b)(1) and 130.7(b)(2) of this section shall include a priority ranking for all listed water quality-limited segments still requiring TMDLs, taking into account the severity of the pollution and the uses to be made of such waters and shall identify the pollutants causing or expected to cause violations of the applicable water quality standards. The priority ranking shall specifically include the identification of waters targeted for TMDL development in the next two years.

(5) Each State shall assemble and evaluate all existing and readily available water quality-related data and information to develop the list required by §§130.7(b)(1) and 130.7(b)(2). At a minimum "all existing and readily available water quality-related data and information" includes but is not limited to all of the existing and readily available data and information about the following categories of waters:

(i) Waters identified by the State in its most recent section 305(b) report as "partially meeting" or "not meeting" designated uses or as "threatened";

(ii) Waters for which dilution calculations or predictive models indicate nonattainment of applicable water quality standards;

(iii) Waters for which water quality problems have been reported by local, state, or federal agencies; members of the public; or academic institutions. These organizations and groups should be actively solicited for research they may be conducting or reporting. For example, university researchers, the United States Department of Agriculture, the National Oceanic and Atmospheric Administration, the United States Geological Survey, and the United States Fish and Wildlife Service are good sources of field data; and

(iv) Waters identified by the State as impaired or threatened in a nonpoint assessment submitted to EPA under section 319 of the CWA or in any updates of the assessment.

(6) Each State shall provide documentation to the Regional Administrator to support the State's determination to list or not to list its waters as required by §§130.7(b)(1) and 130.7(b)(2). This documentation shall be submitted to the Regional Administrator together with the list required by §§130.7(b)(1) and 130.7(b)(2) and shall include at a minimum:

(i) A description of the methodology used to develop the list; and

(ii) A description of the data and information used to identify waters, including a description of the data and information used by the State as required by §130.7(b)(5); and

(iii) A rationale for any decision to not use any existing and readily available data and information for any one of the categories of waters as described in §130.7(b)(5); and

(iv) Any other reasonable information requested by the Regional Administrator. Upon request by the Regional Administrator, each State must demonstrate good cause for not including a water or waters on the list. Good cause includes, but is not limited to, more recent or accurate data; more sophisticated water quality modeling; flaws in the original analysis that led to the water being listed in the categories in §130.7(b)(5); or changes in conditions, e.g., new control equipment, or elimination of discharges.

(c) Development of TMDLs and individual water quality based effluent limitations.

(1) Each State shall establish TMDLs for the water quality limited segments identified in paragraph (b)(1) of this section, and in accordance with the priority ranking. For pollutants other than heat, TMDLs shall be established

at levels necessary to attain and maintain the applicable narrative and numerical WQS with seasonal variations and a margin of safety which takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality. Determinations of TMDLs shall take into account critical conditions for stream flow, loading, and water quality parameters.

(i) TMDLs may be established using a pollutant-by-pollutant or biomonitoring approach. In many cases both techniques may be needed. Site-specific information should be used wherever possible.

(ii) TMDLs shall be established for all pollutants preventing or expected to prevent attainment of water quality standards as identified pursuant to paragraph (b)(1) of this section. Calculations to establish TMDLs shall be subject to public review as defined in the State CPP.

(2) Each State shall estimate for the water quality limited segments still requiring TMDLs identified in paragraph (b)(2) of this section, the total maximum daily thermal load which cannot be exceeded in order to assure protection and propagation of a balanced, indigenous population of shellfish, fish and wildlife. Such estimates shall take into account the normal water temperatures, flow rates, seasonal variations, existing sources of heat input, and the dissipative capacity of the identified waters or parts thereof. Such estimates shall include a calculation of the maximum heat input that can be made into each such part and shall include a margin of safety which takes into account any lack of knowledge concerning the development of thermal water quality criteria for protection and propagation of a balanced, indigenous population of shellfish, fish and wildlife in the identified waters or parts thereof.

(d) *Submission and EPA approval.* (1) Each State shall submit biennially to the Regional Administrator beginning in 1992 the list of waters, pollutants causing impairment, and the priority ranking including waters targeted for TMDL development within the next two years as required under paragraph (b) of this section. For the 1992 biennial submission, these lists are due no later than October 22, 1992. Thereafter, each State shall submit to EPA lists required under paragraph (b) of this section on April 1 of every even-numbered year. For the year 2000 submission, a State must submit a list required under paragraph (b) of this section only if a court order or consent decree, or commitment in a settlement agreement dated prior to January 1, 2000, expressly requires EPA to take action related to that State's year 2000 list. For the year 2002 submission, a State must submit a list required under paragraph (b) of this section by October 1, 2002, unless a court order, consent decree or commitment in a settlement agreement expressly requires EPA to take an action related to that State's 2002 list prior to October 1, 2002, in which case, the State must submit a list by April 1, 2002. The list of waters may be submitted as part of the State's biennial water quality report required by §130.8 of this part and section 305(b) of the CWA or submitted under separate cover. All WLAs/LAs and TMDLs established under paragraph (c) for water quality limited segments shall continue to be submitted to EPA for review and approval. Schedules for submission of TMDLs shall be determined by the Regional Administrator and the State.

(2) The Regional Administrator shall either approve or disapprove such listing and loadings not later than 30 days after the date of submission. The Regional Administrator shall approve a list developed under §130.7(b) that is submitted after the effective date of this rule only if it meets the requirements of §130.7(b). If the Regional Administrator approves such listing and loadings, the State shall incorporate them into its current WQM plan. If the Regional Administrator disapproves such listing and loadings, he shall, not later than 30 days after the date of such disapproval, identify such waters in such State and establish such loads for such waters as determined necessary to implement applicable WQS. The Regional Administrator shall promptly issue a public notice seeking comment on such listing and loadings. After considering public comment and

making any revisions he deems appropriate, the Regional Administrator shall transmit the listing and loads to the State, which shall incorporate them into its current WQM plan.

(e) For the specific purpose of developing information and as resources allow, each State shall identify all segments within its boundaries which it has not identified under paragraph (b) of this section and estimate for such waters the TMDLs with seasonal variations and margins of safety, for those pollutants which the Regional Administrator identifies under section 304(a)(2) as suitable for such calculation and for thermal discharges, at a level that would assure protection and propagation of a balanced indigenous population of fish, shellfish and wildlife. However, there is no requirement for such loads to be submitted to EPA for approval, and establishing TMDLs for those waters identified in paragraph (b) of this section shall be given higher priority.

[50 FR 1779, Jan. 11, 1985, as amended at 57 FR 33049, July 24, 1992; 65 FR 17170, Mar. 31, 2000; 66 FR 53048, Oct. 18, 2001]

§ 130.8 Water quality report.

(a) Each State shall prepare and submit biennially to the Regional Administrator a water quality report in accordance with section 305(b) of the Act. The water quality report serves as the primary assessment of State water quality. Based upon the water quality data and problems identified in the 305(b) report, States develop water quality management (WQM) plan elements to help direct all subsequent control activities. Water quality problems identified in the 305(b) report should be analyzed through water quality management planning leading to the development of alternative controls and procedures for problems identified in the latest 305(b) report. States may also use the 305(b) report to describe ground-water quality and to guide development of ground-water plans and programs. Water quality problems identified in the 305(b) report should be emphasized and reflected in the State's WQM plan and annual work program under sections 106 and 205(j) of the Clean Water Act.

(b) Each such report shall include but is not limited to the following:

(1) A description of the water quality of all waters of the United States and the extent to which the quality of waters provides for the protection and propagation of a balanced population of shellfish, fish, and wildlife and allows recreational activities in and on the water.

(2) An estimate of the extent to which CWA control programs have improved water quality or will improve water quality for the purposes of paragraph (b)(1) of this section, and recommendations for future actions necessary and identifications of waters needing action.

(3) An estimate of the environmental, economic and social costs and benefits needed to achieve the objectives of the CWA and an estimate of the date of such achievement.

(4) A description of the nature and extent of nonpoint source pollution and recommendations of programs needed to control each category of nonpoint sources, including an estimate of implementation costs.

(5) An assessment of the water quality of all publicly owned lakes, including the status and trends of such water quality as specified in section 314(a)(1) of the Clean Water Act.

(c) States may include a description of the nature and extent of ground-water pollution and recommendations of State plans or programs needed to maintain or improve ground-water quality.

(d) In the years in which it is prepared the biennial section 305(b) report satisfies the requirement for the annual water quality report under section 205(j). In years when the 305(b) report is not required, the State may satisfy the annual section 205(j) report requirement by certifying that the most recently submitted section 305(b) report is current or by supplying an update of the sections of the most recently submitted section 305(b) report which require updating.

[50 FR 1779, Jan.11, 1985, as amended at 57 FR 33050, July 24, 1992]

115.01 DEFINITIONS.

Subdivision 1. **Applicability.** The following words and phrases when used in this chapter and, with respect to the pollution of the waters of the state, in chapter 116, unless the context clearly indicates otherwise, shall have the meanings ascribed to them in this section.

Subd. 2. MS 1990 [Renumbered subd 17]

Subd. 2. **Agency.** "Agency" means the Minnesota Pollution Control Agency.

Subd. 3. MS 1990 [Renumbered subd 8]

Subd. 3. **Depository.** "Depository" means: (a) a disposal facility or stabilization and containment facility for hazardous waste as defined in section 115A.03; and (b) a radioactive waste management facility as defined in section 116C.71, subdivision 7.

Subd. 4. MS 1990 [Renumbered subd 9]

Subd. 4. **Discharge.** "Discharge" means the addition of any pollutant to the waters of the state or to any disposal system.

Subd. 5. MS 1990 [Renumbered subd 13]

Subd. 5. **Disposal system.** "Disposal system" means a system for disposing of sewage, industrial waste and other wastes, and includes sewer systems and treatment works.

Subd. 6. MS 1990 [Renumbered subd 18]

Subd. 6. **Groundwater.** "Groundwater" means water contained below the surface of the earth in the saturated zone including, without limitation, all waters whether under confined, unconfined, or perched conditions, in near-surface unconsolidated sediment or regolith, or in rock formations deeper underground.

Subd. 7. MS 1990 [Renumbered subd 21]

Subd. 7. **Hazardous waste.** "Hazardous waste" means waste as defined in section 116.06, subdivision 11.

Subd. 8. MS 1990 [Renumbered subd 5]

Subd. 8. **Industrial waste.** "Industrial waste" means any liquid, gaseous or solid waste substance resulting from any process of industry, manufacturing trade or business or from the development of any natural resource.

Subd. 9. MS 1990 [Renumbered subd 22]

Subd. 9. **Other wastes.** "Other wastes" mean garbage, municipal refuse, decayed wood, sawdust, shavings, bark, lime, sand, ashes, offal, oil, tar, chemicals, dredged spoil, solid waste, incinerator residue, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, cellar dirt or municipal or agricultural waste, and all other substances not included within the definitions of sewage and industrial waste set forth in this chapter which may pollute or tend to pollute the waters of the state.

Subd. 10. **Person.** "Person" means the state or any agency or institution thereof, any municipality, governmental subdivision, public or private corporation, individual, partnership, or other entity, including, but not limited to, association, commission or any interstate body, and includes any officer or governing or managing body of any municipality, governmental subdivision, or public or private corporation, or other entity.

Subd. 11. MS 1990 [Renumbered subd 2]

Subd. 11. **Point source.** "Point source" means any discernible, confined and discrete conveyance, including, but not limited to, any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged.

Subd. 12. MS 1990 [Renumbered subd 4]

Subd. 12. **Pollutant.** "Pollutant" means any sewage, industrial waste, or other wastes, as defined in this chapter, discharged into a disposal system or to waters of the state.

Subd. 13. MS 1990 [Renumbered subd 12]

Subd. 13. **Pollution of water, water pollution, or pollute the water.** "Pollution of water," "water pollution," or "pollute the water" means: (a) the discharge of any pollutant into any waters of the state or the contamination of any waters of the state so as to create a nuisance or render such waters unclean, or noxious, or impure so as to be actually or potentially harmful or detrimental or injurious to public health, safety or welfare, to domestic, agricultural, commercial, industrial, recreational or other legitimate uses, or to livestock, animals, birds, fish or other aquatic life; or (b) the alteration made or induced by human activity of the chemical, physical, biological, or radiological integrity of waters of the state.

Subd. 14. MS 1990 [Renumbered subd 20]

Subd. 14. **Potable water.** "Potable water" means water which is or may be used as a source of supply for human consumption including drinking, culinary use, food processing, and other similar purposes, and which is suitable for such uses in its untreated state or when treated using generally recognized treatment methods.

Subd. 15. MS 1990 [Renumbered subd 11]

Subd. 15. **Radioactive waste.** "Radioactive waste" means high-level radioactive waste as defined in section 116C.71, subdivision 2f, and low-level radioactive waste as defined in article II of the Midwest Interstate Low-Level Radioactive Waste Compact, as enacted by section 116C.831.

Subd. 16. MS 1990 [Renumbered subd 19]

Subd. 16. **Schedule of compliance.** "Schedule of compliance" means a schedule of remedial measures including an enforceable sequence of actions or operations leading to compliance with an effluent limitation, other limitation, prohibition, or standard.

Subd. 17. MS 1990 [Renumbered subd 16]

Subd. 17. **Sewage.** "Sewage" means the water-carried waste products from residences, public buildings, institutions or other buildings, or any mobile source, including the excrementitious or other discharge from the bodies of human beings or animals, together with such groundwater infiltration and surface water as may be present.

Subd. 18. MS 1990 [Renumbered subd 7]

Subd. 18. **Sewer system.** "Sewer system" means pipelines or conduits, pumping stations, and force mains, and all other constructions, devices, and appliances appurtenant thereto, used for conducting sewage or industrial waste or other wastes to a point of ultimate disposal.

Subd. 19. MS 1990 [Renumbered subd 15]

Subd. 19. **Standards.** "Standards" means effluent standards, effluent limitations, standards of performance for new sources, water quality standards, pretreatment standards, and prohibitions.

Subd. 20. MS 1990 [Renumbered subd 14]

Subd. 20. **Toxic pollutants.** "Toxic pollutants" means those pollutants, or combinations of pollutants, including disease-causing agents, which after discharge and upon exposure, ingestion, inhalation or assimilation into any organism, either directly from the environment or indirectly by ingestion through food chains, will, on the basis of information available to the agency, cause death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions, including malfunctions in reproduction, or physical deformation, in such organisms or their offspring.

Subd. 21. MS 1990 [Renumbered subd 6]

Subd. 21. **Treatment works.** "Treatment works" means any plant, disposal field, lagoon, dam, pumping station, constructed drainage ditch or surface water intercepting ditch, incinerator, area devoted to sanitary land fills, or other works not specifically mentioned herein, installed for the purpose of treating, stabilizing or disposing of sewage, industrial waste, or other wastes.

Subd. 22. MS 1990 [Renumbered subd 3]

Subd. 22. **Waters of the state.** "Waters of the state" means all streams, lakes, ponds, marshes, watercourses, waterways, wells, springs, reservoirs, aquifers, irrigation systems, drainage systems and all other bodies or accumulations of water, surface or underground, natural or artificial, public or private, which are contained within, flow through, or border upon the state or any portion thereof.

History: *1945 c 395 s 1; 1963 c 874 s 2,3; 1969 c 9 s 16; 1973 c 374 s 1-6; 1986 c 425 s 1-5; 1986 c 444*

Midwest Biodiversity Institute
Center for Applied Bioassessment & Biocriteria
P.O. Box 21561
Columbus, OH 43221-0561

Framework and Implementation Recommendations for Tiered Aquatic Life Uses: Minnesota Rivers and Streams

A Report to:
Minnesota Pollution Control Agency

Midwest Biodiversity Institute
Center for Applied Bioassessment & Biocriteria
P.O. Box 21561
Columbus, OH 43221-0561
Chris O. Yoder, Principal Investigator
www.midwestbiodiversityinst.org

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Prepared for:

Minnesota Pollution Control Agency
520 Lafayette Road N
St. Paul, MN 55155-4194

Submitted by:

Chris O. Yoder, Research Director
Center for Applied Bioassessment and Biocriteria
Midwest Biodiversity Institute
P.O. Box 21561
Columbus, Ohio 43221-0561
cyoder@mwbinst.com

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MPCA TALU Implementation Team: Will Bouchard, Dan Helwig, Howard Markus, Scott Niemela, Mark Tomasek.

MPCA Staff: Pat Baskfield, Gerry Blaha, Kim Brynildson, Chandra Carter, Joel Chirhart, Dave Christopherson, Bill Cole, Mike Feist**,** John Genet, Doug Hanson, Steve Heiskary, Paul Hoff, Jeff Jasperson, Greg Johnson, Katrina Kessler, Kevin Kain Kim Laing, Tim Larson, Deb Lindlief, Shannon Lotthammer, Mary Hoffman Lynn, Molly MacGregor, Kevin Molloy, Phil Monson, Angela Preimsberger, Jeff Risberg, John Sandberg, Carol Sinden, Glenn Skuta, Kevin Stroom, Steve Thompson, Wendy Turri, Dana Vanderbosh.

MBI Staff: Edward Rankin, Robert Mueller, Allison Boehler.

Tetratech Staff: Jeroen Gerritsen, Erik Leppo, Lhei Zeng.

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Foreword

The Minnesota Pollution Control Agency (MPCA) has embarked on a detailed developmental effort to determine how the concept of TALU can be applied to Minnesota rivers and streams. This effort is the result of work that began in the early 1990s to develop a robust biological monitoring and assessment program in Minnesota. In the last 20 years Minnesota has developed many of the tools and program capabilities needed to implement a TALU framework. When this process is completed MPCA will be one of a handful of states in the U.S capable of supporting a TALU framework.

The MPCA commissioned this project to determine the key steps and attributes of a process for implementing TALU and biocriteria as part of the MPCA water quality regulatory and management programs. The framework and rationale outlined in this report is based on the TALU and biocriteria developmental experiences of other states and guidance and methods documents that have been produced by U.S. EPA. The process outlined by this report is a collection of existing “best practices” in the development and implementation of a state-based TALU framework. In addition, draft language for the Minnesota Water Quality Standards (WQS) is recommended and will support the rulemaking that will be proposed for adoption in 2014.

This report was completed in fulfillment of Task 3 of the MBI TALU work plan (Appendix A). It contains recommendations by MBI to MPCA based on the best scientific evidence and “best practices” that are currently available. It is advisory in terms of how MPCA might choose to implement the recommendations herein. The recommendations are the result of a participatory process by which MBI was involved in every step of the TALU and biocriteria development with MPCA staff and management. The underpinnings and conceptual tenets of a TALU-based approach have been carefully explained to MPCA management and staff via internal stakeholder engagement. In addition, external stakeholders have been informed at the same level of detail via various meetings and workshops at MPCA headquarters and regional offices.

The report is organized into major sections and subsections as follows:

1. Section 1.0 describes the Minnesota TALU initiative and origins.
2. Section 2.0 provides a detailed description of the TALU framework and its components.
3. Section 3.0 outlines the recommendations for a framework for developing and applying TALUs and biocriteria in the Minnesota WQS.
4. Section 4.0 describes recommendations and examples about how TALUs should be implemented in Minnesota.
5. Section 5.0 describes the likely effects that a TALU approach will have on major Minnesota PCA management programs.

This report reflects the detailed needs within MPCA and how a TALU-based approach might change the current Minnesota WQS and how that in turn might affect current MPCA water quality management programs. As such this report is advisory in nature and implementation of all or parts of the recommendations in this report are solely at the discretion of MPCA who will decide based on internal and external stakeholder consultation. Regulatory adoption of a TALU framework and affiliated standards and criteria will undergo the normal public rule making processes as outlined in the Minnesota Administrative Procedures Act.

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Glossary of Terms

Ambient Monitoring	Sampling and evaluation of receiving waters not necessarily associated with episodic perturbations.
Antidegradation Policy	The part of state water quality standards that protects existing uses, prevents degradation of high quality water bodies unless certain determinations are made, and which protects the quality of outstanding national resource waters. (Currently nondegredation in MN)
Aquatic Assemblage	An association of interacting populations of organisms in a given water body, for example, the fish assemblage or the benthic macroinvertebrate assemblage.
Aquatic Community	An association of interacting assemblages in a given water body, the biotic component of an ecosystem.
Aquatic Life Use (ALU)	A beneficial use designation in which the water body provides suitable habitat for survival and reproduction of desirable fish, shellfish, and other aquatic organisms; classifications specified in State water quality standards relating to the level of protection afforded to the resident biological community by the custodial State agency.
Attainment Status	The state of condition of a water body as measured by chemical, physical, and biological indicators. Full attainment is the point at which measured indicators signify that a water quality standard has been met and it signifies that the designated use is both attained and protected. Non-attainment is when the designated use is not attained based on one or more of these indicators being below the required condition or state for that measure or parameter.
Attribute	A measurable part or process of a biological system.
Beneficial Uses	Desirable uses that acceptable water quality should support. Examples are drinking water supply, primary contact recreation (such as swimming), and aquatic life support.
Benthic Macroinvertebrates	Animals without backbones, living in or on the substrates, of a size large enough to be seen by the unaided eye, and

which can be retained by a U.S. Standard No. 30 sieve (0.595 mm openings). Also referred to as benthos, infauna, or macrobenthos.

Best Management Practice (BMP) An engineered structure or management activity, or combination of these that eliminates or reduces an adverse environmental effect of a pollutant, pollution, or stressor effect.

Biological Assessment An evaluation of the biological condition of a water body using surveys of the structure and function of a community of resident biota; also known as bioassessment. It also includes the interdisciplinary process of determining condition and relating that condition to chemical, physical, and biological factors that are measured along with the biological sampling.

Biological Criteria (Biocriteria) Scientific meaning: quantified values representing the biological condition of a water body as measured by structure and function of the aquatic communities typically at reference condition; also known as biocriteria.

Regulatory meaning: narrative descriptions or numerical values of the structure and function of aquatic communities in a water body necessary to protect a designated aquatic life use, implemented in, or through state water quality standards.

Biological Condition Gradient (BCG) A scientific model that describes the biological responses within an aquatic ecosystem to the increasing effects of stressors.

Biological Diversity Refers to the variety and variability among living organisms and the ecological complexes in which they occur. Diversity can be defined as the number of different taxa and their relative frequencies. For biological diversity, these taxa are organized at many levels, ranging from complete ecosystems to the biochemical structures that are the molecular basis of heredity. Thus, the term encompasses different ecosystems, species, and genes; also known as biodiversity.

Biological Indicator An organism, species, assemblage, or community characteristic of a particular habitat or indicative of a particular set of environmental conditions; also known as a bioindicator.

Biological Integrity — The ability of an aquatic ecosystem to support and maintain a balanced, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitats within a region (after Karr and Dudley 1981).

Biological Monitoring — The use of a biological entity (taxon, species, assemblage) as a detector and its response as a measure of response to determine environmental conditions. Ambient biological surveys and toxicity tests are common biological monitoring methods; also known as biomonitoring.

Biological Survey — The collection, processing, and analysis of a representative portion of the resident aquatic community to determine its structural and/or functional characteristics and hence its condition using standardized methods.

Bioregion — Any geographical region characterized by a distinctive flora and/or fauna.

Clean Water Act (CWA) — An act passed by the U.S. Congress to control water pollution (formally referred to as the Federal Water Pollution Control Act of 1972). Public Law 92-500, as amended. 33 U.S.C. 1251 et seq.; referred to herein as the Act.

CWA Section 303(d) — This section of the Act requires States, territories, and authorized Tribes to develop lists of impaired waters for which applicable water quality standards are not being met, even after point sources of pollution have installed the minimum required levels of pollution control technology. The law requires that these jurisdictions establish priority rankings for waters on the lists and develop TMDLs for these waters. States, territories, and authorized Tribes are to submit their list of waters on April 1 in every even-numbered year.

CWA Section 305(b) — Biennial reporting required by the Act to describe the quality of the Nation's surface waters, to serve as an evaluation of progress made in maintaining and restoring water quality, and describe the extent of remaining problems.

Criteria A limit on a particular pollutant or condition of a water body presumed to support or protect the designated use or uses of a water body. Criteria may be narrative or numeric and are commonly expressed as a chemical concentration, a physical parameter, or a biological assemblage endpoint.

DELT Anomalies The percentage of Deformities, Erosions (e.g., fins, barbels), Lesions and Tumors on fish assemblages (DELT). An important fish assemblage attribute that is a commonly employed metric in fish IBIs.

Designated Uses Those uses specified in state water quality standards for each water body or segment whether or not they are being attained.

Disturbance Any activity of natural or human causes that alters the natural state of the environment and its attributes and which can occur at or across many spatial and temporal scales.

Ecological integrity The summation of chemical, physical, and biological integrity capable of supporting and maintaining a balanced, integrated adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitats in the region.

Ecoregion A relatively homogeneous geographical area defined by a similarity of climate, landform, soil, potential natural vegetation, hydrology, or other ecologically relevant variables; ecoregions are portioned at increasing levels of spatial detail from level I to level IV.

Existing Uses Those uses actually attained in a water body on or after November 28, 1975, whether or not they are included in the state water quality standards (November 28, 1975 is the date on which U.S. EPA promulgated its first water quality standards regulation in 40CFR Part 131). Existing uses must be maintained and cannot be removed.

Functional Organization	The summation of processes required for normal performance of a biological system (may be applied to any level of biological organization).
Index of Biotic Integrity (IBI)	An integrative expression of site condition across multiple metrics comprised of attributes of a biological assemblage. It refers to the index developed by Karr (1981) and explained by Karr et al. (1986). It has been used to express the condition of fish, macroinvertebrate, algal, and terrestrial assemblages throughout the U.S. and in each of five major continents.
Metric	A calculated term or enumeration representing an attribute of a biological assemblage, usually a structural aspect, that changes in a predictable manner with an increased effect of human disturbance.
Monitoring and Assessment	The entire process of collecting data from the aquatic environment using standardized methods and protocols, managing that data, analyzing that data to make assessments in support of multiple program objectives, and disseminating the assessments to stakeholders and the public.
Multimetric Index	An index that combines assemblage attributes, or metrics, into a single index value. Each metric is tested and calibrated to a scale and transformed into a unitless score prior to being aggregated into a multimetric index. Both the index and metrics are useful in assessing and diagnosing ecological condition.
Narrative Biocriteria	Written statements describing the narrative attributes of the structure and function of aquatic communities in a water body necessary to protect a designated aquatic life use.
Natural Condition	This includes the multiplicity of factors that determine the physical, chemical, or biological conditions that would exist in a water body in the absence of measurable impacts from human activity or influence.
Numeric Biocriteria	Specific quantitative and numeric measures of the structure and function of aquatic communities in a water body necessary to protect a designated aquatic life use.

Reference Condition

The condition that approximates natural, unimpacted to best attainable conditions (biological, chemical, physical, etc.) for a water body. Reference condition is best determined by collecting measurements at a number of sites in a similar water body class or region under minimally or least disturbed conditions (by human activity), if they exist. Since undisturbed or minimally disturbed conditions may be difficult or impossible to find in some states, least disturbed conditions, combined with historical information, models or other methods may be used to approximate reference condition as long as the departure from natural or ideal is comprehended. Reference condition is used as a benchmark to establish numeric biocriteria and can be further described as follows:

Minimally Disturbed Condition (MDC) – This term describes the condition of the biota in the absence of significant human disturbance and it is the best approximation of biological integrity.

Historical Condition (HC) - The condition of the biota at some point in its history. It may be a more accurate estimator of true reference condition (i.e., biological integrity) if the historical point chosen is before the effect of any adverse human disturbance. However, more than one historical reference point is possible (e.g., pre-industrial, pre-Columbian).

Least Disturbed Condition (LDC) – Least disturbed condition is found in conjunction with the best available physical, chemical, and biological habitat conditions given today's state of the landscape.

Best Attainable Condition (BAC) – This is the expected condition of least disturbed sites under the implementation of BMPs for a sufficient period of time. This is a condition that results from the convergence of management goals, best available technologies, and a public commitment to achieving environmental goals (e.g., as established by WQS) under prevailing uses of the landscape. BAC may be equivalent to either to either MDC

	or LDC depending on the prevailing level of human disturbance in a region.
Reference Site	A site selected to represent an approximation of reference condition and by comparison to other sites being assessed. For the purpose of assessing the ecological condition of other sites, a reference site is a specific locality on a water body that is minimally or least disturbed and is representative of the expected ecological condition of other localities on the same water body or nearby water bodies.
Regional Reference Condition	A description of the chemical, physical, or biological condition based on an aggregation of data from reference sites that are representative of a water body type in an ecoregion, subregion, bioregion, or major drainage unit.
Stressors	Physical, chemical, and biological factors that can adversely affect aquatic organisms. The effect of stressors is apparent in the biological responses.
Use Attainability Analysis (UAA)	A structured scientific assessment of the physical, chemical, biological or economic factors affecting attainment of the uses of water bodies.
Use Classes	A broad capture of a designated use for general purposes such as recreation, water supply, and aquatic life.
Use Subclasses	A subcategorization of use classes into discrete and meaningful descriptions. For aquatic life this would include a hierarchy of warmwater and cold water uses and additional stratification provided by different levels of warmwater uses and further stratification by water body types.
TALU-Based Approach	The TALU-based approach includes tiered aquatic life uses (TALU) based on numeric biological criteria and implementation via an adequate monitoring and assessment program that includes biological, chemical, and physical measures, parameters, indicators and a process for stressor identification.
Tiered Aquatic Life Uses (TALUs)	As defined: The structure of designated aquatic life uses that incorporates a hierarchy of use subclasses and

stratification by natural divisions that pertain to geographical and water body class strata. TALUs are based on representative ecological attributes and these should be reflected in the narrative description of each TALU tier and be embodied in the measurements that extend to expressions of that narrative through numeric biocriteria and by extension to chemical and physical indictors and criteria.

As used: TALUs are assigned to water bodies based on the protection and restoration of ecological potential. This means that the assignment of a TALU tier to a specific water body is done with regard to reasonable restoration or protection expectations and attainability. Hence knowledge of the current condition of a water body and an accompanying and adequate assessment of stressors affecting that water body are needed to make these assignments.

Total Maximum Daily Load (TMDL) The maximum amount of a pollutant that a body of water can receive while still meeting water quality standards. Alternatively, a TMDL is an allocation of a water pollutant deemed acceptable to attain the designated use assigned to the receiving water.

Water Quality Standards (WQS) A law or regulation that consists of the designated use or uses of a water body, the narrative or numerical water quality criteria (including biocriteria) that are necessary to protect the use or uses of that particular water body, and an antidegradation policy.

Water Quality Management A collection of management programs relevant to a water resource protection that includes problem identification, the need for and placement of best management practices, pollution abatement actions, and measuring the effectiveness of management actions.

List of Acronyms

ALU	Aquatic Life Use
BCG	Biological Condition Gradient
BMPs	**Best Management Practices**
CFR	Code of Federal Regulations
CWA	Clean Water Act
EPT	Ephemeroptera, Plecoptera, Trichoptera
FIBI	Fish Index of Biotic Integrity
IBI	Index of Biotic Integrity
M&A	Monitoring and Assessment
MIBI	Macroinvertebrate Index of Biotic Integrity
MPCA	Minnesota Pollution Control Agency
MSHA	Minnesota Stream Habitat Assessment
NPDES	National Pollutant Discharge Elimination System
QHEI	Qualitative Habitat Evaluation Index
TALU	Tiered Aquatic Life Use
TMDL	Total Maximum Daily Load
UAA	Use Attainability Analysis
WLA	Waste Load Allocation
WQS	Water Quality Standards
WWTP	Wastewater Treatment Plant

Executive Summary

Background

Stream biology integrates watershed water quality conditions because biological communities integrate multiple stressors which occur at both local and watershed-level scales. Fish and macroinvertebrates communities have different ecological requirements, so they respond to different stressors thereby providing a more comprehensive measure aquatic life condition. Minnesota's water quality standards (WQS) are designed to protect aquatic life and apply to most waters of the state. However, the current WQS are not sufficient to protect or manage the wide diversity of aquatic resources in Minnesota and are in need of an update to improve water quality management outcomes.

Water Quality Standards

The objective of the Clean Water Act is to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters." As part of this objective, Minnesota protects all Class 2 waters for aquatic life. For example, cold water streams (Class 2A) are protected to "permit the propagation and maintenance of a healthy community of cold water sport or commercial fish and associated aquatic life and their habitats". To achieve protection of aquatic life designated uses, conditions are set using chemical, physical, and biological criteria, which are sometimes also referred to as standards. All three types of criteria are used, with chemical criteria historically the most prevalent. For example in cold water streams, these waters need to meet a minimum condition of 7.0 mg/L of dissolved oxygen to protect for fish growth and survival. Although historically less common, biological criteria or "biocriteria" have become more widespread because they have the advantage of directly measuring attainment of the aquatic life use. Because the designated use determines the criteria that are applied, it is imperative that the correct use is applied to a water body; otherwise management efforts could be less effective. The development and implementation of numeric biocriteria create the opportunity to improve WQS by refining uses for Minnesota's rivers and streams.

Overview of Tiered Aquatic Life Uses (TALU)

Tiered aquatic life uses or "TALU" are a water quality standard structure that is based on the biological potential of appropriately classified water bodies. The TALU framework recognizes that the ecological potential of a water body can legitimately vary in accordance with the natural features of aquatic ecosystems. This supports defining classes and subclasses of water bodies in accordance with their ecological attributes within a structure of designated aquatic life uses. In addition, TALUs for streams and rivers further refines Minnesota's WQS which recognizes that there are differences in the potential for restoration and protection among all waters. TALU achieves these goals by providing additional protection to high quality waters and setting more appropriate biological and chemical goals for waters impacted by historical impacts (for example channelized streams). TALUs are an outgrowth of the cumulative knowledge about aquatic ecosystems that have become central to aquatic ecological assessment and represent an integration of WQS and monitoring and assessment. Adoption within a TALU framework will provide a more direct assessment of the biological condition of

Minnesota's rivers and streams and will result in better environmental outcomes. This revision will only impact Minnesota's aquatic life uses (Classes 2 and 7) for streams and rivers.

Tiered Designated Uses and Criteria

As noted earlier, the existing WQS for protecting aquatic life uses are a statewide, one-size-fits-all approach. A In contrast, TALU is a framework of refined designated aquatic life uses and biological and chemical criteria that are linked to the condition of similar water bodies that are managed appropriately. This is achieved through *representative ecological attributes* that are reflected in the narrative description of each TALU tier and are protected by numeric biocriteria and by the associated chemical and physical indictors and criteria. TALUs are assigned to water bodies based on the protection and restoration of *ecological potential*. This means that the assignment of a TALU tier to a specific water body is done with regard to reasonable restoration or protection expectations and their attainability. Knowledge of the current condition of a water body and adequate assessment of stressors affecting that water body are needed to make these assignments. Conversely TALU does not provide a basis for *"user preferences"* (i.e., accommodations for effluent conveyance, drainage conveyance, land use practices, prior existing conditions). TALUs are based first on ecological attributes and potentials, not on the activities that affect a water body. They also do not serve as a rationale for the *a priori* relaxation of pollution controls or impairment determinations. Finally, a TALU framework does not provide an "easy exit" from an *impaired waters* listing. While TALU may provide more than one "choice" for WQS that determine TMDL listings and requirements, a rigorous and objective process of assessment is required (i.e., a TALU structured use attainability analysis [UAA]) to determine if the original basis for a TMDL needs to be reconsidered or revised. As a result, TALUs could affect existing pollution control or water quality management requirements that may not have been adequately considered in the development of existing requirements.

TALU Implementation Recommendations for Minnesota

It is recommended that Minnesota Pollution Control Agency (MPCA) adopt the framework of detailed narratives measured by numeric biological criteria as described in this report. The framework consists of a set of designated use subcategories within a framework of warmwater and cold water ecotypes. Added to this is the stratification provided by the stream classification structure for fish and macroinvertebrate assemblages and with numeric expectations being calibrated to water body class specific goals.

TALU Use Tier	Description
Exceptional	High quality waters
General	Good quality waters – Equivalent to Minnesota's current aquatic life use goal
Modified	Waters with modified habitat – Examples include channelized streams
Limited	Waters with limited habitat – Examples include ephemeral channelized streams and concrete revetments

The proposed framework has a number of implications for Minnesota's WQS and to programs associated with water quality management. As part of the development of a TALU framework, the MPCA has been working to develop new and improved tools and engaging with internal and external stakeholders to determine how TALU will be implemented in WQS programs. The goal is to develop the tools that will be employed to effectively and efficiently manage refined stream uses and will fit with existing programs. Some of the major implications of the TALU framework are as follows:

- **Exceptional Use Waters:** The designation of these high quality waters is based on the demonstration that the water body meets exceptional biological goals. These waters will need to be protected or restored using more stringent biological goals and for some pollutants, more stringent chemical standards.
- **Modified Use Waters:** These water bodies will be designated by demonstration that general use goals are not met and a UAA determines that the biology is limited by habitat that has been modified in a legal manner (e.g., legal under ditch law). To protect this use tier less restrictive biological criteria and some chemical criteria would be applied.
- **Limited Use Waters:** Limited use waters will be designated by demonstration that modified use goals are not met and a UAA determines that the biology is severely limited by habitat that has been modified in a legal manner (e.g., legal under ditch law). Many of these water bodies will be ephemeral. To protect limited Use waters they will need to meet chemical criteria that could be equivalent to the current Class 7 standard.
- **Monitoring and assessment:** The current intensive watershed management approach is sufficient to support a TALU framework, however the selection of monitoring stations and the number of stations could be increased to better address use designations and other water quality management activities (e.g., permitting).
- **Documentation of changes over time:** As part of a TALU monitoring and assessment program, incremental changes in water quality can be documented. This allows entities working to improve water quality to document and show progress toward a goal.
- **Stressor Identification and UAA Tools:** When the biology is determined to not be attaining the General Use, the MPCA will need to have the tools and knowledge to determine in a timely manner if a lower use is appropriate (i.e, UAA) and if the water body does not attain the designated use, what stressors are resulting in nonattainment. TALU incorporates the concept of pollution into assessments of condition and provides an opportunity to address the key stressors that are the most determinant of biological condition. In doing so, TALU allows assessment and water quality management efforts to focus on the correct problems
- **Data Management:** To support a TALU framework new database and GIS tools are needed to document designated uses, criteria, assessments, and other water quality management actions in these waters. This will need to include a transparent system that allows stakeholders to review and participate in decisions made in these waters.
- **How TALU Can Affect Major MPCA Water Quality Management Programs**: The data collected to support a TALU framework also provides information that can be integral for development of total maximum daily loads (TMDLs), watershed planning, Pollutant Discharge Elimination System (NPDES) permitting, and any other program that has the protection of designated aquatic life uses as a goal.

Adoption of TALU in Minnesota is planned for 2014. Through the adoption of a TALU framework for Minnesota streams, refined designated uses and their associated criteria will result in improved management of these systems by producing better more appropriate assessments of goals and by providing support to associated water quality management programs.

Framework and Implementation Recommendations for Tiered Aquatic Life Uses: Minnesota Rivers and Streams

Chris O. Yoder, Principal Investigator
Center for Applied Bioassessment & Biocriteria
Midwest Biodiversity Institute
P.O. Box 21561
Columbus, OH 43221-0561

1. Introduction & Project Description

The Minnesota Pollution Control Agency (MPCA) is seeking to develop a framework for the development and adoption of tiered aquatic life uses (TALUs) for Minnesota rivers and streams. Specifically the MPCA requested that MBI assist with the following tasks:

1) Leading discussions regarding the regulatory and technical applications of biological standards and a TALU framework to internal and external stakeholder groups;

2) Identifying the implications of the proposed changes to each stakeholder's program activities and interests;

3) Developing an implementation plan for internal stakeholders that will suggest options to modify their programmatic activities in response to the new biological standards and TALU framework; and,

4) Providing technical assistance on biological criteria and TALU, including review and recommendations related to index of biotic integrity (IBI) development, the Biological Condition Gradient (BCG), habitat indicators of beneficial uses, impairment thresholds, and the other criteria used to designate an aquatic life use that are legally and scientifically defensible, environmentally effective, understandable by stakeholders, and amenable to implementation by a public agency.

In brief, the MPCA requested assistance for developing a framework for TALU and biological criteria for Minnesota rivers and streams. This entails the detailed description of designated use tiers (i.e., the narrative description of each), how biological criteria are derived for each tier, and how such a system of tiered uses and biocriteria can be implemented via monitoring and assessment to support all relevant water quality management programs. The full details of the work plan appear in Appendix A.

1.1 Project Accomplishments to Date

The MPCA TALU project was initiated by contract on February 18, 2008. Since that time several work plan tasks have been either fully or partially executed. These are summarized by work plan task as follows:

Task 1 – Internal and External Stakeholder Meetings

Between June and September 2008 a series of presentations about the basic fundamentals of a TALU-based approach[1] and the potential implications for changes to the Minnesota WQS were made to MPCA management and staff. These were intended to educate and inform MPCA about the basic principles of a TALU approach and to seek input from managers and staff about the potential impacts of TALU.

At about the same time a general presentation was made to invited external stakeholders. More detailed and focused stakeholder meetings were held in January 2009 at five regional MPCA locations across the state. This was followed up by a more detailed and focused series of meetings and presentations organized by major management programs and interests (e.g., municipalities, industries, stormwater interests, agricultural interests, state agencies, etc.). The feedback gained from these events was used to adjust and modify both the TALU work plan and the technical approach to developing the various tools and criteria that comprise a TALU approach.

Task 2 – Exploratory Data Analyses and Indicator Development

The work plan includes a series of technical development tasks to provide the tools and products that are seen as being essential for TALU development and implementation in Minnesota. These included five specific technical tasks:

Task 2a consisted of a detailed review of the MPCA biological indices and assessment criteria. This led to the revision of the statewide indices and their replacement with a set of fish and macroinvertebrate IBIs that were based on a natural classification scheme developed by MPCA staff. These indices are the basis of the numeric biocriteria that are an essential component of TALU-based biocriteria.

Task 2b consisted of a review of the current structure of designated aquatic life uses and how these might be changed by a transition to tiered uses. The results of that process are documented in this implementation plan and reflect the detailed narratives of the new TALU-based TALUs.

Task 2c consisted of the detailed development of a calibrated Biological Condition Gradient (BCG). This was accomplished under the leadership of Jeroen Gerritsen and included technical sessions with MPCA staff that resulted in the development of BCG levels for each fish and macroinvertebrate stream and river class. The principal product of this effort were detailed rules for the use of a fuzzy set model that is a key implementation mechanism for determining the BCG membership of a sample. This process produced a draft report that details these technical developments (Gerritsen et al. 2009).

[1] The "TALU based approach" includes tiered aquatic life uses (TALU) based on numeric biological criteria and implementation via an adequate monitoring and assessment program that includes biological, chemical, and physical measures, parameters, indicators and a process for stressor identification.

Task 2d examined the comparability of boat electrofishing data collected by the MPCA and the MDNR. Each agency utilizes different sampling approaches and protocols. This task determined how comparable are the results, particularly in terms of using the MDNR data to determine attainment of the TALU-based biocriteria. This project was executed in 2010 and included a final report (Mueller et al. 2010).

Task 2e involved the development of detailed relationships between the MPCA fish and macroinvertebrate IBIs and metrics with the Minnesota Stream Habitat Assessment (MSHA) and its component attributes. This was accomplished by analyzing the extant MPCA statewide database and is needed to conduct the use attainability analyses (UAA) that are inherent to the implementation of a TALU-based approach. That project is nearing completion and is currently documented in a draft report by MBI (Rankin and Yoder 2011).

These are the principal technical products that are currently completed or near completion. Additional technical tasks are ongoing and include Tasks 4 and 5 that are detailed in a newly revised work plan (Appendix A).

2. Rationale for Tiered Aquatic Life Uses

Designated aquatic life uses are State or Tribal descriptions of the biological goals for their water bodies. Ideally, use designations are assigned to a water body based on the *potential* aquatic assemblage that can realistically be sustained given the regional reference condition and the level of protection afforded by the applicable criteria. The TALU framework recognizes that the ecological potential of a water body or can legitimately vary in accordance with the natural features of aquatic ecosystems. As such this supports defining classes and subclasses of water bodies in accordance with their ecological attributes and within a structure of designated aquatic life uses. U.S. EPA's current thinking (U.S. EPA 2005, 2011) is that a TALU framework can accomplish the following:

- accommodate and account for observable differences in expected biological condition in water bodies in different ecological regions;
- provide an objective means of describing the biological potential for a specific classes or subclasses of water bodies;
- recognize and accommodate observable differences in biological restoration potential among waters with different types and levels of legacy and background stressors;
- reflect an understanding of the relationship between stressors and biological community response (i.e., the BCG/human disturbance gradient [HDG] intersection);
- guide the selection of environmental indicators for monitoring and assessment and make fuller use of available biological data as an incremental measure of condition; and,
- better articulate a stressor-response model that maximizes the likelihood of success of water quality based management actions (WQS, assessment, 303[d] listings/Total Maximum Daily Load (TMDL), National Pollution Discharge Elimination System (NPDES) permits, nonpoint source assessment, stormwater management, etc.).

TALUs are an outgrowth of the cumulative knowledge about aquatic ecosystems that have become central to aquatic ecological assessment and are consistent with 30+ years of empirical observation. These include:

- surface waters and the biological assemblages they support are predictably and consistently different across the continent (stratification of ecotypes, classification along natural gradients, ecological regions concept);
- within the same ecological regions, different water body types (e.g., headwater streams, wadeable streams, small rivers, large rivers, lakes, reservoirs, wetlands, etc.) support predictably different compositional properties of key aquatic assemblages (water body classification);
- within a given class or subclass of water bodies, observed biological condition in a specific water body is a function of the level of stress (mostly of anthropogenic origin) to which the water body has been subjected (U.S. EPA's Biological Condition Gradient; Davies and Jackson 2006);

- similar stressors at similar intensities produce predictable and consistent biological responses in waters within a water body ecotype, and those responses can be detected and quantified along the BCG and also in terms of deviations from expected conditions (i.e., reference condition);
- water bodies exposed to higher levels of stress will exhibit biological performance that increasingly departs from the applicable reference condition than do waters exposed to lesser levels of stress (congruence of the BCG and the HDG; U.S. EPA 2005, Davies and Jackson 2006), and,
- the routine and systematic application of adequate monitoring and assessment (Yoder 1998) will generate sufficient data such that empirical relationships between biological condition and response and stressor/exposure variables can be produced and used to diagnose causes and set more detailed and stratified management criteria and goals; key to success in this function is the capacity to incrementally measure biological condition along the BCG (Yoder et al. 2008).

In essence TALUs represent a distinct refinement of the traditional application of general and fishery-based uses that are commonplace in state WQS and status-based monitoring and assessment. TALU brings about an integration of WQS and monitoring and assessment that generally does not exist under a general uses framework.

2.1 Defining TALUs

TALUs conjure up varied expectations among diverse stakeholder groups. This is likely because they represent both a change in the general operation of state water quality management programs and stand to alter certain decisions that were made on the basis of single-dimension uses and criteria. Hence it is important to clarify here what TALUs are and what they are not.

2.1.1 What TALUs Are

TALUs are a framework of refined designated uses and narrative and numeric biological criteria that are linked to the BCG. In brief, TALUs are:

- A reflection of the whole ecosystem. TALUs are based on *representative ecological attributes* and these should be reflected in the narrative description of each TALU tier and be embodied in the measurements that extend to expressions of that narrative through numeric biocriteria and by extension to chemical and physical indictors and criteria.
- Assigned to water bodies based on the protection and restoration of *ecological potential*. This means that the assignment of a TALU tier to a specific water body is done with regard to reasonable restoration or protection expectations and attainabilities. Hence knowledge of the current condition of a water body and an accompanying and adequate assessment of stressors affecting that water body are needed to make these assignments.

An acceptable TALU program will incorporate these properties into the narratives of the designated aquatic life use tiers, how the numeric biological criteria are derived, and how specific TALUs are assigned to specific water bodies.

2.1.2 What TALUs Are Not

While the incorporation of TALUs into a state's WQS may represent a modification in how water quality goals are visualized and how prior decisions were made, they *are not* intended to provide for, accommodate, or accomplish any of the following:

- TALUs do not provide a basis for *"user preferences"* (i.e., accommodations for effluent conveyance, drainage conveyance, land use practices, prior existing conditions, etc.) – TALUs are based on ecological attributes and potentials, not on the activities that affect a water body;
- TALUs do not serve as a rationale for the *a priori* relaxation of pollution controls – TALUs may affect existing pollution control or water quality management requirements making them more or less stringent depending on site-specific circumstances that may not have been adequately considered in the development of existing requirements; and,
- TALUs do not provide an "easy exit" from an *impaired waters* listing – while TALUs may now provide more than one "choice" for WQS that in turn determine TMDL requirements, a rigorous and objective process of assessment is required (i.e., a TALU structured use attainability analysis) to determine if the original basis for a TMDL needs to be reconsidered or revised.

This does not mean that TALUs might not play a role in resolving issues that include some of the above that have gone unresolved under a framework of general uses. Relative to how some decisions were made under such a system, some new decisions may be viewed as being more or less stringent. The more accurate view of such changes is that because these decisions are now based on a more rigorous and systematic assessment process and the closer approximation of true potential, that such represents neither an "upgrade" or "downgrade", but rather a more accurate reflection of verified potential and site-specific circumstances.

2.2 *Clean Water Act Goals – The "Drivers"*

A critical objective of the 1972 Clean Water Act (CWA) is to . . . "restore and maintain the chemical, physical, and biological integrity of the Nation's waters" (CWA sec 101[a][2]). In the scientific literature, an aquatic ecosystem that possesses chemical, physical, and biological integrity is described as being capable of "supporting and maintaining a balanced, integrated, adaptive community of organisms having a composition and diversity comparable to that of the natural habitats of the region" (Frey 1977). Over the intervening years, our understanding of how to define and measure the integrity of aquatic systems has been better developed. The term integrity has been further refined in the literature to mean . . . "a balanced, integrated, adaptive system having a full range of ecosystem elements (genes, species, assemblages) and processes (mutation, demographics, biotic interactions, nutrient and energy dynamics, metapopulation dynamics) expected in areas with no or minimal human influence" (Karr 2000). The aquatic biota residing in a water body are the result of complex and interrelated chemical, physical, and biological processes that act over time and on multiple scales (e.g., instream, riparian, landscape; Karr et al. l986; Yoder l995). By directly measuring the condition of the aquatic biota, we are able to more accurately define the aquatic community that is the "product" of these factors.

2.2.1 Water Quality Standards Overview

Section 101[a][2] of the CWA establishes broad national goals and objectives such as the chemical, physical, and biological integrity provision. Other sections of the CWA establish the programs and authorities for implementation of those goals and objectives. Section 303[c] sets up the basis of the current WQS program. WQS are parts of State (or, in certain instances, federal) law that define the water quality goals of a water body, or parts of a water body, by designating the use or uses of the water body and by setting criteria necessary to protect those uses. The standards also include an antidegradation policy consistent with 40 CFR Part 131.12.

In recognition of the uncertainties regarding the attainment of biological integrity, the CWA also established an interim goal for the protection and propagation of fish, shellfish, and wildlife and recreation in and on the water as a guiding principle for the development of WQS. The interim protection and propagation goal for aquatic life has been interpreted by U.S. EPA to include the protection of the full complement of aquatic organisms residing in or migrating through a water body. The protection afforded by WQS includes a representative aquatic community (e.g., fish, benthic macroinvertebrates, algae, etc.), not just the protection of commercially important or special status (e.g., rare, threatened, endangered) species.

> "The fact that sport or commercial fish are not present does not mean that the water may not be supporting an aquatic life protection function. An existing aquatic community composed entirely of invertebrates and plants, such as may be found in a pristine tributary alpine stream, should be protected whether or not such a stream supports a fishery. Even though the shorthand expression 'fishable/swimmable' is often used, the actual objective of the Act is to restore the chemical, physical and biological integrity of our Nation's waters (Section 101[a][2]). The term 'aquatic life' would more accurately reflect the protection of the aquatic community that was intended in Section 101[a][2] of the Act." (Appendix G, EPA-823-B-94-005)

The representative assemblage of aquatic organisms residing in, or migrating through, a water body will vary depending on the water body type and other factors that are considered in the development and derivation of TALUs. For example, fish, benthic macroinvertebrates, and increasingly periphyton, are common aquatic assemblages that are typically measured by States and Tribes when assessing the condition of their streams and rivers. In headwater streams and many wetlands, amphibians are an important component of the biotic assemblages for this water body ecotype and functionally replace fish when they are absent or cannot be used as a reliable indicator assemblage. Hence the concept is clearly to protect the whole ecosystem and its representative attributes.

2.2.2 U.S. EPA "TALU Methods" Development

U.S. EPA has supported the development of state and tribal bioassessment programs via the production of methods documents, case studies, regional workshops, and evaluations of individual state and tribal programs since 1990 when they released national program guidance (U.S. EPA 1990). This was followed by a series of workshops, pilot program documents, and limited technical assistance to the states. In 2000, EPA convened an intensive developmental and implementation process for incorporating TALUs and numeric biocriteria in state and tribal water quality programs. This included a steering committee comprised of EPA staff, States, and active researchers and a working group comprised of EPA program and research staff, state managers, and leading academic researchers. This process culminated in the release of the document entitled *Use of Biological Information to Better define Designated Aquatic Life Uses in State and Tribal Water Quality Standards: Tiered Aquatic Life Uses (August 2005).* This document provides examples of practical and scientifically sound approaches to using biological information to tier designated aquatic life uses. As such U.S. EPA believes that the use of biological information can help improve water quality protection and encourages States and Tribes to incorporate biological information into their decision making processes.

The successful development and implementation of TALUs is directly dependent on the rigor, comprehensiveness, and integration of the bioassessment program as a component of the broader monitoring and assessment (M&A) and water quality standards (WQS) programs. The quality and make-up of these programs ultimately determines the quality and accuracy of the outputs of the primary water quality management programs such as NPDES permitting, TMDLs, nonpoint source management (319 program), and watershed planning. A TALU-based approach plays a key role in determining not only the WQS that are applied to a given management scenario, but also in determining the extent and severity of impaired waters through the application of numeric biocriteria via adequate M&A (Yoder and Barbour 2009). Hence the development and implementation of TALUs may alter prior determinations and actions that were based on general uses and less than adequate M&A.

2.2.3 State TALU Program Development

In addition to the U.S. EPA supported framework and tool documentation, selected states have implemented TALU-based programs. Ohio and Maine have the most tenured and mature programs and each has been described in detail in U.S. EPA (2005) and each state has posted their TALU documentation and program products on their respective websites[2].

EPA has supported a state program review process which has been conducted at least once with 22 different states and several tribes. An essential component of this review is determining a state's status in terms of meeting needs for developing and implementing a TALU-based approach to monitoring and assessment and WQS. A hypothetical timeline that describes the sequence of steps including the development of a baseline bioassessment program, initial support for management programs, development of biocriteria, increasingly

[2] Ohio EPA: http://www.epa.ohio.gov/dsw/bioassess/ohstrat.aspx;
Maine DEP: http://www.maine.gov/dep/water/monitoring/biomonitoring/index.html.

sophisticated support for all relevant water quality management programs, and long-term maintenance of a TALU-based program. The ultimate goal is use of biological information to more precisely define aquatic life uses and the development of numeric biological criteria (Figure 2-1). The essential first step is for a state to determine where their program is along this timeline. MPCA used this process to determine that rigor of their program in 2005 and what tasks were yet to be accomplished to reach the above stated goals. The next step is for the state to undergo a critical technical elements review (Yoder and Barbour 2009) that determines the technical level of rigor of the bioassessment program. This process helped MPCA produce a detailed work plan for the eventual development and adoption of numeric biocriteria and TALUs in their WQS, supported by a Level 4 program by 2013 (Table 5-1). This constitutes a working example of how states can use the results of the overall program review and critical technical elements process to develop a "blueprint" for making orderly improvements and attaining full TALU status.

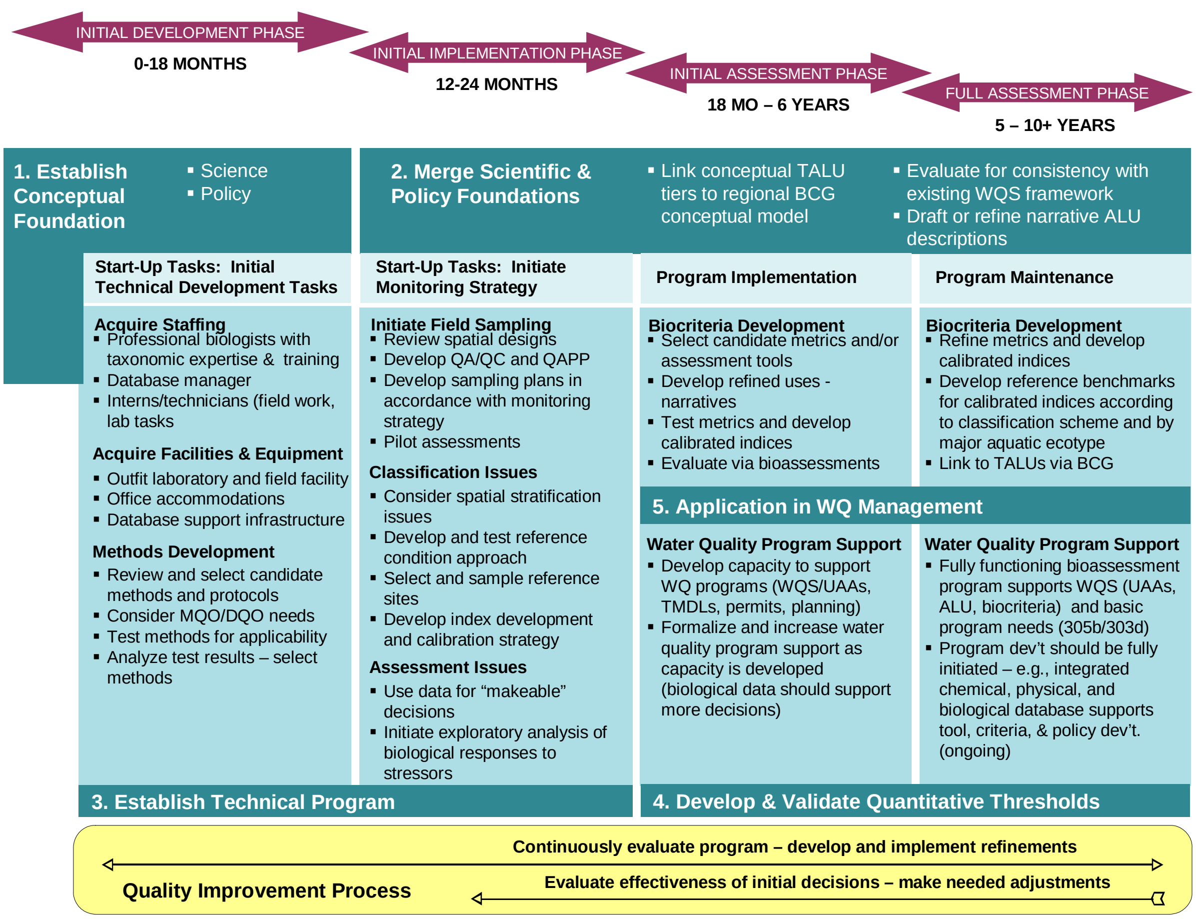


Figure 2-1. Timeline for full TALU program development and implementation intended to be used by States/Tribes to determine current program status with respect to the development and implementation goals of the TALU approach (from U.S. EPA 2005).

The results of the 22 state reviews indicate that 12 States function at a technical rigor consistent with a Level 2 program. Of the remaining States, two are consistent with a Level 4 program, and nine are at Level 3; no program is currently at Level 1. There were no strong geographic or jurisdictional patterns evident in the results. The relationship of the level of rigor to whether a state has or is capable of developing TALUs and numeric biocriteria is depicted in Table 2-1. Of the 22 states that have been part of the program evaluation process, two have fully developed TALUs and biocriteria in their WQS (each has a level 4 programs). One level 3+ program has TALUs in their WQS, but has not fully completed the process. Of the five other states that have TALU development programs in place (with the eventual adoption in their WQS as a goal) two are level 3+ and three are level 3. Only two of the remaining level 3 programs have no TALU developments underway at present. Of the remaining states that have no TALU development activities, all are level 2 programs.

Table 2-1. Status of state adoption and/or development of tiered aquatic life uses and numeric biological criteria in their water quality standards with respect to the latest level of rigor as determined by the critical technical elements process.

Level of Rigor [# states]	TALU in WQS	TALU in Development	None
L4 [2]	2		
L3+ [3]	1	2	
L3 [5]		3	2
L2 [12]			12
Total [22]	2	6	14

2.3 State Water Quality Standards

Although the CWA gives the U.S. EPA an important role in determining appropriate minimum levels of protection and providing national oversight, it also gives considerable flexibility and discretion to States and Tribes to design their own programs and establish levels of protection beyond a minimally acceptable program. Section 303 directs States and authorized Tribes to adopt WQS to protect public health and welfare, enhance the quality of water, and serve the purposes of the CWA. “Serve the purposes of the Act” (as defined in Sections 101[a][2], and 303[c] of the CWA) means that WQS should:

- include provisions for restoring and maintaining chemical, physical, and biological integrity of State and Tribal waters;
- provide, wherever attainable, water quality for the protection and propagation of fish, shellfish, and wildlife and recreation in and on the water (i.e., “fishable/swimmable”); and,
- consider the use and value of State and Tribal waters for public water supplies, propagation of fish and wildlife, recreation, agricultural and industrial purposes, and navigation.

State WQS provide an important foundation for water quality-based management programs. With the public participating in their adoption (see 40 CFR 131.20), such standards serve the dual purposes of establishing the water quality goals for specific water bodies and serving as the regulatory basis for the establishment of water quality-based management strategies beyond the technology-based levels of treatment required by Sections 301 and 306 of the CWA.

WQS are an integral part of state water quality management programs under the CWA. Designated or beneficial uses are intended to describe the existing and potential "uses" of a water body and as such establish and articulate the goals for a water body. The attendant chemical, physical, and biological criteria are intended to provide the measurable properties of the designated use and can be used to measure existing quality and to develop requirements for managing activities that impact the quality of that water body. Criteria have predominantly been written in chemical concentration terms, but also have included physical properties and narrative statements of desired conditions. In 1990 U.S. EPA issued national guidance for the development and adoption of biological criteria recommending that states adopt narrative biocriteria by 1993 and numerical biological criteria by 1996 (U.S. EPA 1990). As such biological criteria represent a significant advancement over a purely chemical approach to WQS by incorporating a more complete and reliable measure of designated use attainment status (Rankin 2003; Yoder 1995) and incorporating monitoring and assessment as an integral part of the overall process of defining and setting designated aquatic life uses.

2.3.1 Designated Uses

It is in designating uses that States and Tribes establish the environmental goals for their water resources and then measure attainment of these goals. In designating uses, a State or Tribe weighs the environmental, social, and economic consequences of its decisions. The regulation allows the State or Tribe, with public participation, some flexibility in weighing these considerations and adjusting these goals over time. However, reaching a conclusion about the uses that appropriately reflect the current and potential future uses for a water body, determining the attainability of those goals, and appropriately evaluating the consequences of a designation can be a difficult and controversial task. A principal function of designated uses in WQS is to communicate the desired state of surface waters to water quality managers, the regulated community, and the interested public. An effective designated use system is one that translates readily into indicators (e.g., numeric water quality criteria, biological indices) that respond in predictable ways to stress and can be evaluated using data collected from the water body. Experience with implementation of various State designated use systems suggests that, regardless of the system employed, States that use biological data as part of their assessment program apply some type of refined, or tiered, aquatic life use approach to guide interpretation of their biological data. Some states have either made this explicit by adopting the tiers directly into their WQS as designated uses or implicit by using tiers in their monitoring and assessment protocols. Although the benefits of more specificity may apply to any of the designated uses described in CWA section 303, it may be most relevant for aquatic life uses.

A water body's designated use(s) are those uses specified in WQS, whether or not they are being attained (40 CFR 131.3[f]). The "use" of a water body is the most fundamental description of its role in the aquatic and human environments. All of the water quality protections established by the CWA emanate from the water body's designated use. As designated uses are critical in determining the water quality criteria that apply to a given water body, determining the appropriate designated use is of paramount importance in establishing criteria that are appropriately protective of that designated use. Section 131.10 of the regulation describes the State's responsibilities for designating and protecting uses. The regulation requires or allows for:

- that States and Tribes specify the water uses to be achieved and protected;
- protection of downstream uses;
- establishing sub-categories and seasonal uses;
- the definition of criteria for determining attainability;
- the consideration of six factors of which at least one must be satisfied to justify the removal of a designated use that is not an existing use;
- the maintenance of existing uses;
- the upgrading of uses that are presently being attained but which are not designated; and,
- the establishment of conditions and requirements for conducting use attainability analyses (UAAs).

In addition, the regulations effectively establish a "rebuttable presumption" that uses consistent with the protection and propagation of fish, shellfish, and wildlife and recreation in and on the water are attainable and should apply to all water bodies, unless it has been demonstrated that such uses are not attainable via an acceptable UAA process. The classification of the waters of a State must also take into consideration the use and value of the water body for public water supply, protection and propagation of fish, shellfish, and wildlife, recreation in and on the water, and agricultural, industrial, and other purposes, including navigation.

Changes to the designated use(s) of a specific water body are subject to U.S. EPA review and approval (40 CFR 131.21). The regulations allow States to subcategorize or refine the aquatic life use designations for a water body and set the appropriate criteria to reflect the varying needs of such subcategories of uses (see 40 CFR 131.10[c]). While this has generally been described as differentiating such broad concepts as cold water and warm water fisheries, the implications are such that it can extend to more detailed distinctions provided the mechanisms are consistent and sufficiently predictable. As such this is what a TALU framework offers in the way of refining designated uses.

2.3.2 Aquatic Life Uses

Aquatic life uses are a significant component of state WQS. They are intended to provide for the restoration and protection of aquatic life in all surface water bodies as has already been described. Designated aquatic life uses are the most broadly applicable of all designated uses and the application of the criteria usually result in the most stringent requirements for water quality management. While criteria for other uses may have lower concentrations, aquatic life are generally applied at critical low flows which translates to lower discharge loading allowances. This is especially true of water quality based limitations for NPDES permits under steady-state assumptions of receiving water dilution and effluent flows. The management requirements for the most widely applicable chemical/physical parameters such as dissolved oxygen (D.O.), ammonia-N, temperature, and common heavy metals are generally dictated by aquatic life protection endpoints. Exceptions to this are bioaccumulative parameters such as mercury and PCBs which are usually dictated by human and wildlife health effects. Nevertheless, virtually all water quality management issues will involve requirements for the protection of aquatic life. More recently criteria based directly on attributes of the aquatic biota have been developed. Termed biological criteria these are based on sampling of aquatic assemblages and employ numeric indices that are anchored in regional reference conditions and developed and calibrated to provide a linear measure of ecological quality across the entirety of the stressor gradients that impact aquatic systems. Where they have been developed and used in a systematic monitoring and assessment program the result is a more comprehensive approach to water quality management and more accurate and comprehensive criteria including previously deemphasized components such as habitat, flow, and more importantly their interactions with chemical/physical attributes.

2.3.3 Tiered Aquatic Life Uses (TALUs)

It has been long established that aquatic communities can vary significantly from water body to water body hence it makes equivalent sense that the goals set for each can likewise vary – that is one of the major tenets of the TALU framework. A major challenge in assigning designated use tiers is distinguishing the natural variability that is a function of aquatic ecotype (e.g., cold water vs. warmwater, headwater vs. large river, high gradient vs. low gradient wetland dependent streams) and geographic location (e.g., ecoregions) from the variability that results from exposure to stressors. By accounting for natural variability in aquatic systems via stratification of similar attributes and expectations, biologically-based TALUs account for a major source of uncertainty and error in otherwise one-size-fits-all water quality management efforts. TALU is an enhancement of the rote replication of CWA section 303 uses in that it is a more refined framework that expresses designated uses in very specific terms and includes subclassifications that also exact different levels of protection. TALU includes subcategories based on aquatic assemblage types, including descriptions of the core assemblage attributes that are representative of each subcategory (e.g., cold water and warmwater fisheries).

States and Tribes have adopted varying levels of TALUs in their programs. These range from what is effectively informal policy application via monitoring and assessment to narrative biocriteria to the full adoption of TALUs and numeric biocriteria. Most are presently developing the technical program in an effort to further tighten the linkage between their narrative use statements and numeric biological criteria (U.S. EPA 2002). Thus far three States (Maine, Ohio, and Vermont) have either sufficiently developed both their technical program and WQS rule language to qualify as “TALU States”. While their approaches for tiering aquatic life uses may differ in detail and bioassessment methods, their TALU frameworks share the following core elements:

- Biological information is the basis for the use designations.
- Numeric biological indicators or biocriteria are developed for each use.
- Development of tiers is based on data from comprehensive, robust monitoring program.

The insights and experiences from States and Tribes that have adopted TALUs and numeric biocriteria in their WQS, as well as from those currently developing biological assessment and criteria programs, reveal the values of TALUs implemented in State and Tribal WQS (Table 2-2).

2.3.4 TALU Options for States

A TALU approach describes ecologically-based subcategories of water body types, such as A, B, C or descriptive titles such as Warmwater Habitat, Exceptional Warmwater Habitat, Modified Warmwater Habitat, etc. Furthermore, subclassifications within each subcategory that pertain to regionally specific (i.e., ecoregions, subregions, bioregions) or other attributes (i.e., stream size, gradient, temperature) are assigned as each is apparent in the development and application process. Also, to the extent that there are other waterways that may share the same characteristics, an approach that describes categories and subcategories of use classifications in sufficient detail allows similar waterways to be consistently and predictably classified, thereby eliminating the need or risk of having to continually develop "new use classification categories" via a site specific UAA process. This is a more workable and clearer approach to establishing a multi-tiered use classification system under state water quality regulations. As we have learned via the state program evaluation process (e.g., including the critical technical elements evaluation; Yoder and Barbour 2009) most state aquatic life use designations are either too vague, too broad, or rely too much on site-specific assumptions rather than the above described classification and subclassification scheme. Furthermore, by integrating the task of determining the appropriate classification of specific water bodies with a routine spatial monitoring and assessment program the task of vetting the appropriateness of a use designation is resolved ahead of its use in water quality management (e.g., NPDES permits, TMDLs). One problem with most conventional UAAs at present is that they are initiated by the realization that the use designation may be inappropriate as revealed by the application of a TMDL or permit, which places an inappropriate burden on the WQS program and not enough on the M&A program to resolve these issues ahead of their application in WQ management.

Based on past and current practice among states that use biological data at some level to make assessment decisions, there are four options that are available (Figure 2-2). These include:

1. Applying biological data as described in methods or guidance manuals for making general decisions about water body status, mostly for 305b/303d purposes, and under a "one-size-fits-all" general or fishery based use designation framework;

2. Applying biological data under a specific policy adopted by the state for the use of such data to make decisions;

3. Adoption of a narrative biocriterion in the WQS that consists of qualitative goal statements for biological condition and a translator mechanism adopted as policy for applying biological data to make decisions; and,

Table 2-2. The value added features of a TALU-based framework in a state water quality management context with references to applicable EPA regulations (after U.S. EPA 2005, Table 1-2).

Value-added Attribute	Explanation	Supporting WQS Regulation
Set more appropriate designated ALUs	Define ALUs in a more precise way that is nether under-protective of existing high quality resources nor overprotective for waters that have been extensively or irretrievably altered.	40 CFR 131.10 40 CFR 131.12 (protect high quality waters) 40 CFR 130.23 (Support attainment decisions and diagnose causes)
Strengthen the linkage between designated ALUs and how attainment is assessed	TALUs help to clarify and refine water quality goal statements so numeric biological, chemical, and physical criteria can be adopted to protect the use.	40 CFR 131.10 40 CFR 131.12 (protect high quality waters) 40 CFR 130.23 (Support attainment decisions and diagnose causes)
Enhance public understanding and participation in setting water quality goals	TALUs provide a common frame of reference for generic yardstick to more clearly recognize common ground and differences in desired environmental goals of various stakeholders as designated uses are adopted.	40 CFR 131.20[a][b]

4. Adoption of TALUs that represent detailed narrative goal statements for biological tiers that are directly relevant to the Biological Condition Gradient and as measured by numeric biological endpoints that serve as quantitative measures of attainment of each tier; the narrative language should specify how the numeric endpoints are derived in terms of resource stratification and reference thresholds and how they are to be measured; the numeric endpoints are adopted as biocriteria in the WQS.

Options 1 and 2 seem to be the "easiest" to implement, but they lack a firm regulatory foundation and may be seen as being "optional" for decision-making. Option 3 provides for a direct link to the WQS, but it lacks the specificity needed for applying TALUs and for supporting certain regulatory decisions - it can also encumber a "rule by reference" label. Option 4 may be the more "difficult" and time consuming to develop and implement, but it provides the strongest and most compelling legal foundation.

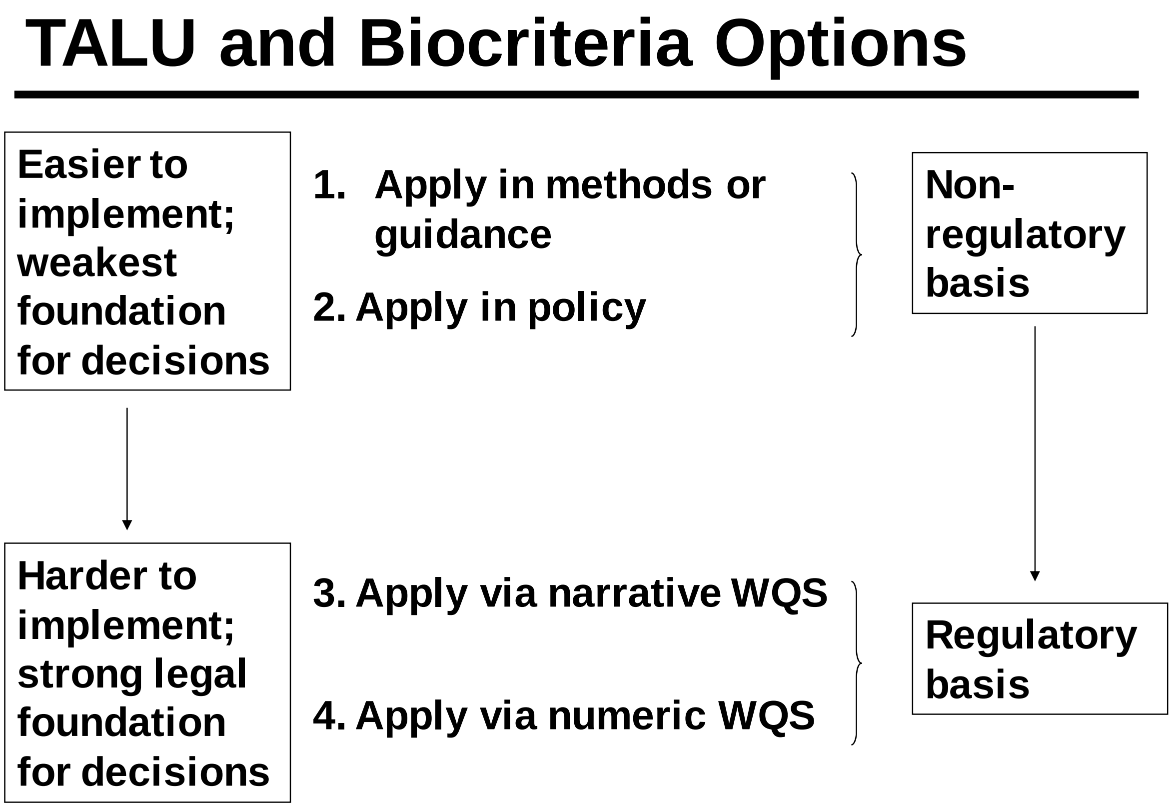


Figure 2-2. Options presently available to states and tribes for developing and implementing biological criteria and tiered aquatic life uses. The numbers correspond to the discussion of each in the text.

2.3.5 Narrative and Numeric Biocriteria

Elements of a narrative biocriterion generally include the following:

- Waters of the State shall be of sufficient quality to support aquatic species without detrimental changes in the resident biological communities.
- Without detrimental changes in the resident biological communities *means no loss of ecological integrity when compared to natural conditions at an appropriate reference site or region.*
- Ecological integrity *means the summation of chemical, physical, and biological integrity capable of supporting and maintaining a balanced, integrated adaptive community of*

> *organisms having a species composition, diversity, and functional organization comparable to that of natural habitats in the region.*

Narrative biocriteria necessarily contain general language (e.g., without detrimental change) that cannot be precisely measured, thus a numeric translator is required and is usually implemented via a policy statement and/or methods guidance. While the above narrative contains the appropriate ecological intent and language, it lacks the quantitative aspects of what EPA expects for a TALU.

Numeric biological criteria require additional defining language in the designated use narrative that pertains to stratification between different types of streams and rivers (e.g., headwaters, small streams, large rivers, great rivers, etc.), ecotype specificity (cold and warmwater, low or moderate gradient, etc.) biogeographical regions, and the level of protection afforded by tiered uses as illustrated by the following example from the Ohio WQS (Warmwater Habitat use tier):

> "Warmwater" – these are waters capable of supporting and maintaining a balanced, integrated, adaptive community of warmwater aquatic organisms having a species composition, diversity, and functional organization comparable to the twenty-fifth percentile of the identified reference sites within each of the following ecoregions: the interior plateau ecoregion, the Erie/Ontario lake plains ecoregion, the western Allegheny plateau ecoregion and the eastern corn belt plains ecoregion. For the Huron/Erie lake plains ecoregion, the comparable species composition, diversity and functional organization are based on the ninetieth percentile of all sites within the ecoregion. For all ecoregions, the attributes of species composition, diversity, and functional organization will be measured using the index of biotic integrity, the modified index of well-being, and the invertebrate community index as defined in "Biological Criteria for the Protection of Aquatic Life: Volume II, Users Manual for Biological Field Assessment of Ohio Surface Waters," as cited in paragraph (B) of rule 3745-1-03 of the Administrative Code. In addition to those water body segments designated in rules 3745-1-08 to 3745-1-32 of the Administrative Code, all upground storage reservoirs are designated warmwater habitats. Attainment of this use designation (except for upground storage reservoirs) is based on the criteria in Table 7-14 of this rule. A temporary variance to the criteria associated with this use designation may be granted as described in paragraph (F) of rule 3745-1-01 of the Administrative Code.

This represents a fully developed TALU narrative that accomplishes the following:

- it defines the overall goal of the TALU tier;
- it identifies and quantifies the reference benchmarks that correspond to this TALU tier;
- it explicitly states a linkage to the accepted methodologies;
- it explains the relationships with other non-aquatic life uses and any exceptions;
- it states any variance provisions; and,

- it references the quantitative numeric biological criteria and these are further stratified by water body ecotype and ecological region.

When combined with a systematic and routine re-sampling of regional reference sites it sets the stage for potential future revisions based on any cues from empirically measured reference condition. In this case the regional reference sites are re-sampled once every ten years.

2.3.6 Biocriteria Application Language in WQS

Biocriteria are a relatively new concept in WQS and they serve primarily as a direct measure of aquatic life use attainment status hence their application in water quality management needs to be defined. This will also clarify their relationship with other chemical, physical, and narrative water quality criteria. We recommend that this be accomplished by appropriately modifying the already detailed application language in the Minnesota WQS (7050.0150). Such language indicates the most commonly occurring options that are available to the state (i.e., the Director, Board, Commissioner, etc.) when biocriteria indicate attainment and non-attainment of aquatic life uses. This also presumes that the state is operating a bioassessment program that is consistent with at least an upper Level 3 and preferably Level 4 under the U.S. EPA *Critical Technical Elements of a Bioassessment Program* (Barbour and Yoder 2008; Yoder and Barbour 2009) and is implemented following the principles of Adequate Monitoring and Assessment (Yoder 1998). Less rigorous programs will simply not be equipped to reliably produce the assessment outcomes and implement the management options that are detailed by the following guidelines. The biocriteria implementation language should explicitly emulate the following and also include detailed options for various management responses:

1) **Define what role the biological criteria will play in the WQS**: This includes stating the extent of their "presumptive applicability", i.e., the biological criteria provide a direct measure of the attainment of the specified designated aquatic life use tiers (i.e., in lieu of a former reliance on chemical/physical surrogates).

2) **State the data requirements**: This includes how the determination of aquatic life use attainment status and the accompanying stressor identification processes are executed. Options include:

    - Frequency, magnitude, and duration provisions – while biocriteria inherently transcend these existing issues that are common to chemical/physical surrogate indicators, a clear statement about what comprises an exceedence is needed;
    - For multiple assemblage assessments (at least two assemblages comprise a level 4 program) mixed findings by each assemblage will need to be addressed;
    - Tier-specific provisions, i.e., higher than CWA minimum use tiers will require a showing of attainment by both assemblages.

3) **State the options for a finding of full attainment**: This includes stating the relationship of biological criteria to other water quality criteria including chemical-specific, narrative, and whole effluent toxicity criteria and endpoints. Management response options include:

- Designating biocriteria as the preferred arbiter of aquatic life use attainment.
- Detailing options for chemical/physical and whole effluent criteria when these are exceeded to include alternate management responses consistent with the biocriteria attainment, revising reasonable potential assumptions within a WLA or TMDL, conducting a site-specific criteria modification, or developing a UAA.

4) **State the options for a finding of non-attainment**: This includes any situation, in which the biocriteria indicate non-attainment, including when the biocriteria are the only indication of non-attainment. Management response options can include:

- A UAA will be conducted to determine the attainability of the designated use tier that is currently assigned to the water body(ies) in question; this will be especially important in previously unassessed, inadequately assessed, and/or default use designated waters.
- The appropriate use will be established prior to new or additional regulatory or management actions.
- When the appropriate use tier is established, the cause(s) of any biocriteria non-attainment *will be* determined based on an *adequate* assessment of the river or stream segment subject to the application of the WQS and subsequent management actions (i.e., NPDES permit, TMDL, 401 certification, stormwater permitting, etc.); designating biocriteria impairments with unknown causes should be extremely rare in this process.
- This is not a justification to supersede other management policies such as anti-backsliding.

Furthermore, language about how a finding of biocriteria non-attainment will affect the consideration of additional regulatory controls on permitted point sources is usually requested to clarify the relationship to a previously issued NPDES permit. Additional permit requirements are based on the following assessment and will generally not be imposed unless:

- The point source is reasonably shown to be a contributing cause to the biocriteria non-attainment; this can include the showing of non-attainment triggering a review of prior reasonable potential determinations or other WLA assumptions.
- The application of alternate treatment/control technologies can reasonably be expected to restore the impaired status.
- Due consideration has been given to the technological and economic feasibility of alternate treatment/control technology required to attain the limitations imposed by this process.

The above comprise the principles by which TALU narratives, numeric biological criteria, and specific application language can be written in the Minnesota WQS. However, given that the Minnesota WQS already include a structure of aquatic life uses, narrative biological criteria, and language for the application of chemical, physical, and biological monitoring data in making use assessments, that existing structure will need to be considered in adapting the new TALUs and numeric biocriteria within that existing framework.

3. A TALU Framework for Minnesota

An important objective of this project is to describe a detailed framework of TALUs and biological criteria for Minnesota rivers and streams. Furthermore, it is implied that such a framework should be consistent with current and emerging U.S. EPA guidance (e.g., U.S. EPA 2005), published methods (e.g., Davis and Simon 1995), and the precedents established by other states that are developing (e.g., Illinois, Vermont, Florida, California), or that already have adopted tiered uses and biocriteria in their WQS (e.g., Ohio, Maine). U.S. EPA, Region V initiated a process in 2002 by which the status of the monitoring and assessment, bioassessment, and WQS programs of the six state's (including Minnesota) would be assessed and in relation to their capacity to support TALU development and implementation. This was initially detailed in a 2004 status report (MBI 2004) and in two major workshops and follow-up visits to each state including Minnesota.

3.1. Minnesota WQS

The primary objective of the CWA is the restoration and maintenance of the chemical, physical and biological integrity of the Nation's waters. States are responsible for adopting and revising WQS and must consider their use and value in protecting public water supplies, propagation of fish and wildlife, recreation, agriculture, industrial and navigation purposes. Minnesota adopted a beneficial use framework that includes uses for drinking water, aquatic life and recreation, industry, agriculture and wildlife, aesthetic enjoyment and navigation, limited resource value waters and other uses. Implicit in the CWA and the federal regulations was the presumption that the aquatic life use should be considered attainable unless proven otherwise through the completion of a use-attainability analysis. Thus, in Minnesota, all waters are considered fishable and swimmable with the exception of waters designated as limited resource value waters (Class 7), which are protected for secondary body contact only.

The Minnesota WQS are codified in the Minnesota Administrative Rules at Chapter 7050, Waters of the State. Parts 7050.0130 to 7050.0227 apply to all waters of the state, both surface and underground. This includes a classification system of beneficial uses applicable to waters of the state, narrative and numeric WQS that protect specific beneficial uses, antidegradation provisions, and other provisions to protect the physical, chemical, and biological integrity of waters of the state. Parts 7050.0400 to 7050.0470 classify all surface waters within or bordering Minnesota and designate the beneficial uses for which these waters are protected. This applies to point source and nonpoint source discharges and to the physical alterations of wetlands. Other water quality rules of general or specific application that include any more stringent WQSs or prohibitions are preserved.

The WQS exist in part for Minnesota to meet the goals of the Federal CWA. With respect to the protection of aquatic life, the Minnesota WQS comprise what we refer to as a "general use" framework in which the designated use consists of a generalized statement of intent and the accompanying criteria are comprised of a list of chemical and physical parameters. The beneficial uses are codified at Chapter 7050.0140 and include the protection of aquatic life, recreation, water supply, and fish consumption and they are specified across seven distinct classes as follows:

> ***Subpart 1. Introduction.*** *Based on considerations of best usage and the need for water quality protection in the interest of the public, and in conformance with the requirements of Minnesota Statutes, section 115.44, the waters of the state are grouped into one or more of the classes in subparts 2 to 8. The classifications are listed in parts 7050.0400 to 7050.0470. The classifications should not be construed to be in order of priority, nor considered to be exclusive or prohibitory of other beneficial uses.*
>
> ***Subpart 2. Class 1 waters, domestic consumption.***
> *Domestic consumption includes all waters of the state that are or may be used as a source of supply for drinking, culinary or food processing use, or other domestic purposes and for which quality control is or may be necessary to protect the public health, safety, or welfare.*
>
> ***Subpart 3. Class 2 waters, aquatic life and recreation.***
> *Aquatic life and recreation includes all waters of the state that support or may support fish, other aquatic life, bathing, boating, or other recreational purposes and for which quality control is or may be necessary to protect aquatic or terrestrial life or their habitats or the public health, safety, or welfare.*
>
> ***Subpart 4. Class 3 waters, industrial consumption.***
> *Industrial consumption includes all waters of the state that are or may be used as a source of supply for industrial process or cooling water, or any other industrial or commercial purposes, and for which quality control is or may be necessary to protect the public health, safety, or welfare.*
>
> ***Subpart 5. Class 4 waters, agriculture and wildlife.***
> *Agriculture and wildlife includes all waters of the state that are or may be used for any agricultural purposes, including stock watering and irrigation, or by waterfowl or other wildlife and for which quality control is or may be necessary to protect terrestrial life and its habitat or the public health, safety, or welfare.*
>
> ***Subpart 6. Class 5 waters, aesthetic enjoyment and navigation.***
> *Aesthetic enjoyment and navigation includes all waters of the state that are or may be used for any form of water transportation or navigation or fire prevention and for which quality control is or may be necessary to protect the public health, safety, or welfare.*
>
> ***Subpart 7. Class 6 waters, other uses and protection of border waters.***
> *Other uses includes all waters of the state that serve or may serve the uses in subparts 2 to 6 or any other beneficial uses not listed in this part, including without limitation any such uses in this or any other state, province, or nation of any waters flowing through or originating in this state, and for which quality control is or may be necessary for the declared purposes in this part, to conform with the requirements of the legally constituted state or national agencies having jurisdiction over such waters, or for any other considerations the agency*

may deem proper.

Subpart 8. Class 7 waters, limited resource value waters.
Limited resource value waters include surface waters of the state that have been subject to a use attainability analysis and have been found to have limited value as a water resource. Water quantities in these waters are intermittent or less than one cubic foot per second at the $7Q_{10}$ flow as defined in part 7050.0130, subpart 3. These waters shall be protected so as to allow secondary body contact use, to preserve the groundwater for use as a potable water supply, and to protect aesthetic qualities of the water. It is the intent of the agency that very few waters be classified as limited resource value waters. The use attainability analysis must take into consideration those factors listed in Minnesota Statutes, section 115.44, subdivisions 2 and 3. The agency, in cooperation and agreement with the Department of Natural Resources with respect to determination of fisheries values and potential, shall use this information to determine the extent to which the waters of the state demonstrate that:

A. *The existing and potential faunal and floral communities are severely limited by natural conditions as exhibited by poor water quality characteristics, lack of habitat, or lack of water;*

B. *The quality of the resource has been significantly altered by human activity and the effect is essentially irreversible; or*

C. *There are limited recreational opportunities, such as fishing, swimming, wading, or boating, in and on the water resource.*

The conditions in items A and C or B and C must be established by the use attainability analysis before the waters can be classified as limited resource value waters.

This framework and implementation plan will deal primarily with subparts 3 and 8 (Class 2 and 7) in terms of how a TALU-based approach will be structured by the Minnesota WQS. The current Minnesota WQS include specific classes for aquatic life and primarily for distinctions between warmwater and cold water aquatic life in subpart 3. These are currently defined at 7050.0222 "Specific WQS for Class 2 waters of the state; aquatic life and recreation" as follows:

Subpart 2. Class 2A; Aquatic Life Cold water Habitat *The quality of Class 2A surface waters shall be such as to permit the propagation and maintenance of a healthy community of cold water sport or commercial fish and associated aquatic life, and their habitats (see definitions in subp. 2b). These waters shall be suitable for aquatic recreation of all kinds, including bathing, for which the waters may be usable. This class of surface waters is also protected as a source of drinking water.*

Subpart 4. Class 2B; Aquatic Life Warmwater Habitat. *The quality of Class 2B surface waters shall be such as to permit the propagation and maintenance of a healthy community* *of cool or warm water sport or commercial fish and associated aquatic life, and their habitats (see definitions in subp. 4b). These waters shall be suitable for aquatic recreation of all kinds, including bathing, for which the waters may be usable. The applicable standards are given below.*

Proposed new tiered uses will replace these “general” uses and follow the rationale described in Sections 3.1.1. and 3.1.2 as follows. In addition, we recommend that Class 7 be eliminated and replaced by the new tiered uses. Existing Class 7 waters will be evaluated the same as current 2A and 2B waters via the UAA process described in Section 4.

3.1.1 The Need for a Minnesota TALU Framework

Over the past 30+ years the Minnesota WQS have been modified to reflect more recent scientific understanding of certain criteria in order to better protect both human health and aquatic life. However the current aquatic life use framework has not reflected the most recent advances in our understanding of the CWA aquatic life goals and how to achieve them. MPCA has initiated a long term project to develop and implement a TALU-based approach to WQS and monitoring and assessment. Minnesota is working to revise its WQS (MN Rule Chapter 7050) to incorporate a TALU framework for rivers and streams in the state. The TALU framework represents a significant revision to the WQSs of the state’s aquatic life use classification. The TALU framework builds upon existing WQSs with a goal of improving how water resources are monitored and managed. Additionally, these changes advance the ability to identify “stressors” and develop effective mechanisms to improve and maintain the condition of waters in the state of Minnesota.

The CWA requires states to assign beneficial uses to water bodies and to develop WQS to protect those uses. Most surface waters in Minnesota are protected for aquatic life and recreation, which means they must be “fishable and swimmable”. There are two primary sub-classes of streams protected for aquatic life including a cold water stream class (2A) and a warmwater stream class (2B). While the current system of beneficial uses and WQS has served Minnesota well, advances in the fields of biological assessment and stream ecology have led to the recognition that all waters are not the same and that there exists a diversity of the water body types. For example, within rivers and streams, factors like water body size, geographic location, hydrology, water temperature, and stream gradient influence chemical, physical and biological composition. The inherent differences in water bodies combined with a rigid and inflexible set of standards and beneficial uses have led to chemical and biological goals that are often under protective of the highest-quality resources and overprotection of some water bodies that for various reasons will likely never achieve certain chemical and biological standards. In short, MPCA now recognizes that proper management of our water bodies requires a more considered and comprehensive approach, one in which the goals are tailored to specific water body types and uses. In response to these challenges, MPCA is proposing to modify the beneficial use framework for aquatic life. The new TALU framework would allow for better goal-setting processes through the application of a framework that recognizes tiers, or levels of aquatic life-use based on a stream’s type and potential. For example, under a tiered system of aquatic life uses, our highest-quality rivers and streams might belong to an "exceptional use" subclass, with water chemistry and biological standards designed to protect the higher use. Additionally, under a TALU framework, uses could be designed to more appropriately reflect the potential of channelized streams and ditches. The fundamental goal of TALU is to set biological and chemical goals that are protective, yet attainable following U.S. EPA guidelines for conducting use attainability analyses (UAA). The TALU framework fully complies with CWA requirements which allow for the establishment of subcategories of the major uses, as long as existing uses are protected. At the same time, it allows MPCA to utilize the latest scientific knowledge to develop appropriate standards and uses and meet the increasingly complex challenges of protecting our water resources.

Traditionally, aquatic life has been protected primarily through the application of water chemistry based standards. For example, the Minnesota standard for dissolved oxygen in all non-cold water streams is 5 parts per million (ppm). These chemically-based standards have been, and will remain, an important aspect of our protection measures. However, the addition of biological monitoring and biological standards will complement and enhance the chemical standards by:

- Providing a direct way to monitor, assess, and ultimately to protect aquatic life.
- Providing a mechanism to identify water quality problems that chemical measurements might miss or underestimate.
- Improving our ability to accurately identify the wide diversity of stressors that impact Minnesota's water resources.

Even if Minnesota recognized aquatic life as a stand-alone use designation, it would not completely satisfy the interim goal of the CWA for states to support healthy, self-sustaining populations of fish, shellfish and other aquatic life in surface waters. While it has been recognized for some time that there is natural variability within aquatic assemblages in Minnesota streams, the current WQS do not adequately reflect the detail of those differences. These include differences in habitat types (i.e., stream size, substrates, flow regime, thermal regime, etc.) and patterns of geological and geographical attributes across the state. MPCA engaged in a process to incorporate this in the development of revised biological indices (i.e., the partitioning accomplished by stream and river classes) as a necessary first step towards adopting a TALU framework in the Minnesota WQS. Furthermore, present assessments of aquatic life use attainment are based on a simple pass/fail framework, even though the stratification accomplished by the biological index refinements is an advancement over applying a uniform statewide IBI. Within the water bodies that are considered to be fully attaining the current set of general aquatic life uses, some have inherently better water quality and biodiversity than others. As such a one-size-fits-all aquatic life use framework is unable to distinguish an adequate level of protection for these higher quality waters. Conversely, it could also result in waters that are of an inherent or irretrievably lower quality being listed as impaired because of unrealistic expectations. This can result in water quality management resources being devoted to issues with a minimal or no environmental return on investment.

Once a TALU framework for Minnesota is developed and implemented a "one-size-fits-all" approach may still be applicable for some numeric chemical criteria such as xenobiotic and bioaccumulative substances. However, simply keeping streams and rivers free from these compounds does not necessarily provide a measure as to whether or not existing high quality waters are being adequately protected. A preoccupation with keeping waters free from toxics also fails to acknowledge that some waters are simply not going to provide for high or even moderate quality aquatic assemblages due to natural conditions or legacy impacts that are irreversible. As a result of the aforementioned limitations, Minnesota's WQS framework is in need of refinement to enhance the designation of appropriate aquatic life uses and the assessment of the attainment of those uses.

3.1.2 Minnesota TALU Framework

The Minnesota TALU framework is built upon a scientific model called the biological condition gradient (BCG; Davies and Jackson 2006). This model describes how biological communities change with increasing levels of stress. The BCG is based on the concept that water bodies receiving higher levels of stress have biological communities with lower condition compared to water bodies receiving lower levels of stress (Figure 3-1). The BCG provides a common framework to interpret changes in biological condition regardless of geography or water resource type. It permits a more accurate determination and classification of Minnesota's aquatic resources which improves the ability to make well-informed decisions on aquatic life designations. Another advantage of the BCG is that it provides a means to communicate existing and potential uses to the public. The development of a set of BCGs specific to each of the aquatic resource classes was accomplished (Gerritsen et al. 2009) by MPCA biologists with assistance from MBI and Tetratech. The development of warmwater BCG models involved input from biological experts familiar with biological communities in Minnesota from the MPCA and Minnesota DNR. BCG models were developed for fish and macroinvertebrates for each of the 7 warmwater stream classes. A cold water BCG is currently in development via a U.S. EPA funded regional project and involved experts from Minnesota, Wisconsin, Michigan, and several tribes located in those states. In Minnesota this included 2 classes each for fish and macroinvertebrates. Model development for each class involved reviewing biological community data from monitoring sites and then assigning that community to a BCG level. A sufficient number of samples were assessed to develop a model which can duplicate the panel's BCG level assignments. Using the BCG and reference condition stream stations permits the MPCA to develop biological criteria that are protective, consistent, and attainable across the State (MPCA 2012a). The adoption of a TALU framework for Minnesota achieves several goals:

Biological Standards. Numeric water quality criteria that are codified in the Minnesota WQS are currently based on chemical and physical criteria such as dissolved oxygen, temperature, and pH. These criteria do not directly measure the health or condition of biological communities which include fishes, insects, mussels, aquatic plants and algae. Although chemical and physical measures can tell us a lot about water quality, these criteria are essentially surrogates for a direct measure of the biological community. This can be problematic due to the large number and diversity of the stressors that impact biological communities which include chemicals, reduced oxygen, sedimentation, increased temperature, and habitat degradation (Figure 3-2). As a result, the monitoring of chemical and physical parameters for all potential stressors can become too cumbersome to be practical. Rather than measuring the wide variety of stressors, biological communities can be monitored as they are a direct measure of the response of the biota to a wide range of physical and chemical stressors. In other words, their condition is a reflection of all the impacts of multiple stressors over time. A major goal of the CWA and Minnesota's WQS is to protect the fish, invertebrates, and other aquatic organisms in Minnesota's waters. Therefore, it is sensible that we use a direct measurement of these communities to monitor their condition. Furthermore, if water resources are not suitable to support healthy aquatic communities, they may not be suitable for a variety of human activities such as fishing and swimming.

Natural Variability. One of the strengths of the TALU approach is its ability to address the natural variation in water resources across Minnesota. Minnesota's diverse water resources mean that "one-size-fits-all" standards lead to errors in assessment and management. In other words, we need to have different expectations for different water resources. For example, streams along the North Shore are very different from streams in southern Minnesota and we would expect that the biological communities in those streams under natural conditions to be different. The TALU framework takes into account these natural differences and requires that comparisons be made between streams with similar expectations.

The BCG and Reference Condition. The biological monitoring program in Minnesota relies on BCG models and the "reference condition" approach to set expectations for water bodies. The BCG is a conceptual model of aggregated biological knowledge used to describe changes in biological communities along a gradient of increasing stress. The BCG provides a common "yardstick" of biological condition that is rooted in the natural condition. As a result, the BCG can be used to develop of biocriteria that are consistent across regions and stream types in Minnesota. This is particularly important for a state such as Minnesota where the range of existing quality is regionally distinct and extreme (i.e., near pristine to highly degraded). The reference condition approach identifies waterbodies that are least stressed and uses them to establish the "reference condition." Once this reference condition has been established, then waterbodies with unknown condition can be compared to this baseline. If the condition of the waterbody is lower than that of the reference condition, it would be considered impacted or stressed. The use of a reference condition relies on the development of accurate expectations for least stressed sites. Using the BCG and reference condition approach biological criteria were developed to protect Minnesota's aquatic life goals (MPCA 2012a).

High Quality Water Resources. A shortcoming of the current water quality framework is that high quality resources are often under protected. At present there is a framework to protect the degradation of high quality waters called antidegradation, but there are still elements of Minnesota's antidegradation provisions in rule that can allow considerable degradation of these waters without violating the CWA. TALU establishes a higher tier of use to protect these high quality waters. Once a water body has been established as meeting the requirements of a high quality water resource, the resource needs to be protected to maintain that status. The concept of protecting the "existing" use of a water body is one of the most important tenets of the CWA.

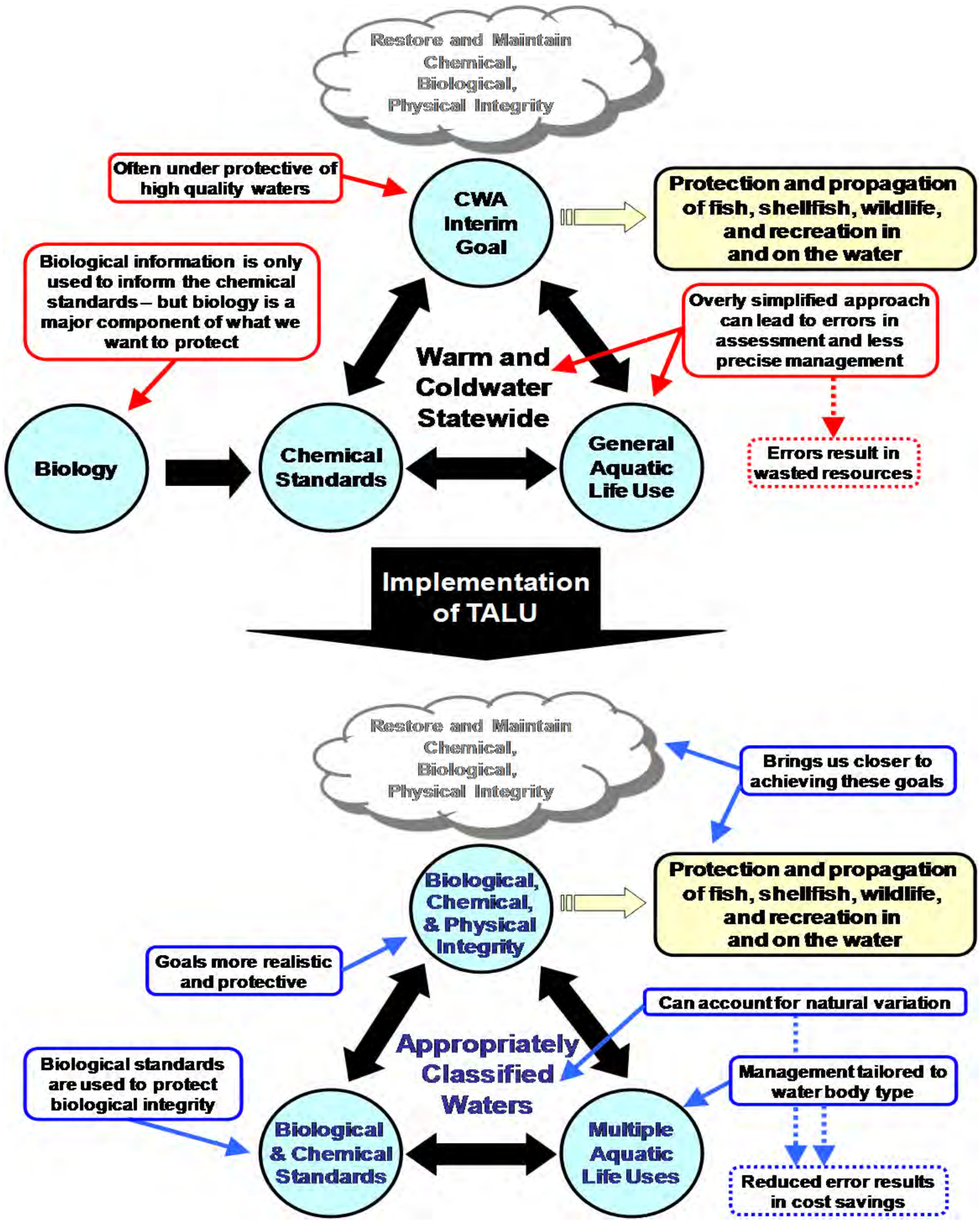


Figure 3-2. The characterization of CWA goals, Minnesota aquatic life uses, and new biological standards before and after implementation of a TALU framework.

Modified or Limited Water Resources. There are water resources in this State that will not in the near future meet the CWA interim goals due to historical or legacy impacts. These legacy impacts include streams under drainage maintenance or other irreversible hydromodification that preclude attainment of goals. For example, channelized streams and ditches would be included under this category. TALU provides a mechanism to monitor and set realistic expectations for waters that are unlikely to meet goals due to legacy impacts. The expectations are fully protective of the existing uses for each water body and recognize their historical and current site specific context. This element of TALU allows for the establishment of realistic expectations for water bodies that have multiple and well established uses.

Some other goals/benefits of TALU adoption include:

- Monitoring of incremental improvements in water quality. This allows entities working to improve water quality to document and show progress toward a goal.
- TALU helps guide development and modification of WQS to produce improved standards.
- TALU merges the design and practice of monitoring and assessment with the development and implementation of WQS.

Achieving these goals through the TALU framework will bring Minnesota closer to the protection and maintenance of the biological, chemical, and physical integrity of water resources in the state.

3.2 A Revised Aquatic Life Use Framework for Minnesota

We propose here the following conceptual structure of designated aquatic life uses as either a modification or outright replacement for the current General Use standards framework as it applies to aquatic life. This would also seem to eventually necessitate the clarification of the other non-aquatic life use subcategories that are currently bundled together under General Use standard, but that is not a purpose of this plan. However, it will be an MPCA decision about how the new TALU-based WQS will be structured within chapter 7050.

There are several factors that we considered in recommending a revised structure for designated aquatic life uses in Minnesota. The current framework of the biological assessment approach including the development and use of multimetric indices and their derivation and calibration based on “minimally disturbed” to “least impacted” regional reference condition makes a tiered structure the most attractive option. As such this framework consists of distinct descriptions of categorical use subcategories or “tiers” of expected condition and potential quality. This also includes distinct “warmwater” and “cold water” assemblage baselines for Minnesota rivers and streams that will be directly included in the TALU framework. The major aquatic life use subcategories proposed herein are described as follows:

Exceptional - These are waters that exhibit the highest quality of “exceptional” assemblages (as measured by assemblage attributes and indices) on a Minnesota Biological Condition Gradient (BCG) basis; narrative descriptors such as “exceptional” can be used as the distinguishing descriptors in the designated use narrative, but other descriptive terms are possible. These communities have minimal changes in structure of the biotic assemblage and in ecosystem function which is the ultimate goal of the CWA. It functions as a preservation use, which means it is intended for waters that already exhibit or have the realistic potential to attain an exceptional quality as measured by the biological criteria.

General – These are waters that harbor "typically good" assemblages of freshwater organisms (as measured by assemblage attributes and indices) and that reflect the lower range of the central tendency of "least impacted" regional reference condition. In the language of the BCG, they are communities that can be characterized as possessing "*overall balanced distribution of all expected major groups; ecosystem functions largely maintained through redundant attributes*". As such this use represents the minimum CWA goal attainment threshold and it serves as the principal restoration use for management programs. It also serves as the "triggering threshold" for when a UAA is required to determine the attainability of this designated use tier for specific river or stream segments.

Modified – These are waters that have been extensively altered and currently exhibit legacy physical modifications that pre-date the November 28, 1975 existing use date in the Federal Water Quality regulations (40CFR Part 131). These waters have been determined to be in non-attainment of the General use biological criteria and have been determined to be incapable of attaining those criteria via a UAA. The biological criteria for the Modified use are established based on a separate population of "modified reference sites" that exhibit these types of modifications with little presence of other types of stressors. Possible subcategories include channelization for flood control and agricultural drainage and impoundments created by run-of-river low head dams. Separate reference populations are needed to derive the numeric biocriteria for each subcategory.

Limited - These are waters that have been substantially altered and currently exhibit severe and essentially irretrievable legacy modifications that pre-date the November 28, 1975 existing use date in the Federal Water Quality regulations (40CFR Part 131). These waters have been determined to be in non-attainment of the Modified biological criteria and have been determined to be incapable of attaining those criteria via a UAA. The biological criteria for the Limited Resource use are established at the "poor" level of biological performance in keeping with preventing nuisance conditions. As such the biocriteria for this use are not based on a distinct set of "limited reference" sites. Possible subcategories include small drainageway maintenance for flood control and severe restrictions of the channel for different purposes (e.g., via concrete revetments).

The preceding describes the general circumstances under which one of the four categorical tiers would apply. However, the narrative language for each use will need to include more detailed and descriptive language to include the following:

1) A definitive statement about the overall goal of the use tier. An example is using the definition of biological integrity (Frey 1977; Karr and Dudley 1981) as follows:

“. . . these are waters capable of supporting and maintaining a balanced, integrated, adaptive community of warmwater aquatic organisms that are comparable to . . .”

2) A description of the geographic applicability of the use tier (or subclass) – an example for Minnesota would be the fish and macroinvertebrate stream and river classes.
3) A clear statement about how attainment of each use tier is to be measured, at least by reference to numeric endpoints in rule.
4) A reference to the method(s) documentation that must be followed to generate the data from which the biological data is processed and attainment can be determined. This could also include any certifications or credible data qualifications.
5) Any exceptions to the applicability of the use tier, i.e., that the use does not apply to non-aquatic life uses and their criteria, variance provisions, etc.

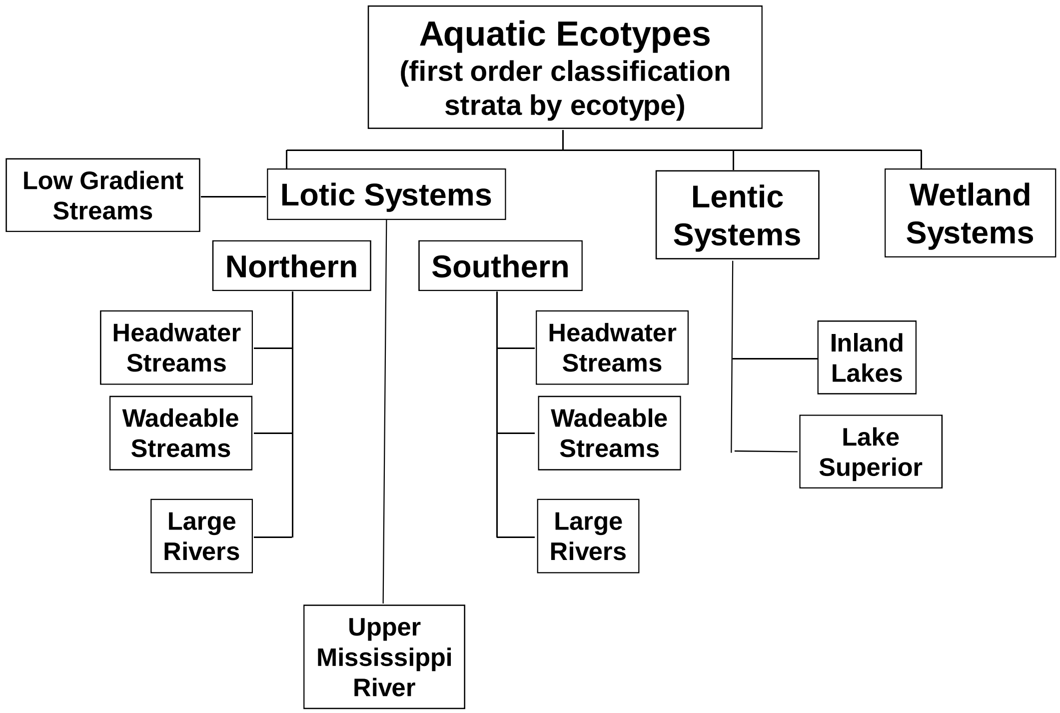
The specific narrative language and accompanying numeric biological criteria for each use tier within the warmwater and cold water subclasses is developed next and serve as the narratives for the new tiered designated uses for adoption in chapter 7050. There will be cold water and warmwater distinctions for at least the exceptional and general subcategories. The modified and limited resource use subcategories will be applicable to warmwater streams and rivers exclusively.

Figures 3-3 through 3-5 depict the organizational hierarchy of the new aquatic life use structure including the overall distinction of aquatic ecotypes (Figure 3-2), the distinctions between warmwater (Figure 3-3) and cold water (Figure 3-4), and the use tiers and subcategories within each (Figures 3-3 and 3-4). This is the organization that we expect based on the developmental work accomplished by MPCA. However, modifications to the ecotype classifications and refinements to the TALU tiers (the tier specific subcategories in particular) are possible in the future as they are recognized based on the feedback provided by consistent TALU program implementation.

3.2.1 Proposed Tiered Uses and Numeric Biocriteria for Minnesota

Based on the preceding guidelines, four overall aquatic life use tiers are recommended for Minnesota that includes numeric biocriteria for fish and macroinvertebrates and within each of the nine natural classes for rivers and streams for each assemblage. We feel that the already developed bioassessment methods and indices for Minnesota (MPCA 2012b) are sufficiently rigorous for supporting the implementation of numeric biocriteria. Our purpose herein is to describe a framework and structure for tiered uses with linkages to the current bioassessment methodologies used by MPCA.

The four general “tiers” described in Section 3.2 are recommended at this time while also recognizing the possibility that further refinements or subclasses may become apparent as the TALU framework is implemented by MPCA. At present Minnesota has what might be



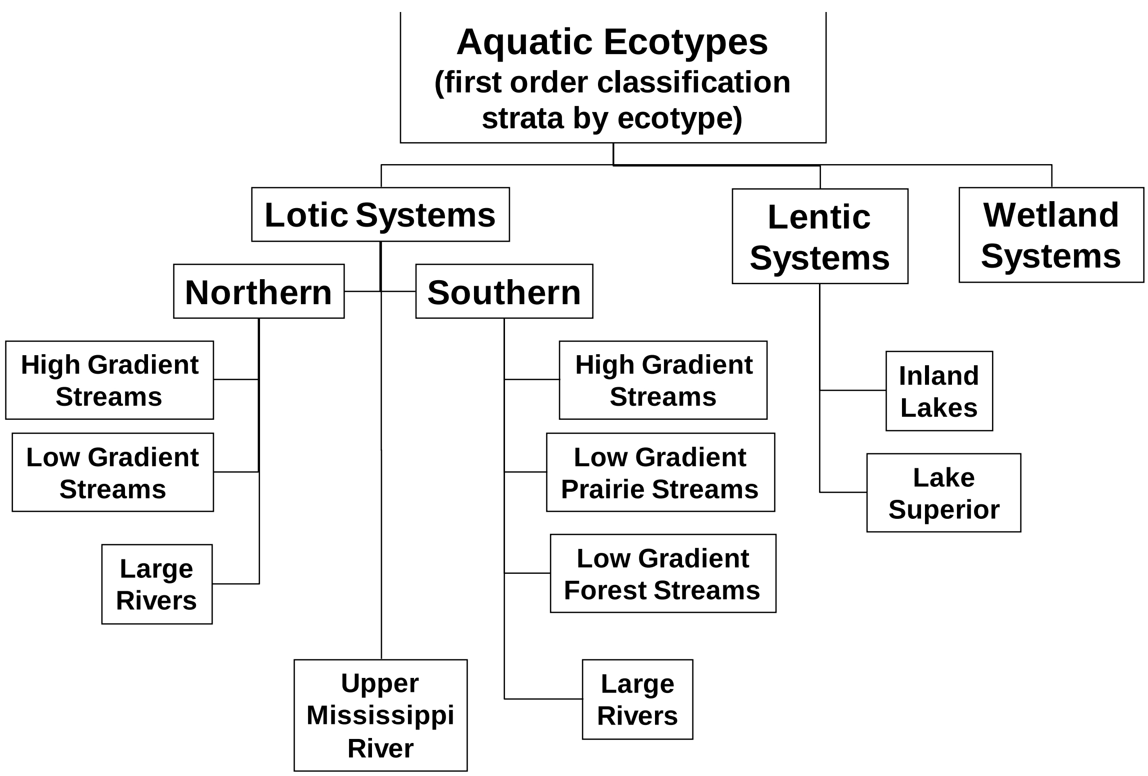


Figure 3-3. First order classification of aquatic ecotypes for fish (upper) and macroinvertebrates (lower) showing the classification strata for the lotic ecotype in Minnesota. Classification strata are possible for lentic and wetland systems, but are not the subject of this project. Upper Mississippi River is below Twin Cities Lock and Dam #1.

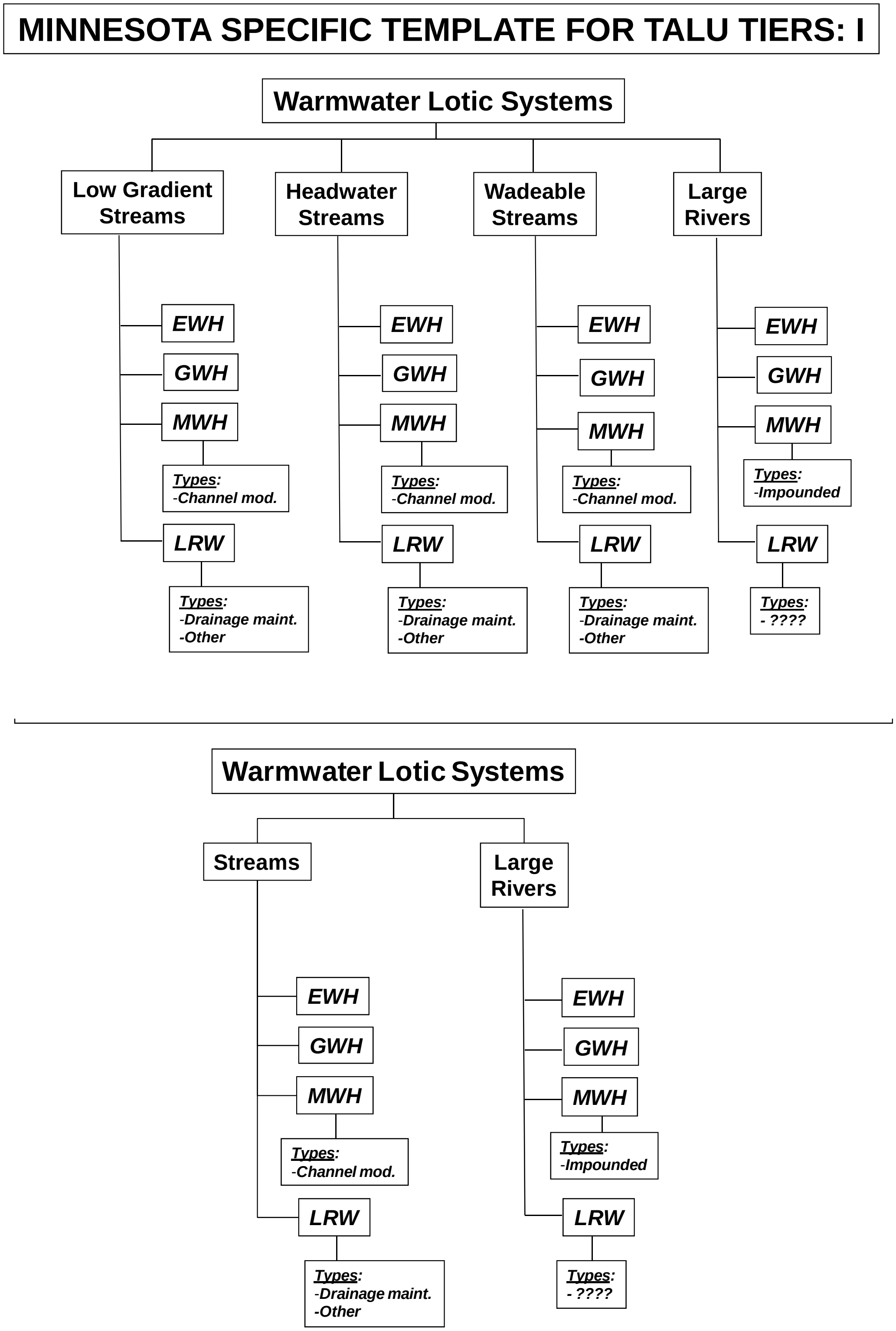


Figure 3-4. Tiered aquatic life uses for fish (upper) and macroinvertebrates (lower) for the warmwater lotic ecotype classifications to which it is expected to apply. Distinct fish and macroinvertebrate IBIs and BCG rules apply to each lotic classification. Numeric biocriteria are derived for each tier (EWH = Exceptional Warmwater Habitat; GWH = General Warmwater Habitat; MWH = Modified Warmwater Habitat; LRW = Limited Resource Water) and by disturbance type for MWH and LRW.

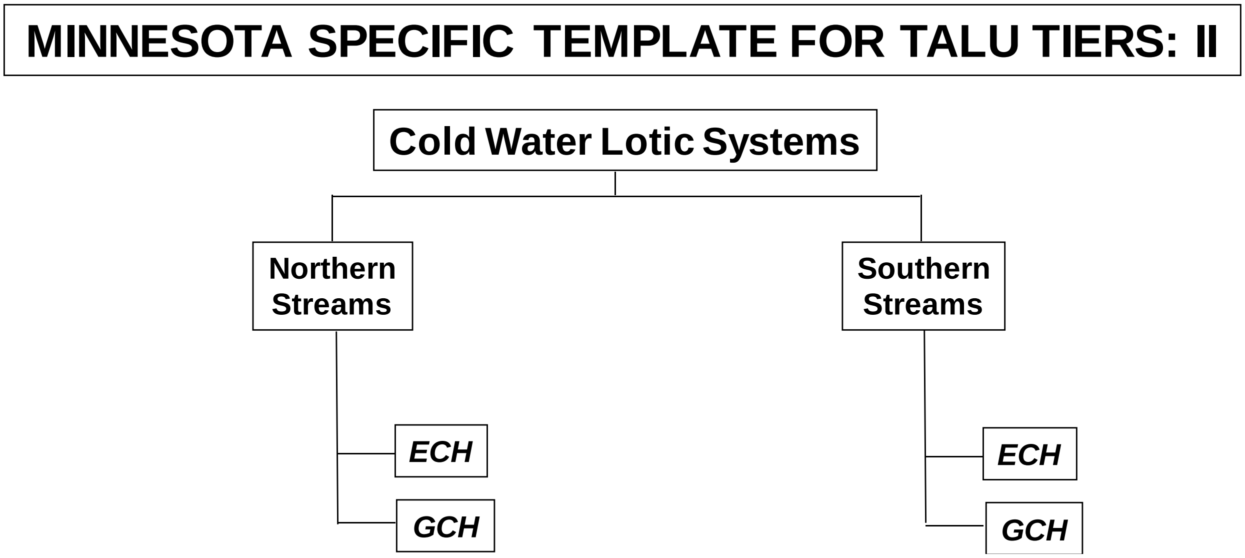


Figure 3-5. Tiered aquatic life uses for the cold water lotic ecotype classifications to which it is expected to apply. Distinct fish and macroinvertebrate IBIs and BCG rules apply to each lotic classification and numeric biocriteria are derived for each tier (ECH = Exceptional Cold water Habitat; GCH = General Cold water Habitat).

considered as "non-regulatory" biological criteria (see Figure 2-1) that are largely applied via methodological guidance detailed in their 305[b] reporting and 303[d] listing process (MPCA 2011). Adopting the TALU framework described herein will result in a firmer regulatory basis via the tiered uses and numeric biocriteria.

3.2.2 Designated Use Narratives Applicable to Minnesota Rivers and Streams

The recommended designated use narratives are composed here to reflect the previously described provisions in Sections 3.1 and 3.2 about what each use tier narrative should include and to reflect the biological methods and indices/models upon which the numeric biocriteria and their application will take place. The following is the recommended 7050 rule language for the warmwater use subclass as follows:

> *"Exceptional Warmwater" – these are waters capable of supporting and maintaining an exceptional and unusual balanced, integrated, adaptive community of warmwater aquatic organisms having a species composition, diversity, and functional organization comparable to the 75th percentile of Biological Condition Gradient Level 3 as specified in Calibration of the Biological Condition Gradient for Streams of Minnesota (Gerritsen et al. 2009). For all stream and river classes, the attributes of species composition, diversity, and functional organization will be measured using the fish-based Index of Biotic Integrity as defined in "Manual for Calculating Fish Index of Biotic Integrity Scores for Streams and Rivers in Minnesota" and the macroinvertebrate Index of Biotic Integrity as defined in "Manual for Calculating Macroinvertebrate Index of Biotic Integrity Scores for Streams and Rivers in Minnesota" as cited in [reference to analytical methods part of 7050 goes here]. Attainment of this use designation is*

based on the criteria in [refers to table of biocriteria values in 7050.0222].

"General Warmwater" – these are waters capable of supporting and maintaining a balanced, integrated, adaptive community of warmwater aquatic organisms having a species composition, diversity, and functional organization comparable to the median of Biological Condition Gradient Level 4 as specified in Calibration of the Biological Condition Gradient for Streams of Minnesota (Gerritsen et al. 2009). For all stream and river classes, the attributes of species composition, diversity, and functional organization will be measured using the fish-based Index of Biotic Integrity as defined in "Manual for Calculating Fish Index of Biotic Integrity Scores for Streams and Rivers in Minnesota" and the macroinvertebrate Index of Biotic Integrity as defined in "Manual for Calculating Macroinvertebrate Index of Biotic Integrity Scores for Streams and Rivers in Minnesota" as cited in [reference to analytical methods part of 7050 goes here]. Attainment of this use designation is based on the criteria in [refers to table of IBI biocriteria values in 7050.0222] except in instances where biological data is not readily available.

"Modified Warmwater" – these are waters that have been the subject of a use attainability analysis and have been found to be incapable of supporting and maintaining a balanced, integrated, adaptive community of warmwater organisms due to irretrievable modifications of the physical habitat. Such modifications are of a long-lasting duration (i.e., twenty years or longer) and may include the following examples: extensive stream channel modification activities permitted under sections 401 and 404 of the act or [Minnesota Statutes Chapter 103E], and extensive permanent impoundment of free flowing water bodies. [any other precluding categorical activities added here] Numeric biocriteria are derived from a distinct population of "impacted reference" sites reflecting only the categorical impacts implied in this definition (MPCA 2012a). For all stream and river classes, the attributes of species composition, diversity, and functional organization will be measured using the fish-based Index of Biotic Integrity as defined in "Manual for Calculating Fish Index of Biotic Integrity Scores for Streams and Rivers in Minnesota" and the macroinvertebrate Index of Biotic Integrity as defined in "Manual for Calculating Macroinvertebrate Index of Biotic Integrity Scores for Streams and Rivers in Minnesota" as cited in [reference to analytical methods part of 7050 goes here]. Attainment of this use designation is based on the criteria in [refers to table of IBI biocriteria values in 7050.0222] and by the categorical subclasses based on the modification type.

"Limited Resource Water" - these are waters that have been the subject of a use attainability analysis and have been found to lack the potential for any resemblance of any other aquatic life subclass. The use attainability analysis must demonstrate that the extant fauna is substantially degraded and that the potential for recovery of the fauna to the level characteristic of any other aquatic life habitat is realistically precluded.

While a hierarchy of four tiers of aquatic life uses is recommended here, the specific language included above can be modified to accommodate the specific needs of the Minnesota WQS (i.e., other rule references, exclusions, variances, etc.) or it can be accounted for in the MPCA implementation language described in Section 3.5.

3.3 Numerical Biological Criteria for Minnesota Rivers and Streams

The just described designated use narratives are the essential first part of a TALU. The numerical biological criteria are the essential second part and they are derived in accordance with the stated conditions of the narrative. As such the thresholds that are described in the narrative are the numerical biocriteria as derived from the class-specific BCG models and the regional reference datasets that are used to derive and calibrate the biological indices. The rigor of these datasets is an important linchpin in this process and is evaluated as part of the Critical Elements process (Yoder and Barbour 2009). At this point we recommend utilizing the newly developed set of calibrated biological indices and the classification scheme employed for each as the basis of the numeric biocriteria. The narratives are written such that future changes can be accommodated without making any changes to the designated use narratives themselves.

Key to the derivation of numeric biocriteria is the reference threshold for each biological index that is selected for each aquatic life use tier. The biocriteria applicable to the highest TALU tiers are intended to correspond to the upper levels of the BCG, i.e., levels 1, 2, and 3. The upper tiers that represent level 1 and upper level 2 conditions can also be used to develop more refined antidegradation tiers.

3.3.1 Regional Reference Condition

The most recent available guidance on reference condition can be found in Stoddard et al. (2006). This paper describes a framework for organizing reference condition and recognizing that there are differences between minimally disturbed and least impacted reference conditions. The concept of a reference condition is used to describe the standard or benchmark against which current condition is compared. However the phrase itself can have many meanings and different contexts. Stoddard et al. (2006) stated the need for reference condition to refer to the “naturalness” of the aquatic biota in terms of its structure and function. As such this anchors reference condition in the upper levels of the Biological Condition Gradient (BCG). To organize and standardize the use of reference condition Stoddard et al. (2006) defined the following hierarchy of reference condition:

- **Minimally Disturbed Condition (MDC)** – This term describes the condition of the biota in the absence of significant human disturbance and it is the best approximation of biological integrity. It is acknowledged that finding actual sampling sites that are truly undisturbed by the global influence of human activities is probably not possible. This would be especially true of the agricultural, urbanized, and industrialized Midwestern U.S. of which Minnesota is a part. MDC also recognizes that some natural variability in biological indicators will always occur and needs to be recognized when empirically describing this condition.

- **Historical Condition (HC)** – This term describes the condition of the biota at some point in their history. It may be an accurate estimator of true reference condition (i.e., biological integrity) if the historical point chosen is before the start of any human disturbance. However, many of the historical reference points are possible (e.g., pre-industrial, pre-Columbian). A recent example of developing and accessing historical conditions was described by Armitage and Rankin (2009) for the Wabash River basin of Indiana and by Rankin and Yoder (2010) for the Upper Mississippi River.

- **Least Disturbed Condition (LDC)** – Least disturbed condition is found in conjunction with the best available physical, chemical, and biological habitat conditions given today's state of the landscape. It is ideally described by evaluating at data collected at sites selected according to a set of explicit criteria defining what is ''best'' or least disturbed by human activities. The resulting least disturbed biological conditions will vary from region to region and/or water body type and class and are developed iteratively with the goal of establishing the least amount of human disturbance based primarily on stressors that can be delineated by geographic information system data, proximity to obvious sources of impact (e.g., large point sources), and other evidence of disturbance at a site. As such this represents an evaluation and ranking of the "cultural setting" represented by candidate reference sites. The first attempts at selecting reference sites were largely based on qualitative measures (e.g., Yoder and Rankin 1995a), but more recently they have included more quantitative measures of landscape disturbance (U.S. EPA 2006). Because the condition of the overall environment may change through time as restoration and/or degradation proceeds, this condition may change through time. Hence the expectation that a level 4 bioassessment program will provide for the regular re-sampling of reference condition (e.g., once every 10 years). This enables the tracking of any changes in reference condition to include a recalibration of the biological indices, the biological criteria, or both on a predictable basis (Yoder and Rankin 1995a). The CWA and federal regulations preclude any lowering of the numeric biocriteria once they are established in the WQS.

- **Best Attainable Condition (BAC)** – This is the expected condition of least disturbed sites under the implementation of best management practices (BMPs) for a sufficient period of time. This is a condition that results from the convergence of management goals, best available technologies, and a public commitment to achieving environmental goals (e.g., as established by WQS) under prevailing uses of the landscape. BAC may be equivalent to either to either MDC or LDC depending on the prevailing level of human disturbance in a region. It is not invariable because the above factors can vary over time. In some cases where historical disturbance has been extensive and widespread it may not satisfy the minimum CWA goals for aquatic life, hence alternate approaches to setting biological criteria may be needed.

The span of reference conditions represented by the just described hierarchy is illustrated as it relates to the Biological Condition Gradient (BCG) in Figure 3-6 (modified from Stoddard et al. 2006). In a region where the majority if not all of the reference sites truly represent minimally disturbed conditions the reference sites would score in levels 1 and 2 of the BCG along the axis

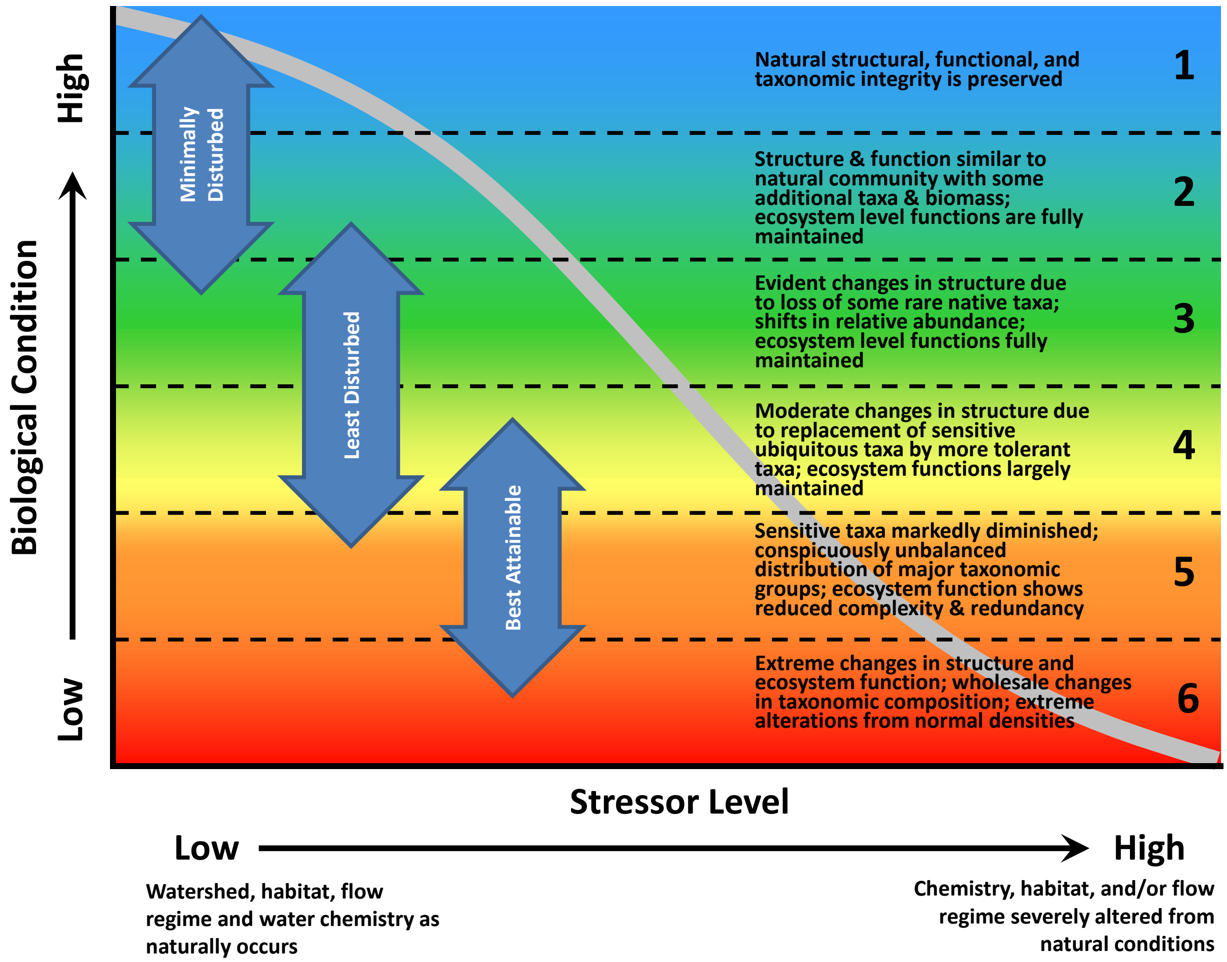


Figure 3-6. The distribution of minimally disturbed, least disturbed, and best attainable reference condition along the axis of biological condition against the level of stress. Minimally disturbed, least disturbed, and best attainable are shown as they relate to their position in the Biological Condition Gradient (BCG; Davies and Jackson 2006). Adapted from Stoddard et al. (2006).

of the biological index. In a region with fewer minimally disturbed reference sites and an increasing number of least impacted reference sites, the range along the biological index axis would extend into levels 3 and 4 of the BCG. In regions that have no minimally disturbed sites and a majority of least disturbed and best attainable sites, the range along the biological index axis would extend into tier 4 and perhaps even tier 5 of the BCG. Under no circumstances should least impacted reference sites occupy tier 5 and extend into tier 6. This would illustrate a lack of any redeeming reference condition and an alternate approach would be needed to derive numerical biocriteria consistent with CWA goals. Modified and limited reference sites would be expected to represent tier 5 and even into to tier 6, almost by definition, because neither attains the minimum CWA goal. Referring specifically to this standardized framework of reference condition and clearly indicating which practical definition of reference condition is being used to set biocriteria will make biological criteria and the assessments upon which they are based more comparable between the classification regions.

3.3.2 Minnesota Reference Condition

Another important aspect of this framework is that a better understanding of the quality of the applicable regional reference condition will better standardize how numeric biological criteria are established. The relative quality of the regional reference condition is a key variable in determining at what percentile of the reference distribution (i.e., the threshold) of a biological index that represents the minimally acceptable biocriterion for CWA purposes. The actual distribution of empirically measured reference condition also influences how many upper level tiers might be needed and where those biocriteria are set. An example is displayed in Figure 3-7 that depicts the reference site scores for the Minnesota stream and river classification strata. These are the fish and macroinvertebrate IBI scores at minimally to least disturbed reference sites for each fish and macroinvertebrate class. The IBIs were derived and calibrated for each classification strata and the numerical biocriteria derived by the BCG tiers. This framework ensures that the resultant numeric biocriteria are consistent with the goals of the CWA and hence are protective of their designated uses and hedge against unintentional bias that may be introduced by including too many potentially marginal reference sites. The Southern streams and headwaters FIBI GWH biocriterion for fish is above the median reference value (Figure 3-7) and it is doubtful that few if any of those sites represent least impacted reference conditions since the effects of hydromodification and agricultural land use are so extensive and BMPs have not been validated in terms of CWA goal attainment. As such basing the biocriteria thresholds on the median of the BCG tier 4 protects against having the biocriteria determined by what is in this class “best attainable” conditions. In contrast the Northern rivers and streams reflect a preponderance of minimally disturbed conditions as reflected by the position of those FIBI thresholds (Figure 3-7).

3.3.3 Derivation of Numeric Biocriteria for Minnesota Rivers and Streams

An example of how the numeric biological criteria will be structured for Minnesota rivers and streams appears in Table 3-1 and is based on thresholds that correspond to “reference” conditions reflective of Human Disturbance Score (HDS) scores of >61 for headwaters and streams and >45 for large rivers for the General uses. Based on our prior discussion of reference condition this equates to the “bottom” of a least impacted reference condition. Within the Exceptional use an upper tier exceptional biocriterion is being proposed for the Northern Rivers class. The decision about which percentile to select is based on our estimate of the extent of either how “minimally disturbed” of “least impacted” is the prevailing reference condition, with more conservative percentiles (as noted above) being used when that population is comprised predominantly of least impacted and best attainable conditions. In northern classes the 10^{th} percentile of reference sites was used and in southern and statewide classes the 25^{th} percentile was used. Comparison with the BCG indicated that these thresholds most closely matched the median of BCG 4 so this threshold was used to set the General Use (GU) biocriteria values.

For exceptional uses the 75^{th} percentile of IBI scores for reference sites was chosen to be in keeping with the narrative attributes of this tier. This threshold most closely corresponded to the 75^{th} percentile of BCG level 3 and it was used to set biological criteria for the Exceptional Use (EU). Modified Use (MU) criteria were developed by identifying modified “reference” sites

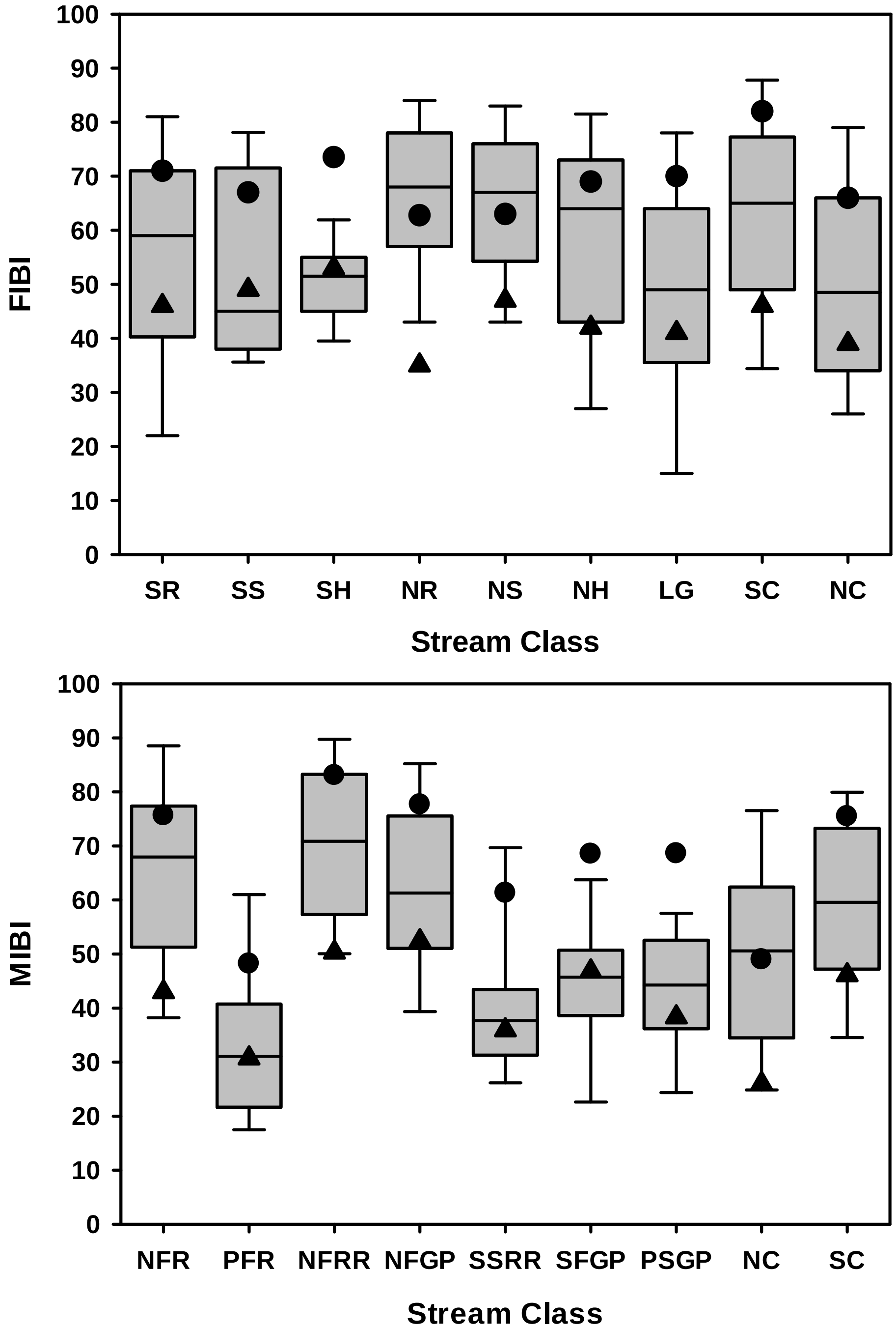


Figure 3-7. Frequency distribution of fish IBI (FIBI; upper) and macroinvertebrate IBI (MIBI; lower) scores at warmwater and cold water (SC and NC) reference sites in Minnesota by classification strata. The General biocriterion (▲) is set at the median of the class-specific BCG tier 4 for all classes. The Exceptional biocriterion (•) is set at the 75th percentile of the class-specific BCG tier 3 for all classes. Symbols: upper and lower bounds of box = 75th and 25th percentiles, middle bar in box = 50th percentile, upper and lower whisker caps = 95th and 5th percentiles; Abbreviations: SR = Southern Rivers, SS = Southern Streams, SH = Southern Headwaters, NR = Northern Rivers, NS = Northern Streams, NH = Northern Headwaters, LG = Low Gradient Streams, SC = Southern Cold water, NC = Northern Cold water, NFR = Northern Forest Rivers, PFR = Prairie Forest Rivers, NFRR = High Gradient Northern Forest Streams, NFGP = Low Gradient Northern Forest Streams, SSRR = High Gradient Southern Streams, SFGP = Low Gradient Southern Forest Streams, PSGP = Low Gradient Prairie Streams, SC = Southern Cold water, NC = Northern Cold water.

that represents the attainable biological condition for these streams. In theory these streams represent the biological condition that is attainable in waters that have been legally modified and which have been subjected to a UAA. To identify these streams, landscape and reach level riparian condition measures were used to select channelized reference streams. Reaches with less than 80% of the riparian disturbed at both the watershed and reach scales were selected. A secondary filter of dissolved oxygen > 4 mg/L and < 12 mg/L was also used to remove reaches that were also impacted by the effects of excessive nutrients. Once these modified "reference" sites were selected, the 25th percentile of IBI scores was determined for each stream class. Nine of the stream classes had very few or no channelized streams and therefore it was determined that development of a Modified Use for these classes was not appropriate. These thresholds were then compared to the BCG and it was determined the reference condition most closely corresponded to the median of BCG level 5. This threshold was used as the Modified Use biocriterion for the classes to which it applies (Table 3-1).

Table 3-1. Draft numeric biocriteria for Minnesota rivers and streams organized by warmwater and cold water ecotypes, stream and river classification strata within each, and the corresponding Exceptional, General, and Modified Uses (NA – not applicable).

Class #	Class Name	EU	GU	MU
	Fish			
1	Southern Rivers	71	46	NA
2	Southern Streams	67	49	33
3	Southern Headwaters	74	53	32
4	Northern Rivers	63	35	NA
5	Northern Streams	63	47	32
6	Northern Headwaters	69	42	22
7	Low Gradient Streams	70	41	15
10	Southern Cold water	82	46	NA
11	Northern Cold water	66	39	NA
	Invertebrates			
1	Northern Forest Rivers	76	43	NA
2	Prairie Forest Rivers	48	31	NA
3	Northern Forest Streams RR	83	51	NA
4	Northern Forest Streams GP	78	49	36
5	Southern Streams RR	61	36	24
6	Southern Forest Streams GP	69	43	28
7	Prairie Streams GP	69	42	21
8	Northern Cold water	49	27	NA
9	Southern Cold water	75	45	NA

3.3.4 Determining Attainment of the TALU-Based Biocriteria

The proposed designated aquatic life use narratives state that attainment will be based primarily on the numeric biocriteria for each use tier and classification stratum. This is consistent with a TALU-based approach in that the biocriteria are the primary response variable while chemical and physical criteria function as indicators of stress and exposure and represent the implementable measures for water quality management. As such, the biocriteria function along the y-axis of the BCG whereas chemical/physical measures function along the x-axis of the BCG. Because this represents a change to the current assessment approach, MPCA may choose to phase biocriteria into the water body assessment process until sufficient assessments are accomplished to determine exactly how to implement the recommended rule language.

The current MPCA process for using biological data is detailed in the *Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment: 305b Report and 303d List* (MPCA 2011). This guidance was the first attempt by MPCA to formally incorporate biological assessments into their water body assessment process. Furthermore, biological indicators are essentially treated as a co-factor with chemical/physical indicators which blurs the distinction between the defined roles of these indicators in a TALU-based approach. The current process for determining attainment and non-attainment is written as follows:

> *Overall assessment of whether an AUID adequately supports aquatic life involves the review of the parameter-level evaluations and data quality in conjunction with all available supporting information (flow, habitat, precipitation, etc.) to make an overall use-support determination. For a given AUID, there may be chemistry indicator data, biological indicator data, or both types of data available for assessment. The final assessment takes into consideration the strength of the various indicators and the quality of the data sets and, in addition, looks at upstream and downstream conditions to gain a better understanding of the interactions between the individual AUID and the larger water body and watershed.*
>
> *In general:*
>
> *a) A stream reach is considered to be fully supporting of aquatic life if:*
>
> - *IBI scores for all available assemblages indicate fully supporting conditions, or*
> - *the criteria for both dissolved oxygen and turbidity/t-tube/total suspended solids are adequately met, and*
> - *other lines of evidence considered comprehensively, including upstream/downstream conditions, do not contradict a finding of full support*
>
> *b) A stream reach is considered to be not supporting if:*
>
> - *IBI scores for at least one biological assemblage indicate impairment, or*
> - *one or more water chemistry parameters indicates impairment, and*
> - *other lines of evidence considered comprehensively, including*

upstream/downstream conditions, do not contradict a finding of non-support

c) If the above criteria are not met and the assessment is inconclusive, the result is a determination of insufficient information.

In cases where an assessment unit has been determined to be not supporting based on biological indicators, water-chemistry parameters are added to the list of impairments only when the chemical impairment is clear enough that the AUID would be considered impaired even without the biological evidence.

Additional guidelines are available in MPCA (2011) that clarify the process and outcome decisions for scenarios a through c above. The programmatic implications to the assessment program are discussed in Section 5.0.

For assessing impairments with biological data, the current procedure is to declare an impairment if the biocriterion for either the fish or macroinvertebrate assemblage is exceeded, a practice that we recommend continue. MPCA also considers confidence intervals around the numeric biocriterion in determining an impairment (Figure 3-8), a practice that we concur with.

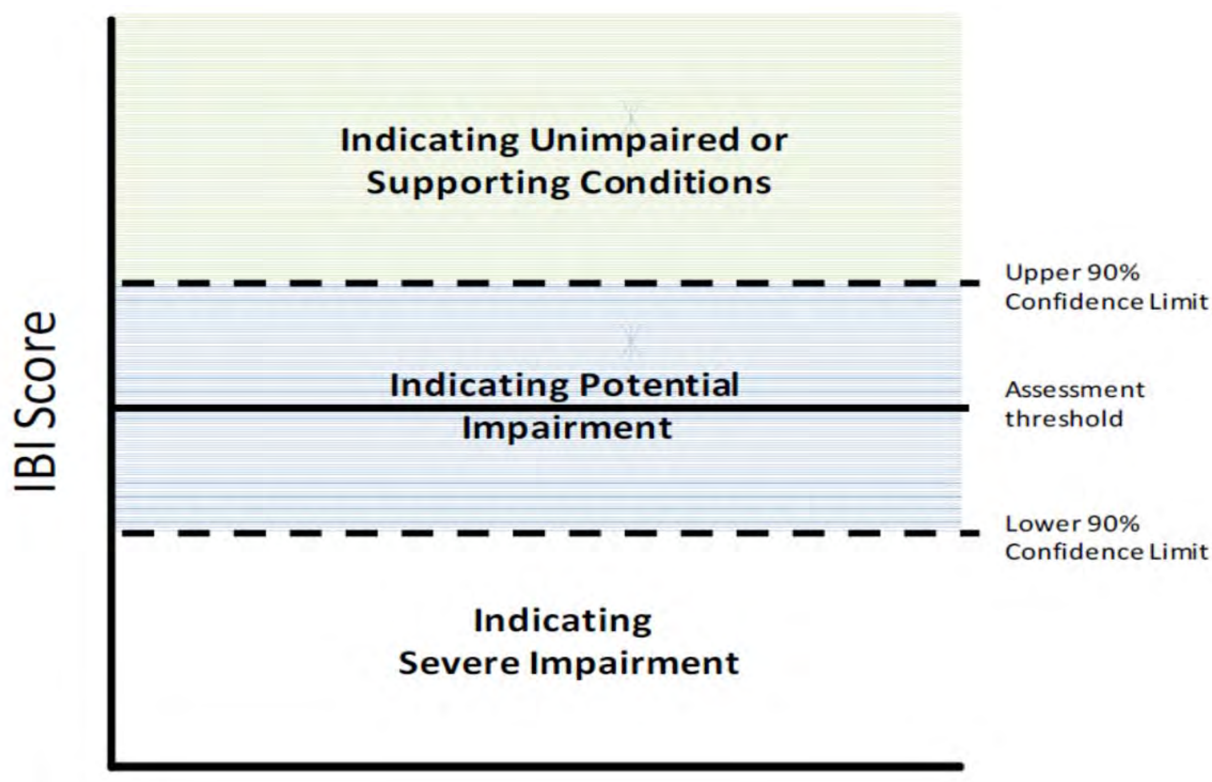


Figure 3-8. General diagram illustrating the characterization of individual biological indicator results (after MPCA 2011).

3.3.5 Biocriteria Application Language

The Minnesota WQS currently provide narrative language for the application of chemical, physical, and biological monitoring data at 7050.0150. As described previously MPCA uses bioassessment results to determine the status of the current general uses primarily for Section 305(b) and 303(d) purposes. Because the application of bioassessment data via a TALU-based approach extends beyond status and impairment listings, application language is recommended that clarifies the options available to water quality management programs in sufficient detail so as to not only be transparent to those programs and external stakeholders, but providing options for findings of attainment and non-attainment. The principles of this language in the Minnesota WQS were described in Section 2.3.6 and should be the basis for the proposed rule language. We feel that this clause is needed to more firmly clarify the roles of biological, chemical, and physical parameters and indicators than it is in the current assessment guidelines. While the potential stratification of certain chemical and physical parameters that result from task 5 of the TALU work plan may help to align chemical/physical and biological results, there will be situations where they do not “agree” hence a consistent and codified approach to how these findings are treated will be necessary.

4. TALU Implementation Strategy

The implementation of a TALU-based approach in Minnesota will most directly impact two major water quality management programs, WQS and M&A. The potential changes to the WQS as described in Section 3.0 are in the form of a revised structure of designated aquatic life uses primarily in the form of an increased number of subcategories of warm and cold water habitats and in "detaching" aquatic life from the current general use framework that combines it with recreational uses. Section 3 already provides the details about the content and substance of the aquatic life uses. What is left now is to refine and finalize the specific rule language and structure within a rule-making proposal.

How TALU affects the current MPCA M&A program is perhaps the more detail laden aspect of TALU adoption and implementation, hence this section is devoted to that issue. TALU implementation is entirely dependent on the state monitoring and assessment program hence an understanding about how TALU might impact the monitoring strategy is an essential next step.

4.1 Minnesota Monitoring Strategy

The MPCA and its partner agencies and organizations conduct numerous surface and groundwater monitoring activities to provide information about the status of the state's water resources and to identify potential or actual threats to the quality of surface and groundwater, choose options for protecting and restoring waters that are impaired, and evaluate the effectiveness of implemented management plans. The goal of the MPCA and its partners is to provide information to assess – and ultimately to restore or protect – the integrity of Minnesota's waters. The MPCA has been developing a watershed approach since 2007 as a key strategy and organizing principle to guide its surface and groundwater quality monitoring activities and many other aspects of the agency's water program (MPCA 2011). Two landmark events that have enabled the MPCA to develop and begin implementing the watershed approach are passage of Minnesota's Clean Water Legacy Act (CWLA) in 2006 and passage of the Clean Water, Land and Legacy Amendment (Amendment) in 2008. The CWLA and the Amendment have provided a structure and a source of revenue that have greatly improved the ability of the MPCA and its partner agencies and organizations to achieve the MPCA's strategic plan vision of clean, sustainable surface and groundwater.

Since preparation of the 2004 – 2014 Water Quality Monitoring Strategy, the MPCA has changed the organizing approach for its water program from the major river basin scale (there are portions of 10 major river basins within the state of Minnesota) to the "major," or eight-digit hydrologic unit code (HUC) level, watershed approach. There are 81 of these major watersheds in Minnesota. The MPCA and its partners began implementing the watershed approach in 2007 following a pilot monitoring study that was conducted in the Snake River Watershed in 2006. The MPCA's watershed approach involves intensively monitoring the streams and lakes within a major watershed and in an unbiased manner to:

- determine the overall health of these water resources;

- identify impaired waters, and,
- identify waters in need of additional protection efforts to prevent impairments.

Follow-up monitoring is then conducted in impaired sub-watersheds to determine the cause(s) of the impairments (i.e. the "stressors" impacting the biological community) and begin identification of pollutant sources and priority management zones. A restoration plan (Total Maximum Daily Load or TMDL) and/or protection strategy and implementation plan is then written for the watershed; following this, partnering agencies and watershed stakeholders can begin BMP improvements based on these efforts. Regulatory efforts continue throughout the process and are adjusted as needed to achieve the clean water goals. A key element of the watershed approach is the goal to assess the condition of Minnesota's waters (all 81 watersheds) via a 10-year cycle that starts over again after the first 10-year cycle is complete. During the second 10-year cycle, the same progression of intensive monitoring to assess current condition and detect any changes, followed by updating of protection and restoration strategies, and then additional implementation efforts, is pursued in each watershed.

MPCA generally categorizes its monitoring activities according to monitoring purpose and how the monitoring data are assessed and used. Monitoring activities are characterized in accordance with one of three categories, as follows:

- Condition monitoring: This type of monitoring is used to identify overall environmental status and trends by examining the condition of individual water bodies or aquifers in terms of their ability to meet established standards and criteria. Condition monitoring may include chemical, physical, or biological measures. The focus of condition monitoring is on understanding the status of the resource, identifying changes over time, and identifying and defining problems at the overall system level. Examples include: the intensive watershed monitoring conducted in Minnesota's major watersheds; probabilistic monitoring conducted at various scales to evaluate the quality of lakes, rivers, and wetlands; and ambient groundwater quality monitoring.

- Problem investigation monitoring: This monitoring involves investigating specific problems or protection concerns to allow for the development of a management approach to protect or improve the resource. Problem investigation monitoring is used to determine the specific causes of impairments to surface water, to evaluate the extent and magnitude of a contaminant plume in groundwater, and to quantify inputs/loads of contaminants to a water body from various sources. It is also used to determine the actions needed to return a resource to a condition that meets standards or goals. Examples include: stressor identification (ID) monitoring in a major watershed that contains impaired waters; monitoring of groundwater and possibly surface water at chemical release sites; and monitoring conducted for Clean Water Partnership and federal CWA Section 319 projects.

- Effectiveness monitoring: This type of monitoring is used to determine the effectiveness of a specific regulatory or voluntary management action taken to improve impaired waters or remediate contaminated groundwater. Effectiveness monitoring allows for the evaluation and refinement of a selected management or remedial action over time to ensure the approach is ultimately successful. Examples of effectiveness monitoring are monitoring conducted following implementation of watershed protection and restoration strategies or BMPs at various scales, such as the subwatershed, watershed, or basin. Also, effluent monitoring that is done to assess the compliance of a facility with a permit, rule or statute (i.e. compliance tracking); in this example, the monitoring data provide information about how regulatory actions applied to a facility affect the facility's contributions to the associated water bodies (not the effect of the facility's contribution on the water body itself).

Formal reviews of the MPCA monitoring and assessment program have been made as part of a detailed engagement with the Region V states by U.S. EPA for TALU development (MBI 2004, MBI 2010). As a result of that process, Minnesota has been exposed to the TALU development and implementation needs of their M&A and bioassessment program through this initiative. This process should utilize the most recent evaluation of the Region V state programs (MBI 2010) which included the most subsequent updates to the critical technical elements reviews, utilizing the latter as a tool to determine specific technical needs and as a tool to enhance a continuous improvement process. Some of these findings spurred the developmental elements that are part of the TALU work plan described in Section 1.

While MPCA has made a commitment to TALU development in their WQS, a similar commitment to TALU implementation M&A will be needed. Currently, the MPCA monitoring strategy emphasizes status monitoring, which is a characteristic of nearly all state programs. It is also a dichotomy in that some states have developed their M&A programs almost exclusively to support status assessments.

The current MPCA monitoring strategy does not specifically address the needs of a TALU-based approach to water quality management. A key challenge is for MPCA to adapt their M&A strategy to include TALU-based monitoring and assessment as a major category. Spatial design is an especially important aspect of TALU implementation since it affects the ability to obtain and apply data to specific streams and rivers and it also has an influence on the awareness and comprehension of multiple stressors. Having said that the MPCA strategy does recognize TALU as an M&A support need as evidenced by the following statement:

> *"The MPCA looks forward to future conversations with EPA as we continue to advance the watershed approach, develop and implement river eutrophication criteria and other new standards, incorporate biological indicators into our monitoring and assessment efforts, and develop and implement the TALU framework for assessing rivers and streams."*

How well the current MPCA watershed design actually supports TALU implementation is being explored as part of the TALU development process by piloting use designation reviews and implementing the newly developed TALU tools in selected watersheds.

4.2 TALU-Based Monitoring and Assessment (M&A)

State monitoring and assessment should be designed and operated to support "day-to-day" water quality management needs in addition to determining statewide status. However, to accomplish both it needs to be implemented such that it can be utilized at the statewide, regional, watershed, and site-specific scales. Besides fulfilling the assessment of status, a sustained TALU-based M&A program "naturally" incorporates strategic support functions and results in improved criteria, methods, tools, and policies. The resulting database it generates is comprised not only of the data, but of the experience gained by producing systematic assessments. It also includes the regular re-sampling of reference sites and the resulting long-term awareness of reference condition. The aggregate database generated by TALU-based M&A allows for comprehensive analysis and interpretation of spatial and temporal trends and tracking the effectiveness of water quality management programs both individually and in the aggregate. The overall program thereby fosters a continuous improvement process through adaptive management because sufficient information is collected at relevant spatial scales and the interpretation of that information is produced to affect management decisions (U.S. EPA 2005). We refer to this as adequate monitoring and assessment (Yoder 1998) the details of which are included herein as Appendix A.

A TALU-based monitoring program is designed and conducted to meet three principal objectives and in the following order:

1) determine if use designations presently assigned to a given water body are appropriate and attainable;
2) determine the extent to which use designations assigned in the state WQS are either attained or not attained; and,
3) determine if any changes in key ambient biological, chemical, or physical indicators have taken place over time, particularly before and after the implementation of point source pollution controls or BMPs.

This sequence and array of objectives is implicitly different than under a non-TALU based approach in one important way – the assessment is used first to *validate the current designated use* as opposed to the usual approach of determining impairment based on the currently assigned use, which in many cases is an assumed "default" use. The problem with this latter approach is that any issues with the currently assigned use will not become apparent until an inaccurate management decision or application triggers a concern over the assigned use. We believe that by addressing the appropriateness of the current use assignment first, everything else automatically "falls into place" thereby eliminating the need for potentially costly and time consuming "after-the-fact" exercises such as TMDL delisting and even more costly use attainability analyses (UAA).

4.2.1 Spatial Design Considerations

Spatial scale is absolutely the most critical aspect of this type of M&A. As the complexity of stressors within a watershed increases, so does the need for increased spatial detail in the sampling design. In addition, TALU assignments can vary from stream to stream within the same watershed as has been shown elsewhere (U.S. EPA 2005, Appendix B, pp. 172-175). Thus a reliance on extrapolation from too few and spatially scattered sampling sites, the statistical integrity of the underlying spatial design notwithstanding, can result in incomplete or even erroneous TALU tier assignments. At the same time it is recognized that not all water bodies will be assessed ahead of certain water quality management actions, thus a prioritization of M&A needs to be integrated into the overall TALU implementation strategy so that the most important and high profile water quality management actions are based on the most accurate WQS. However, by aligning water quality management program schedules within a rotating basin approach to M&A, it should be possible to have most WQS use designation uncertainties resolved *prior to* developing management approaches and plans (e.g., permits, TMDLs, watershed plans, etc.). Ideally, having the management programs aligned with the watershed monitoring approach would be the most efficient approach. However, aligning the monitoring and permitting schedules has been determined to be impractical and instead watershed monitoring to collect the data needed to resolve use designations prior to the review of a permit will need to accommodate the reissuance schedule, even when it is outside of the watershed monitoring schedule.

4.2.2 TALU-Based Assessment Process

The data gathered by systematic TALU-based M&A is processed, evaluated, and synthesized in an assessment report. Each report contains a summary of major findings and recommendations for revisions to stream and river-specific use designations, future monitoring needs, or other actions which may be needed to address existing impairment(s) of designated uses. At the same time, the systematic execution of this type of M&A on a statewide basis builds a long-term database over space and time, creating and sustaining a resource for the development and improvement of tools, criteria, policies, and legislation. In addition TALU-based M&A inherently incorporates a stressor identification process based on having adequate chemical, physical, and biological data in hand when the biological impairments are encountered. Again, this is implicitly broader than status-based M&A that can leave biological impairments incompletely diagnosed or undiagnosed altogether. The compulsion to make as accurate a diagnosis as is feasible of biological impairments revealed by this type of M&A is an assumed part of the biocriteria application language described in Section 2.3.6. Once again, we recognize that this is a departure from current practice where stressor diagnosis is performed as a second year effort. However, we have found that some impairments do not require the same level of diagnosis, hence some situations are amenable to a "short hand" process. Again, this will occur with experience as these assessments are accomplished through time.

4.3 Incorporating M&A Findings into WQS Recommendations

How the monitoring and assessment data and analyses described above are used as an essential part of a TALU process has been generally described via case examples (U.S. EPA 2005) and is available from selected TALU state programs. Use designation reviews and revisions are a direct and routine result of the biological and water quality assessments that are conducted on a stream or river segment and/or watershed basis. Provided that the spatial design is adequate for the meaningful and accurate application of the sampling data to individual streams and stream segments, *the M&A results are the basis for TALU-based use designation* *assignments*. Aquatic life uses are generally designated based on the *demonstrated potential* to attain a particular use tier based on the following sequence (in order of importance):

1) attainment of the numeric biological criteria (if attaining a General use or higher – attainment of the Exceptional biocriteria for both assemblages is required to be designated as EWH); and,

2) if the applicable General use biocriterion is not met, the habitat potential is determined by an analysis of the Minnesota Stream Habitat Assessment (MSHA) habitat attributes which is used to determine the potential to attain the General use at a minimum.

As such this represents a "UAA type" of process even though a UAA is technically not required to designate uses at or above the "CWA minimum" (i.e., one of the General uses in Minnesota).

A TALU-based process is inherently data driven so that the same sequence of decision-making is executed regardless of the relationship of the current use designation to the minimum CWA goal. To designate uses less than General (i.e., Modified or Limited), a UAA ***is required*** and includes the consideration of the factors that essentially preclude General use attainment including the feasibility of restoring the water body. Under a TALU-based approach the following information and knowledge is required:

1) the present attainment status of the water body based on a biological assessment performed in accordance with the requirements of the biocriteria, the Minnesota WQS, and the TALU-based needs for Minnesota (the latter pertains to adequacy of the spatial design);
2) a habitat assessment to evaluate the potential to attain at least the applicable General use; and,
3) a reasonable relationship between the impaired state and the precluding anthropogenic activities or other factors based on an assessment of multiple indicators used in their appropriate indicator roles and a demonstration consistent with 40CFR Part 131.10 [g][1-6].

The above requires that adequately developed tools and processes be available within the State's M&A process in addition to having a TALU framework in the WQS. This represents the "merging of WQS and M&A" that is a signature of the TALU framework.

4.3.1 TALU Management Options Overview

To illustrate the practical options that MPCA will have for making stream or segment-specific TALU assignments based on the results of the M&A process described above, a matrix of TALU management options was developed (Table 4-1). We are assuming here that all Minnesota rivers and streams will have a TALU tier assigned following the adoption of the new designated use tiers. Virtually all rivers and streams will be assigned the most applicable General Use tier as a "default" in the absence of sufficient data. This will be a practical necessity so that other aspects of water quality management that rely on WQS can proceed apace. In practice the

General Use then becomes a default placeholder until an assessment of the "correct" TALU tier can be made.

Table 4-1. Tiered aquatic life use options based on evaluation of default uses currently in the Minnesota WQS and under a new system of tiered aquatic life uses (TALUs).

Current Designated Aquatic Life Use	Monitoring Results	Attains Designated Use?	Management Options Under New TALU-Based Approach
General[3]	**General Use Attainment**	YES	Retain General designation because biocriteria demonstrate attainability.
General	**General Use Non-attainment**	NO	If habitat assessment indicates General is attainable, then retain General use; OR If habitat is impaired & due to 40CFR131[g] factors, change use to Modified or Limited
General	**Exceptional Attainment**	YES	Revise use to Exceptional based on attainment of Exceptional biocriteria by *both* assemblages.
Class 7[4]	**General Use Attainment**	YES	Revise use to General based on attainment of General biocriteria by *both* assemblages.
Class 7	**General Use Non-attainment**	?	If habitat assessment indicates General is attainable, then revise to General use; **OR** -- if habitat is impaired & due to 40CFR131 [g] factors, change use to Modified or Limited[5].

The scenarios in Table 4-1 that start with either the applicable General (equivalent to the current 2A or 2B uses) or the Class 7 designated uses are the only options that can realistically

[3] General – either a General Warmwater or General Cold Water use designation.
[4] Class 7 will remain in place until a site-specific use determination is made.
[5] Limited will be assigned only when Modified is not attainable.

occur. As indicated before, the principal objective of a TALU-based monitoring and assessment program is to determine if the current designated use is appropriate and attainable, which will be either one of the General (2A or 2B) or Class 7 uses in nearly every case. Hence the biological assessment and the attendant habitat assessment tools will be essential in making this determination. If the General Use biocriteria are attained then that is the "best" demonstration that the General Use is attainable at a minimum. If the Exceptional Use biocriteria are attained *by both assemblages,* then that is justification for assigning an Exceptional Use. Both are consistent with the definition of existing use in 40CFR Part 131.1 as:

> *". . . those uses actually attained in the water body on or after November 28, 1975, whether or not they are included in the water quality standards."*

If the General Use biocriteria are not attained, then the accompanying habitat assessment is used to determine if the habitat quality is capable of supporting the General Use. If habitat is sufficient, then General will be the assigned use. If habitat is not sufficient, then the UAA process is employed to determine if there are precluding factors under the EPA WQS regulations (40CFR Part 131.10[g]) that are essentially "permanent" preclusions to General Use attainment. In this case the options are to either effect proven restoration techniques or assign the Modified or Limited Use designations.

4.3.2 TALU Implementation Process Overview

The preceding description of the generally available TALU management options did not convey all of the important details about how TALU is to be implemented on a water body specific basis in Minnesota. The more detailed implementation process is described herein and focuses on a hierarchy of decision points that are described in Figures 4-1 through 4-3. Figure 4-1 is an overview of the first steps of the implementation process that starts with utilizing the results of the supporting biological assessment.[6] The design and execution of the sampling and analysis must be adequate for supporting the analytical and decision-making tasks that are a part of the TALU implementation process - it is an expected part of any state TALU process. The possible steps herein are consistent with the options described in Table 4-1.

4.3.2.1 Step I: Initial Application of Bioassessment in a TALU Process (Figure 4-1)

The initial decisions in Figure 4-1 focus first on biological status, specifically if the General Use biocriteria are attained or not. The reason for this is that the General Use biocriteria are the minimum condition that meets the baseline goal of the CWA, i.e., "the protection and propagation of fish, shellfish, and wildlife". This benchmark is also important because it determines the point at which a UAA is required even though the entire process that is outlined herein is "UAA like" and requires consideration of the same types of data and analyses. If the General Use biocriteria are fully attained by both assemblages, then this use will apply because meeting this
benchmark of attainability has been directly demonstrated. If biological attainment of the

[6] A biological assessment as used herein includes biological indicators and chemical/physical indicators collected by following the adequate watershed monitoring and assessment approach discussed in Section 4.2.

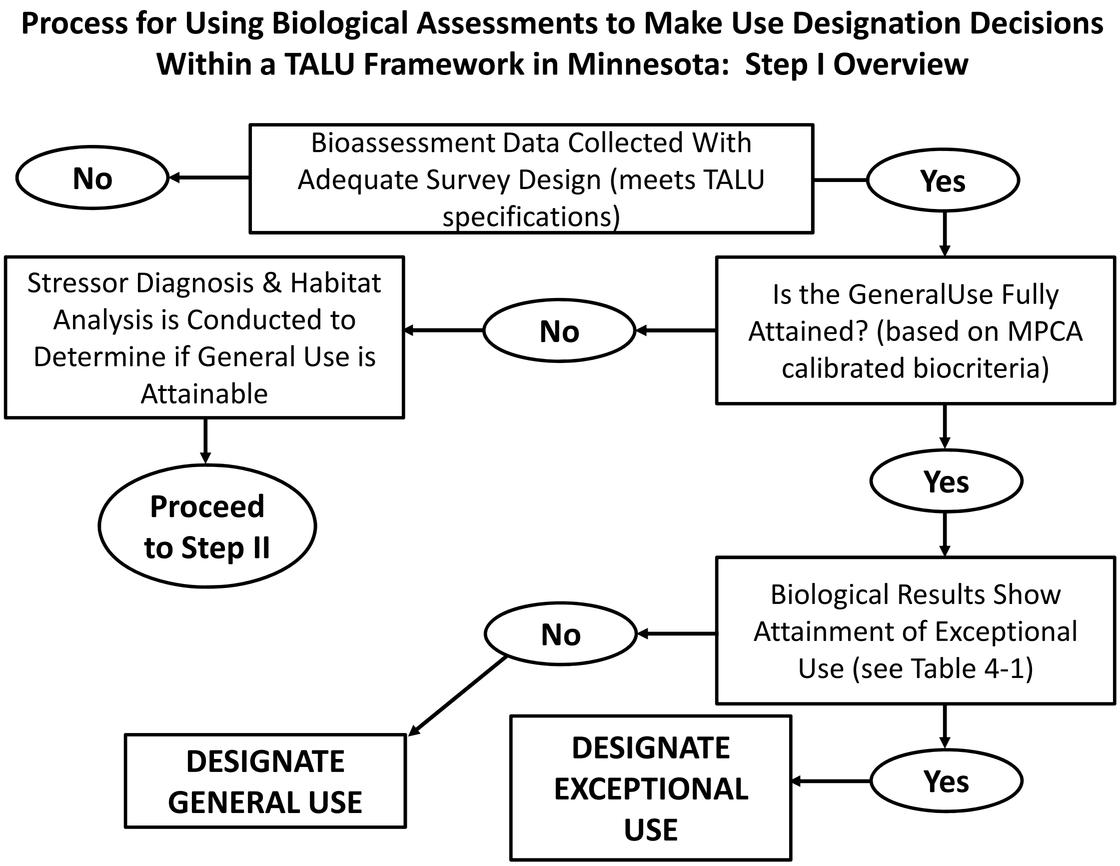


Figure 4-1. Step I: overview of the process for using biological assessments to make use designation decisions in Minnesota based on the proposed TALU framework.

Exceptional Use biocriteria is demonstrated *by both assemblages,* then this use is designated because the attainability of this TALU tier has likewise been demonstrated. Again, each is consistent with the definition of existing use in 40CFR Part 131.3. The Exceptional Use is unique among the TALU tiers in that it requires a showing a biological attainment to be designated as such. Hence it functions as a *preservation use* within a TALU framework, whereas General Use is by comparison a *restoration use.* Hence, attainment of either the General or Exceptional Use biocriteria triggers a straightforward decision to designate those uses (as is also indicated in Table 4-1). Non-attainment of the General Use biocriteria triggers a stressor diagnosis approach that is inherent to a TALU-based program in order to determine if General Use is attainable. This leads to step II -- the process is described in Figure 4-2.

4.3.2.2 Step II: Determining Limitations to General Use Attainment (Figure 4-2)

A finding that the General Use biocriteria are not attained leads to step II (Figure 4-2). The habitat assessment that is conducted as part of the biological assessment is now relied upon to provide the information and analysis that is needed to determine if General Use is indeed attainable. At this point in the process we are simply determining if the attributes of the extant

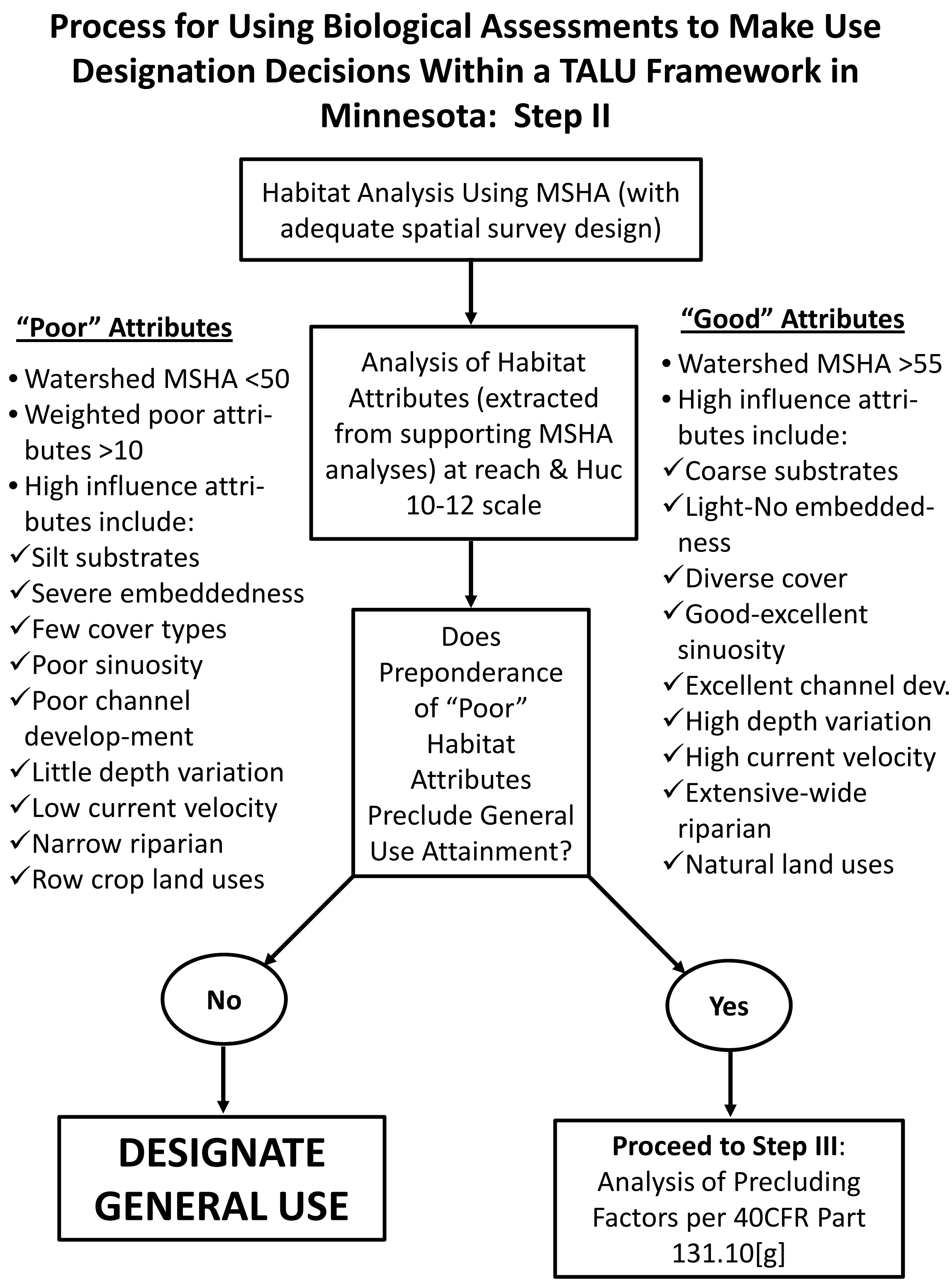


Figure 4-2. Step II: using the analysis of habitat attributes to make decisions about General use attainability.

habitat are sufficient to support biological assemblages consistent with the General Use biocriteria. This requires the use of the supporting analyses of the relationship between MSHA habitat attributes and the biological assemblages that yield sufficiently predictive relationships such that biological attainability can be determined. This descriptive work was accomplished at the stream and river class level utilizing the extant MPCA database and across a sufficiently diverse gradient of habitat quality from very poor to excellent conditions (Rankin and Yoder 2011).

Precedents already exist for this type of process and include the Ohio QHEI analyses by Rankin (1989, 1995). The Minnesota analyses yielded thresholds of MSHA scores that generally correspond to General Use attainment and identified which MSHA attributes provide for a *sufficiently accurate* prediction of General Use attainability. These attributes are expressed as "good" and "poor" attributes (Figure 4-2) the former being comprised of attributes that accumulate to promote biological attainment and the latter having the opposite effect, i.e., those attributes that deter biological assemblages consistent with General Use attainment. The MSHA thresholds and attributes derived for Minnesota (Rankin and Yoder 2011) are used in Figure 4-2. For example, a MSHA score ≥55 is an indication that General Use is attainable, but a score <50 indicates that biological attainment of General Use is less likely. Added to these index thresholds are the occurrence and preponderance of good and poor habitat attributes which help sharpen the decision about General Use attainability. Once this information is analyzed on a reach level basis, a decision about General Use attainability in the absence of direct General Use biological attainment can then be made. If the analysis indicates that habitat is not limiting, then General Use is the resulting decision. However, if the analysis indicates that the habitat attributes are insufficient and therefore limiting then an analysis of the precluding factors consistent with 40CFR Part 131.10[g] is performed (proceed to Step III, Figure 4-3). This process is formally known as a Use Attainability Analysis or UAA.

4.3.2.3 Step III: Use Attainability Analysis (Figure 4-3)

A use that is "lower" than what is recognized as consistent with the CWA, i.e., General Use or higher in Minnesota, can be assigned provided an acceptable UAA is conducted. A UAA is defined as

> *". . . a structured scientific assessment of the factors affecting the attainment of the use which may include physical, chemical, biological, and economic factors as described in §131.10[g]."*

Those criteria are as follows:

40CFR Part 131.10[g]: States may remove a designated use which is not an existing use, as defined in Section 131.3, or establish sub-categories of a use if the State can demonstrate that attaining the designated use is not feasible because:

1) *Naturally occurring pollutant concentrations prevent the attainment of the use; or*

2) *Natural, ephemeral, intermittent or low flow conditions or water levels prevent the attainment of the use, unless these conditions may be compensated for by the discharge of sufficient volume of effluent discharges without violating State water conservation requirements to enable uses to be met; or*
3) *Human caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place; or*
4) *Dams, diversions or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the water body to its original condition or to operate such modification in a way that would result in the attainment of the use; or*
5) *Physical conditions related to the natural features of the water body, such as the lack of a proper substrate, cover, flow, depth, pools, riffles, and the like, unrelated to water quality, preclude attainment of aquatic life protection uses; or*
6) *Controls more stringent than those required by sections 301(b) and 306 of the Act would result in substantial and widespread economic and social impact.*

Process for Using Biological Assessments to Make Use Designation Decisions Within a TALU Framework in Minnesota: Step III

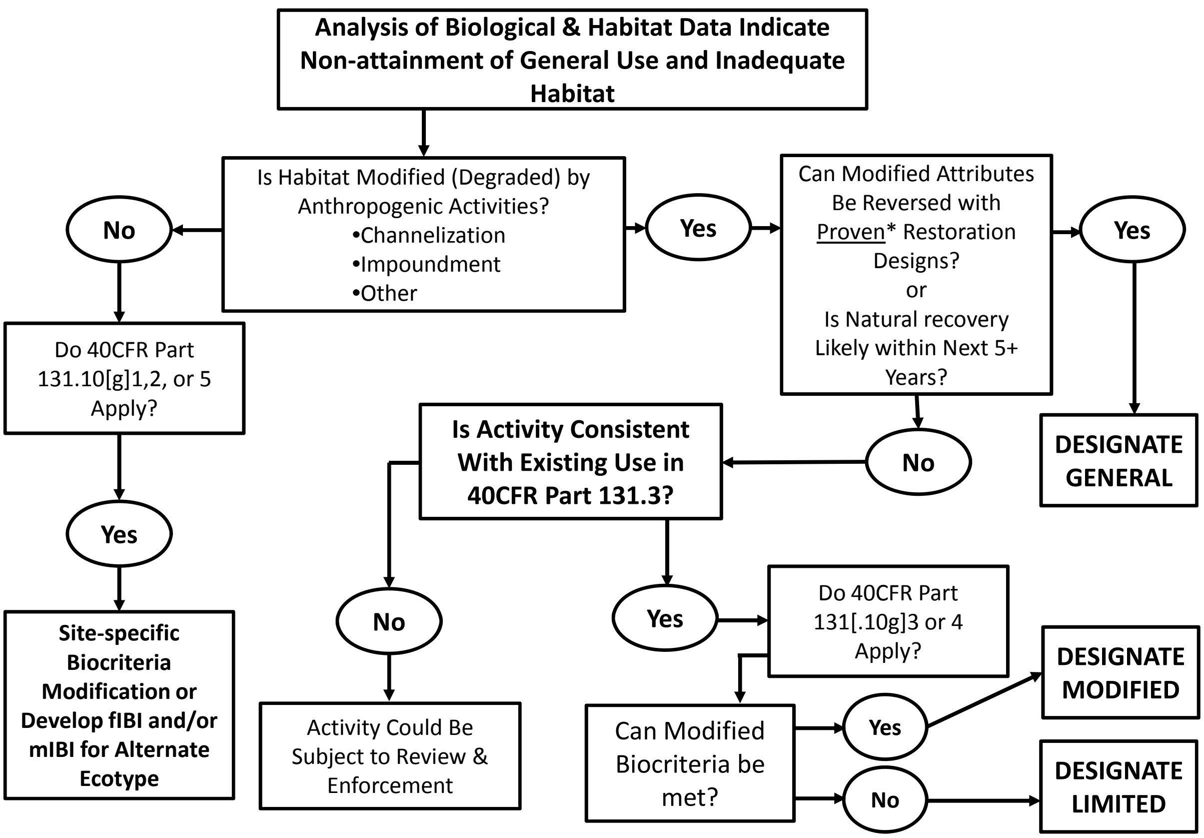


Figure 4-3. Step III: overview of the use attainability analysis parts of the use designation process in Minnesota.

The process arrives at this point because the biological assessment revealed non-attainment of the General Use biological criteria and the analysis of habitat attributes showed habitat to be deficient for supporting biological assemblages consistent with General Use. Since we have already determined that attributes of habitat are insufficient to support General Use, the next task is to determine the "origin" of the deficient habitat, i.e., is it of natural or of anthropogenic (i.e., human action) origin? If it is determined not to be the result of anthropogenic activities, then a determination of whether 40CFR Part 131.10[g][1], [2], or [5] apply is needed. These are considered to be "natural factors" that could preclude attainment of the General Use biological criteria. It would also suggest that either a site-specific modification of the biocriteria is needed or consideration of an alternate ecotype with a distinct biological assessment tool or index is needed. If this phenomenon is encountered on a regional or ecotype basis then the latter option is preferred. In all likelihood the stream and river class-specific development of the biological indices thus far should have "captured" most of these natural factors, but the process is available should something have been overlooked.

We expect almost any habitat caused non-attainment of General Use in Minnesota to be related to anthropogenic habitat impacts that are either of recent or legacy origins. If this is the case then it next needs to be determined if the habitat alterations can be reversed with *proven* restoration designs or if they are of recent enough origin that they are eligible for an enforcement action. By "proven" we are referring to restoration designs that have been shown to restore biological assemblage quality consistent with the General Use biological criteria endpoints and supported by an analysis of restored MSHA attributes. Simply assuming the General Use will be attained because a restoration activity has been undertaken is alone insufficient to satisfy this part of Step III. If there are indeed *proven* designs and these are effectively implemented then General Use could be deemed as attainable. If no restoration actions have been taken or are as yet unproven then the remaining parts of 40CFR Part 131.10[g] will need to be considered.

In Minnesota we expect that the majority of habitat alterations that lead to UAA considerations will most commonly include channelization in support of agricultural row cropping, channelization and other modifications designed to deal with surface runoff in urban settings, and possibly impoundment of riverine habitats by "run-of-river" low head dams (although these are currently not targeted for sampling by MPCA). Each of these has been shown to not only alter habitat such that CWA goals cannot be attained, but also can result in essentially permanent modifications. This is exemplified in 40CFR Part 131.10[g][3] and [4] in that these modifications are due to human actions that are perpetual in their tenure (e.g., [g][3]) and which represent hydrological modifications that cannot be operated in a manner consistent with the General use (e.g., [g][4]). If the actions are consistent with these parts of 40CFR Part 131.10[g] then either the Modified or Limited Uses will be designated. The distinction between Modified and Limited is largely based on the attainability of the Modified biological criteria which are less stringent than the General use biocriteria. A Limited Use biocriteria benchmark equivalent to the 75th percentile of BCG tier 6 is recommended.

4.3.3 Pilot TALU-Based Watershed Assessments

Using the just discussed TALU guidance framework and the technical tools developed to support this process, pilot testing was conducted with MPCA staff using 3 theoretical watersheds as a test of the framework and to determine the limitations of the current spatial monitoring design. The examples include watersheds with a mix of use attainment status (attaining and not attaining), use designation assignment recommendations, monitoring data, and land uses.

4.3.3.1 Agricultural Watershed

In this example there are 4 biological sites in an approximate 25 mile long reach of the primary stream and one location each in two tributaries. The results of applying a TALU framework shows that the General Warmwater Habitat (GWH) subcategory of the General Use suite of uses is the appropriate and attainable aquatic life use in the lower watershed. This is because of the consistent attainment of the General Use biological criteria for this stream class (Figure 4-4). It illustrates the process when biological attainment of at least the General Use occurs (see Fig. 4-1). The example also includes biologically impaired sites (with respect to the GWH biocriteria) that have sufficient habitat to confirm the GWH use where the MSHA indicates sufficient good quality attributes. Hence the restoration goal for these sites is to recover GWH attainment. Two sites in the upper watershed are biologically impaired due to channelization effects on stream habitat. In both cases the MWH use is recommended as the outcome of a UAA. The circumstances and the activities that resulted in the channelization meet the criteria for setting a use lower than the CWA minimum as described in Section 4.3.2. This example also includes unassessed reaches in the upper watershed where the designation will remain at the default use of GWH until sufficient data is collected to show otherwise.

4.3.3.2 Urban Watersheds

The second example is for a watershed predominated by urban land uses (Figure 4-5). In this example there are 3 biological sites on the primary stream and three sites on tributaries. The results indicate non-attainment of the applicable General use biocriteria at all six sites. The two downstream most sites exhibited sufficient habitat to attain the General use hence GWH was retained. At the remaining 4 sites habitat was found to be limiting GWH attainment due to channel modification activities. The Modified Warmwater Habitat (MWH) use is recommended for three of these sites and in accordance with the process in Figures 4-2 and 4-3. At one site flow limitations were such that the Limited use is recommended. The MWH designations were extended upstream only through the channelized reaches thus the unassessed upper portion of the watershed was assigned GWH as a default placeholder.

4.3.3.3 Forested Watershed

The third example is from a predominantly forested watershed with few anthropogenic impacts (Figure 4-6). In this example there are 4 biological sites, 3 on the primary stream and one on a tributary. In this case example the use designation decisions are based on attainment of the General and Exceptional use biocriteria. The downstream most sites attain the Exceptional Warmwater Habitat (EWH) use hence that use was recommended following the process in

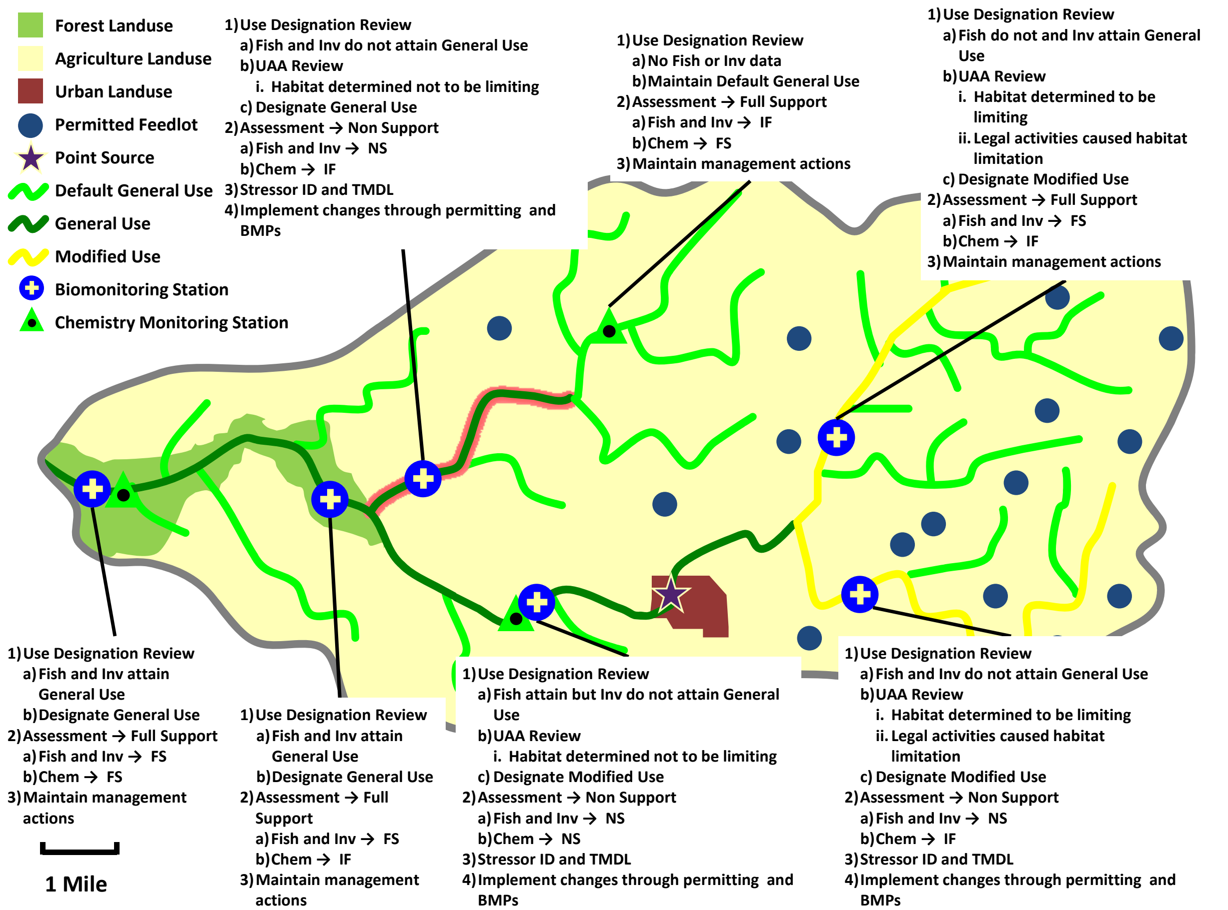


Figure 4-4. Results of applying the MPCA TALU assessment framework in a watershed predominated by agricultural land uses. The result of applying TALU at six sampling locations is described. Sampling sites are indicated by a ✪ symbol.

Figure 4-1. In this case both the fish and macroinvertebrate assemblages met the EWH biocriteria. At the upstream most site fish met the EWH biocriteria, but the macroinvertebrates met GWH, hence the GWH use was retained. The tributary site showed GWH attainment thus confirming that use tier. Several other tributaries were not sampled and are thus considered as unassessed hence the default GWH use was retained.

These three examples generally demonstrate how the designation of the TALU tiers will be conducted as a first step in using bioassessments to first evaluate the appropriateness of the currently assigned aquatic life use, make recommendations for the appropriate TALU-based use, and then conduct the assessment of status based on the recommended TALU tiers.

4.4 Checklist of Technical Tools & Needs

An inventory or checklist of technical tools and needs is discussed here in response to the ongoing development of a TALU-based framework in Minnesota. Some of this has already been accomplished by the evaluation of the Region V state programs (MBI 2004, 2010) and by the

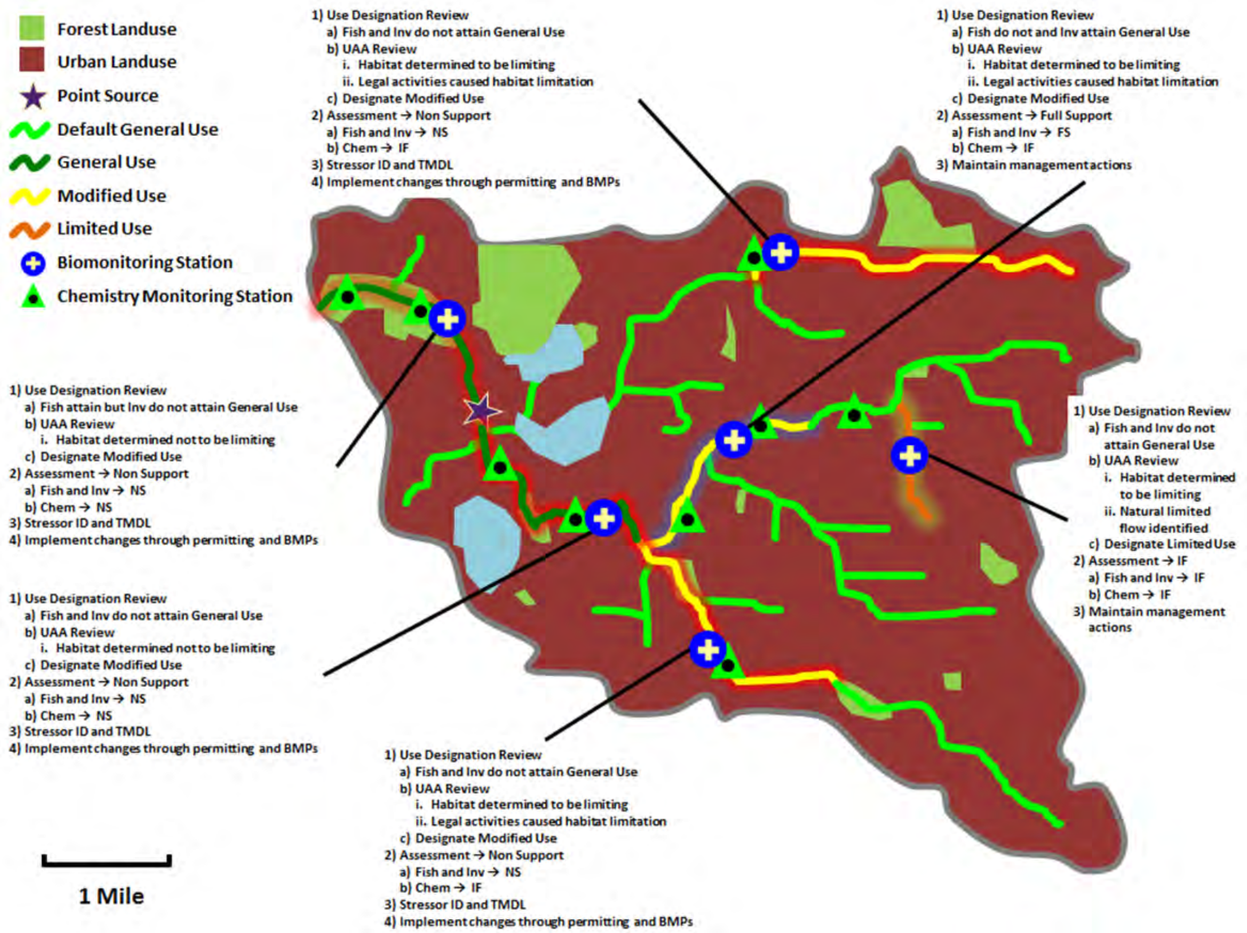


Figure 4-5. Results of applying the MPCA TALU assessment framework to a predominantly urban watershed. The biocriteria attainment status is indicated (GWH Attain) as is the use designation decision for the assessed portion of the streams in the watershed. Sampling sites are indicated by a ✪ symbol.

ongoing critical elements process (Yoder and Barbour 2009; Barbour and Yoder 2008). It should be noted here that the latest critical elements evaluation was based on information as of the 2010 Region V review and that was done as a "desk top" evaluation. A more formal process with the MPCA program needs to be updated to ensure that all developments are captured and understood and in context with the need for a level 4 program to implement a TALU-based approach. The critical elements and state evaluation process is an effective tool for determining the preparedness of a state to implement a TALU-based approach and we recommend that it be updated here to determine if the MPCA is "TALU ready". A mid-level 3 program is needed *at a minimum* to effectively execute a TALU framework and level 4 is the most comprehensive and reliable for that and other purposes including the determination of attainment and non-attainment, stressor identification, and the proper execution of the "UAA type" of process that is the primary driver of the TALU-based approach. The detailed work plan (Appendix A) was developed in part based on prior critical elements reviews conducted in 2002 and 2004 hence that process has influenced the awareness of the technical tools that are needed by MPCA to successfully implement a TALU-based approach.

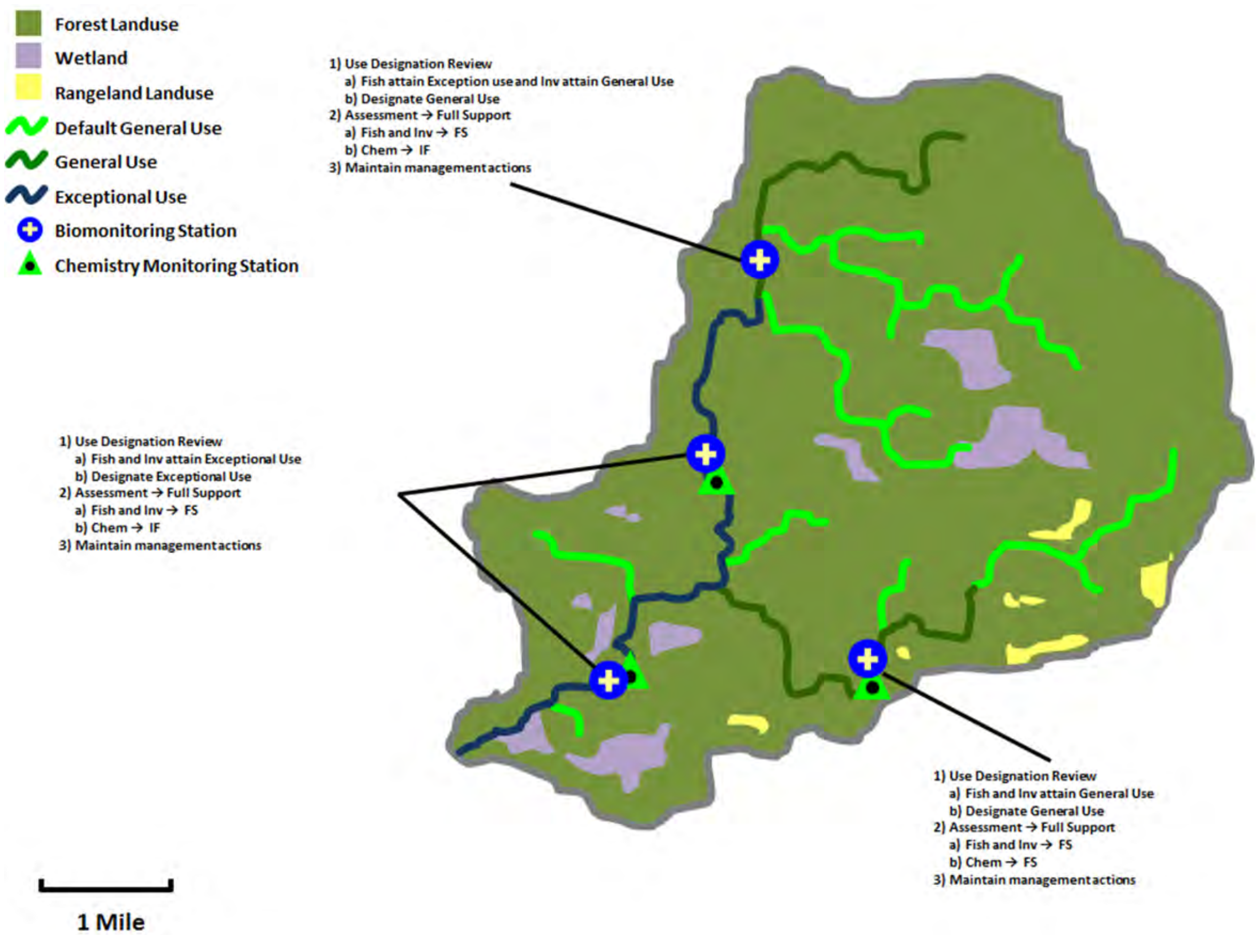


Figure 4-6. Results of applying the MPCA TALU assessment framework to a predominantly forested watershed. The biocriteria attainment status is indicated (EWH Attained and GWH Attained). Sampling sites are indicated by a ✪ symbol.

5. Incorporating TALU into Water Quality Management Programs

The "TALU-based approach" includes TALUs based on numeric biological criteria and implementation via an adequate monitoring and assessment program that includes biological, chemical, and physical measures, parameters, indicators and a process for stressor identification.

WQS are important determinants of both the direction and success of CWA management programs. As the principal custodians of CWA programs, states have the opportunity to determine the structure, content, and technical rigor of their WQS. As part of the state WQS, TALUs are an important component of all three of these aspects. This section focuses on how the adoption of TALUs in the Minnesota WQS might be expected to influence the direction and success of the MPCA CWA management programs.

A traditional view of how WQS affect management programs focuses exclusively on water quality criteria and how changes in these criteria within a "one-size-fits-all" framework will make management goals more or less "stringent". As such the perceptions about adopting a TALU structure in the WQS are "two-dimensional" in that changes in uses have the certain effect of stratifying water quality criteria which then translate directly to more or less stringent management goals and requirements. However, TALU also merges M&A with WQS and their application and as such results in multidimensional effects such that changes in TALU tiers are not necessarily accompanied by corresponding and proportionate changes in the application of water quality criteria. Regional, watershed, reach, and site-specific factors become more important dimensions as they are incorporated into and reflected by M&A results and as such will have a strong bearing on the application of WQS to specific sources and practices. Because a TALU-based approach includes more dimensions and factors than the traditional two-dimensional application of WQS the potential for outcomes that are governed more by regional and watershed level influences are now important considerations. The MPCA biological criteria will be structured into the Minnesota WQS and within the TALU framework. The biological criteria provide an ecologically derived endpoint that directly reflects attainment/non-attainment of designated aquatic life uses. As such, the "starting point" in the application of TALUs is the receiving water body whereas the starting point in traditional water quality management is the regulated activity.

A TALU-based approach when properly developed and implemented is a "modernization" of traditional approaches to setting and implementing WQS. What we term here as the traditional approach to WQS that has emanated from the early 1970s will be significantly modernized by the development and implementation of a TALU-based approach. The incorporation of biological criteria that are in turn defined by the specificity of the TALU tiers represents not only a technical improvement in the measurement of designated aquatic life use attainment, but is an opportunity to address the reality of multiple stressors as opposed to a single parameter or pollutant focused approach. As such it incorporates the concept of pollution[7] into assessments of condition and provides an opportunity to address the key stressors that are the most determinant of biological condition as a result of the accompanying stressor diagnosis aspects of TALU. This in turn better informs water quality management programs about not only which problems to address, but how to better address them from a pre-emptive standpoint. The details about how to develop the designated use language, the biological criteria application language, and the incorporation of biological criteria so that better management outcomes are assured were described in sections 3 and 4.

Figure 5-1. Major State CWA Management Programs and Their Primary Components

Basic Reporting	√ Status √ Trends
TMDLs	√ 303[d] listing √ TMDL dev. √ TMDL effect.
WQS	√ Uses √ UAA √ Criteria √ Antideg.
NPDES	√WQBELs √ Compliance √ Stormwater √ CSO/SSO
Other Permit	√ 401/404 √ State permits
Watersheds	√ NPS mgmt. √ BMP effect. √ Habitat √ Flow √ Priority setting √ Source water

5.1 CWA Management Programs Affected by TALU

WQS ultimately set the goals for management programs through the designation of uses and they provide for the chemical, physical, and biological endpoints that are used to develop management strategies and determine their effectiveness. The major CWA management programs that are part of any state program include basic reporting, WQS, nonpoint source management, watersheds & TMDLs, and permitting. There are important and recognizable components of each of these programs (Figure 5-1) and each are either directly or indirectly affected by the detail in state WQS.

Despite a myriad of attempts over the past 25 years to outline and implement an environmental indicators driven approach to water quality management, the effectiveness of water quality management programs continue to emphasize administrative outputs. These outputs include the quantity and timeliness of activities such as permits issues, backlogs reduced, number of TMDLs, grants awarded, etc. The net result is what we term here as an Administrative Outputs based approach to water quality management in which the goals and measures are based solely on administrative actions (Figure 5-2). In this domain the goal is the performance of a management is judged primarily by attaining administrative accomplishments as measured by programmatic "outputs"[8]. For example, a

[7] The Clean Water Act defines *pollution* as human-induced alteration of waters caused by pollutants as well as non-pollutant agents, such as flow alteration, physical habitat alteration, and introduction of alien taxa [CWA section 502(19)]. *Pollutants* are selected substances that are defined by CWA Section 502(6).

NPDES permitting program is measured by the number of permits issued or re-issued, compliance assistance actions, and the quantity and timing of backlogs. The result of this emphasis is to improve the performance of the program by focusing on the execution of administrative tasks such as efficiency in permit issuance or reductions of backlogs. An environmental indicators approach envisions this shifting this to a resource end "outcomes"[9] based approach (Figure 5-2) where the goal is the attainment of designated uses, which includes aquatic life uses that are a key component of a TALU-based approach. The measures are environmental and include biological, chemical, and physical indicator end-points each being used within their most appropriate role and indicators of stress, exposure, and response (Yoder and Rankin 1998). Under a TALU-based approach this means that the numerical biological criteria are the key response variable which is consistent with how they are defined and codified in the state WQS. Their relationship to other chemical and physical criteria is defined by the biocriteria application language that is a part of the TALU forged modernization of WQS. The overall results of this framework are made manifest when water quality management programs become a means to meeting biological condition goals, not an end in themselves.

Administrative Output vs. Resource Outcomes Based Management

	ADMINISTRATIVE OUTPUTS BASED	RESOURCE END OUTCOMES BASED
Goal:	**Program Performance** (Program execution)	**Environmental Performance** (Attain designated uses)
Measures:	**Administrative Actions** (Lists, Permits, Funding, Rules)	**Indicator End-points** (**Biological**, Chemical, Physical)
Results:	**Improve Programs** (Reduce backlogs, improve timeliness)	**Programs are Tools to Improve the Environment** (Admin. outputs evaluated by environmental end outcomes)

Figure 5-2. Administrative outputs are validated by an environmental based end outcomes approach that is fostered by a TALU framework (after MBI 2004).

States can best execute this approach when administrative program priorities have been sequenced with the monitoring and assessment schedule, usually with the latter being positioned to provide the necessary data and information far enough in advance of developing and then implementing management actions. This sequence especially allows for the designated uses under a TALU-based approach to be reconciled before management

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[8] An output is a discrete administrative accomplishment such as the issuance of a permit or the completion of a TMDL, i.e., it counts the number of management program products.

[9] An outcome is a direct change in the receiving water body as indicated by a chemical, physical, or biological measurement or indicator. As such an outcome is related to an output by being its end result.

actions are designed and implemented. Too often, inadequacies in "one-size-fits-all" general designated uses are not apparent until the consequence of a management action is realized and perhaps too late to reconcile with a "UAA type" of process that is an embedded part of a TALU-based approach.

5.2 An Information Driven Approach to Water Quality Management

When fully designed and implemented, a TALU-based approach fosters an information driven process for developing and assessing the effectiveness of water quality management programs. While the logistics of such an approach first requires the right information to be available "in time" to affect water quality management programs, how such monitoring and assessment information is sequenced is also an important aspect. U.S. EPA has used Figure 5-3 extensively to illustrate the sequence of having monitoring and assessment information positioned so that it can affect the development and assessment of water quality management programs. While the sequence is essentially correct, this and like examples leave out critical details that are essential components of such a process.

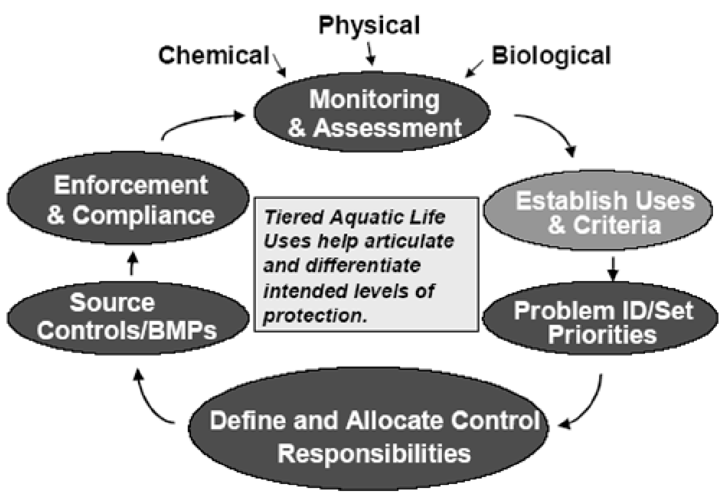


FIGURE 4-1. U.S. EPA Water Quality Based Approach to Pollution Control based on Chapter 7, Water Quality Standards Handbook.

Figure 5-3. The U.S. EPA depiction of how monitoring and assessment fits within a water quality based approach to pollution control and abatement (after U.S. EPA 2005).

5.2.1 Hierarchy of Surface Water Indicators

A carefully conceived ambient monitoring approach, using cost-effective indicators comprised of essential biological, chemical, and physical measures, can ensure that all relevant pollution sources are judged objectively and on the basis of environmental end outcomes. This integrated approach employs a hierarchical continuum that includes administrative and true environmental indicators with the latter arrayed in their "most appropriate roles" as indicators of environmental stress, exposure, and response, respectively (Figure 5-4). This framework was initially described by U.S. EPA (1995a). The framework includes six "levels" of indicators as follows:

Level 1 Actions taken by regulatory agencies (*e.g.,* permitting, enforcement, grants);

Level 2 Responses by the regulated community (*e.g.,* construction of treatment works, pollution prevention);
Level 3 Changes in discharged quantities (*e.g.,* pollutant loadings);
Level 4 Changes in ambient conditions (*e.g.,* water quality, habitat);
Level 5 Changes in uptake and/or assimilation (*e.g.,* tissue contamination, biomarkers, assimilative capacity); and,
Level 6 Changes in health, ecology, or other effects (*e.g.,* ecological condition, pathogenicity).

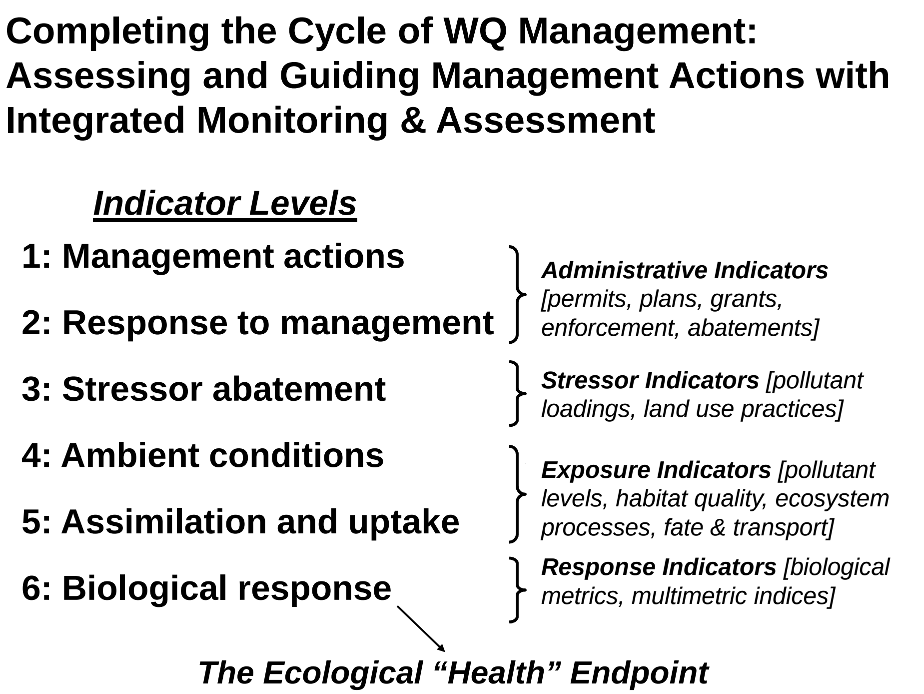


Figure 5-4. Hierarchy of indicators for determining the effectiveness of water quality management and maintaining appropriate relationships and feedback loops between different classes of indicators (modified from U.S. EPA (1995a).

In this process the execution of administrative activities (levels 1 and 2) are followed by changes in pollutant loadings and ambient water quality (levels 3, 4, and 5), all of which lead to measurable environmental "results" (level 6). The process is multi-directional with the level 6 indicators providing feedback about the completeness and accuracy of the process within the preceding hierarchy levels. While the U.S. EPA (1995a,b) hierarchy employs "point source" terminology, it is adaptable to nonpoint sources, other water resource issues, and media other than surface waters. Superimposed on this hierarchy is the concept of stressor, exposure, and response indicators described by Yoder and Rankin (1998).

In order to supply this framework with the necessary biological, chemical, and physical data and assessments an adequate monitoring and assessment program that considers not only what is measured, but the spatial and temporal design of the data collection, the development and completeness of the chemical, physical, and biological indicators, the analytical and interpretive processes used to assemble the data and information into meaningful assessments, and the organizational infrastructure within which it is all accomplished is needed (Yoder 1998). As such, this overall framework includes more than the mere collection of environmental data, but rather emphasizes the development and thoroughness of the assessments that are constructed based on that data. This goes beyond the almost over-emphasized task of assessing statewide status and trends and includes the more detailed task of realizing the integration with water quality management programs on a day-to-day basis and ***at the same scale at which those management actions are applied.*** An important goal for a TALU-based framework is to have the effectiveness of individual water quality management actions and programs determined by environmental *end outcomes* as measured by the information and indicators gained from adequate monitoring and assessment. Inherently embedded in achieving this goal is the adequacy of the essential components of the water quality management infrastructure including WQS. This framework can support any water quality management program where the restoration of designated use attainment is the end goal.

5.2.2 Indicator Discipline – Adherence to Indicator Roles

An important factor in achieving the cost effective approach just described is using chemical, physical, and biological indicators in their most appropriate roles as stressor, exposure, or response indictors. The accurate portrayal of the condition of aquatic resources depends on wider development and use of response indicators and adequate spatial monitoring designs conducted at the same scale of water quality management. Part of the solution to these challenges is to use indicators within their most appropriate roles. The U.S. EPA Environmental Monitoring and Assessment Program (EMAP) first classified indicators as portraying stress, exposure, or response. Yoder and Rankin (1998) further organized the concept defining the most appropriate roles of parameters and measures when used in an adequate monitoring and assessment program. These are categorically described as follows:

Stressor indicators generally include activities and phenomena that impact, but which may or may not degrade or appreciably alter key environmental processes and attributes. These include point and nonpoint source pollutant loadings, land use changes, and other broad-scale influences that most commonly result from anthropogenic activities. Stressor indicators provide the most direct measure of the activities that water quality management attempts to regulate.

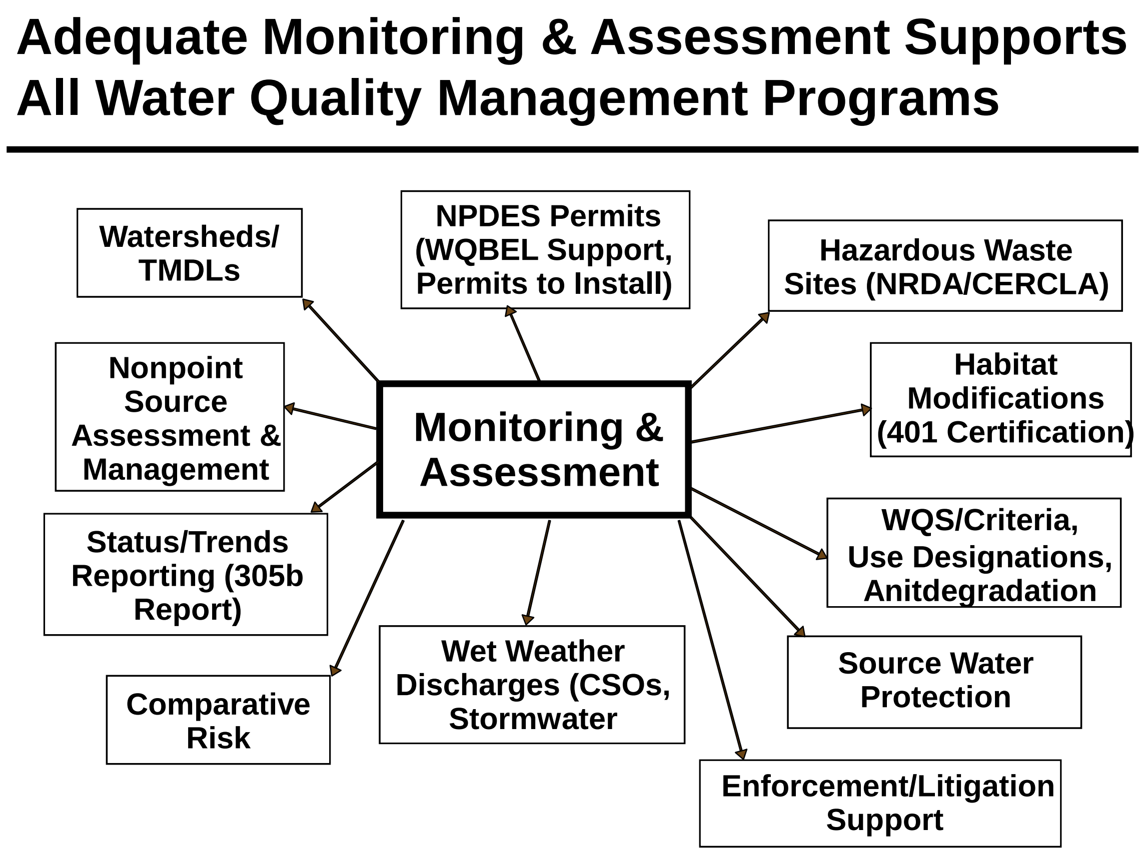
Exposure indicators include chemical-specific, whole effluent toxicity, tissue residues, and biomarkers, each of which suggest or provide evidence of biological exposure to stressor agents. Fecal bacteria also serve as exposure indicators and are used as surrogates for response where direct human response indicators are either lacking or their use would pose an unacceptable risk. These indicators are based on specific measurements that are taken either in the ambient environment or in discharges and effluents, either point or nonpoint source in origin are measures and parameters that reveal the level or degree of an exposure to a potentially deleterious substance or effect that was produced by a stressor event or activity. Chemical water quality parameters and the concentrations at which they occur in the water column fulfill this role. Water quality criteria for toxic substances are developed to indicate chronic, acute, and lethal exposures. Exceedences of these thresholds, either predicted or measured, provide design targets for planning and permitting and assessment thresholds for monitoring and assessment. Fecal bacteria fulfill this role as well, indicating the level of risk posed to humans and other animals by exposure to various levels and durations of potentially harmful pathogens.

Response indicators are measures that most directly relate to an endpoint of concern, i.e., ecological and human health. They are most commonly biological indicators, e.g., aquatic assemblage measures for aquatic life uses and human health for recreational uses and are the most direct measures of the status of designated uses. For aquatic life uses the assemblage and population response parameters that are represented by the biological indices that comprise biological criteria are examples of response indicators. For other designated uses such as recreation and drinking water, symptoms of deleterious effects exhibited by humans would serve as the most direct response indicator, albeit these might prove more difficult to develop and manage. Response indicators represent the synthesis of stress and exposure and are commonly used to represent overall condition or status. The key to implementing a successful indicators and watershed approach that serves as a basis for developing a synthesized “report card” is to ensure that indicators are used within the roles that are the *most appropriate* for each. The inappropriate substitution of stressor and exposure indicators in the surrogate role of response indicators is at the root of the national problem of widely divergent 305(b) and 303(d) statistics reported between the states (NRC 2001). Mapping these indicators to their functional role in monitoring and assessment is best visualized in the hierarchy of indicators depicted in Figure 5-4. This combines their role in a technical sense with their application is a management sense.

5.2.3 Strategic Considerations

Adequate monitoring and assessment is an inherently strategic process. To fully realize its benefits requires an understanding of the multiple uses of information in the management of water resources. A fundamental tenet of adequate monitoring and assessment is that the same set of core resources, methods, standards, data, and information should support multiple program management needs (Figure 5-5). It also requires a commitment to program maintenance and upkeep (i.e., maintenance of adequate resources, facilities, and professionalism) over the long term. Professionalism includes the qualifications of the monitoring and assessment personnel and their ability to carry out all tasks, including data analysis and the sequencing and interpretation of multiple indicators (see Figure 5-4). Indicator usage typically requires specialized expertise in terms of data collection, field observations, laboratory methods, taxonomic practice, and data analysis and interpretation skills. Thus the professional qualification of the personnel who execute and manage a program is a pivotal issue.

Adequate monitoring and assessment provides functional support to individual management programs in two important ways. The first includes “baseline CWA program support” tasks such as determinations of status at multiple scales, UAAs, supporting the regulation and management of specific sources, and providing information to guide watershed planning and restoration programs. The second is that of providing “CWA strategic support” via the systematic accumulation of data, information, knowledge, and experience across various temporal and spatial scales. This includes resources devoted to such tasks as sampling and maintenance of reference sites for determining regional reference condition and developing reference benchmarks for key biological, physical, and chemical indicators and parameters.



program support needs with the same core base of indicators, parameters, and designs.

Many contemporary management needs are not well supported by conventional approaches to water quality criteria and modeling, thus new ways of developing and applying benchmarks and criteria are needed. Developing criteria for nutrients and both clean and contaminated sediments are examples. Other issues such as urbanization and habitat concerns will require landscape and riparian level indicators and objectives. All require robust spatial and temporal datasets. Coupled with this is the need to conduct ongoing applied research and exploratory data analysis with the monitoring program datasets, including the aggregate experience of the program. The ongoing accumulation of data, information, and assessment across different spatial scales provides both the datasets and the assessment experiences. This comprises the strategy for delivering the criteria and benchmarks that will not be delivered by the conventional approach to developing national water quality criteria. Task 5 of the MPCA TALU work plan is an example of this process.

Finally, the recognition that the most important product of adequate monitoring and assessment is the assessment, not just the data, is critical to achieving success. Data by itself has limited usefulness to environmental decision-making unless it is converted to useful information. This means having decision criteria and benchmarks fully integrated into the monitoring and assessment program. It also means adhering to the indicator sequencing and linkage processes that were previously described and most importantly, using indicators within their most appropriate roles. An integrated assessment should serve the needs of multiple programs by the same set of assessments, without the need to generate new or different datasets for each and every management issue.

5.3 How TALU Can Affect Major MPCA Water Quality Management Programs

While we cannot now predict all impacts that the adoption and implementation of TALU will have on MPCA water quality management programs, some general conclusions and descriptions are possible. These are derived in part by knowing how TALU will affect current management processes and also how it has worked where TALUs have been a part of state programs for many years. We will follow the breakdown of major CWA programs as it is depicted in Figure 5-1.

5.3.1 Monitoring and Assessment

Monitoring and assessment is a key component of a TALU approach, but it is also a major CWA program function. States are expected to develop and implement a monitoring strategy that covers the next 10 years of development and implementation. U.S. EPA guidance (U.S. EPA 2003) specified 10 elements that each strategy is to include. MPCA accomplished this recently with their update to the Minnesota Monitoring Strategy (MPCA 2011). The document is both comprehensive and thorough in its attempt to reflect the U.S EPA (2003) guidance. While the strategy describes a stratified approach to the spatial design of surface water monitoring it does not fully describe the TALU specific aspects primarily because it is currently in development. The initial pilot testing described in Section 4 revealed some technical items with monitoring design that includes the following considerations:

1. Spatial density of sampling sites in some watersheds should be improved for assessing the assignment of TALU tiers in selected rivers and streams – this should also improve the delineation of pollution gradients;
2. Having data on both biological assemblages was not available for every site (although it was available at most) – this should be done as a matter of practice given the dual assemblage approach that TALU requires;
3. Chemical/physical data was not able to be paired with every biological site and in some cases this totaled multiple sites in some watersheds – chemical/physical data will need to be paired with biological data and at a sufficient frequency; and,
4. Intensive surveys of specific stream and river segments to assess specific point sources or localized aggregations of impact sources is not included and is only infrequently employed.

These highlight where some modification or supplementation of key aspects of the MPCA monitoring design will be needed and determining this is an important part of the development process and ultimately TALU implementation.

A template for an annual watershed assessment process is depicted in Table 5-1 from the selection of specific watersheds for assessment through detailed study planning, field sampling, data management, data analysis, and reporting are described in their respective sequence.

Table 5-1. Important timelines and milestones in the planning and execution of a watershed assessment process on an annual basis in support of a TALU-based approach.

Timeline	Milestone
December - February: (Months 1-3)	Initial screening of the major hydrologic areas takes place by soliciting input from the various program offices and other stakeholders.
February - March: (Months 3 thru 4)	Final prioritization of issues and definition of specific study areas. Resource allocation takes place and study team assignments are made.
March - May: (Months 4 thru 5)	Study planning takes place and consists of detailed map reconnaissance, review of historical monitoring efforts, and initial sampling site selection by the study team. Final study plans are reviewed and approved.
May - June: (Months 5 thru 6)	Final study plans are used to develop logistics for each field crew. Preparations are made for full-scale field sampling.
June - October: (Months 6 thru 10)	Field sampling takes place with field crews operating somewhat independently on a day-to-day basis, but coordinated by the study plan and the team leader. Study team communication takes place as necessary, especially to resolve unexpected situations.
October - February: (Months 10 thru 14)	Laboratory sample analysis takes place for chemical and biological parameters. Raw data is entered into databases for reduction and analysis. The study team meets to review the information base generated by the field sampling and to coordinate the data analysis and reporting effort.
November - May: (Months 11 thru 17)	Information about indicator levels 3-6 is retrieved, compiled, and used to produce analyses that will support the evaluation of status and trends and causal associations within the study area. Integration of the information (*i.e.,* assessment) is initiated.
May - December: (Months 17 thru 24)	The assessment process is completed by producing working copies of the assessment for review by the study team and a final edit for an internal peer review. Final assessment approved by management for use within and outside of the agency. It is used to support 305b /303d, NPDES permitting, water quality standards (*e.g.,* use designation revisions), and other programs where surface water quality is of concern.

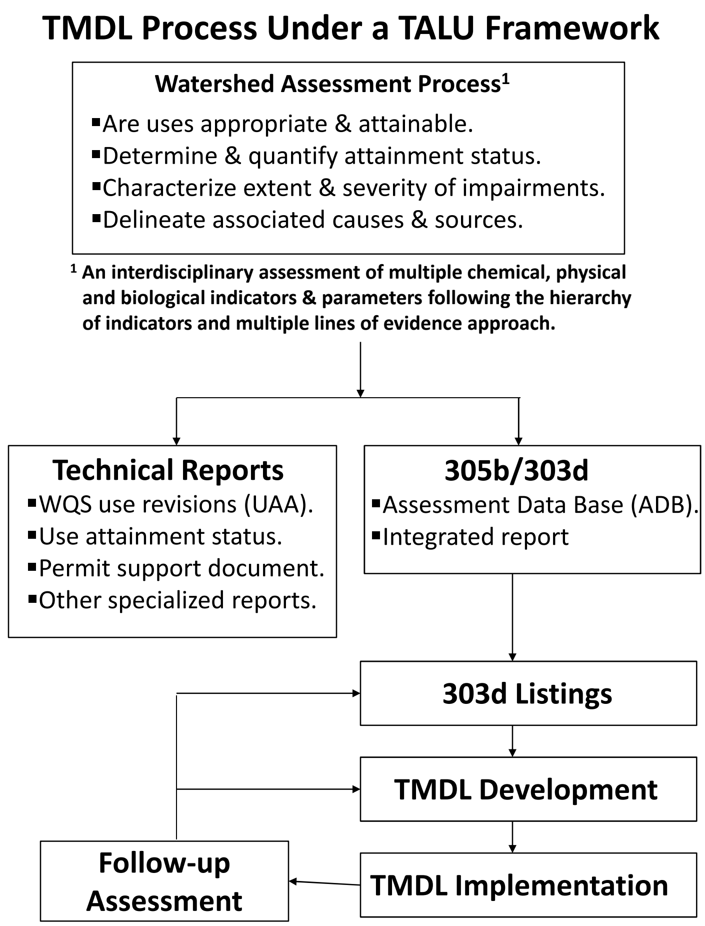


Figure 5-6. Key steps in a TMDL implementation framework within a TALU based framework.

5.3.2 Total Maximum Daily Loads (TMDLs)

The anticipated effect of TALU implementation on TMDLs includes the obvious effect of adding biological assessments to the determination of impairments and the expectation that more and different impairments will be identified (Karr and Yoder 2004). However, the totality of the TALU approach and its influence on the design, conduct, and outcomes of monitoring and assessment will perhaps exert changes in the process of watershed assessment. That process and how it specifically relates to TMDLs is depicted in Figure 5-6. In this approach it is the watershed assessment that is the domain of the TMDL process beginning with the determination of the appropriate and attainable aquatic life uses. This is an essential prerequisite to the determination of impairment under TALU since the attainment/non-attainment biocriteria vary with the use designation tier and within the newly developed stream and river classifications. Instead of using a narrative biocriterion that was applied on a statewide basis, the new biocriteria under the proposed TALU framework are now more detailed and stratified across Minnesota. Hence what may have been considered impaired or not under the former approach may have a different result under the proposed structure of TALUs and biocriteria.

Also included in the watershed assessment process in addition to the use and impairment determinations are the characterization of the severity and extent of impairments and the delineation of causes and sources. While MPCA currently employs a process to delineate stressors associated with findings of impairment via an additional year of investigation, addressing the issue identified in Section 5.3.1 with the inequities of indicator coverage at each site should enable some impairments to be more readily diagnosed with that dataset. This issue certainly bears more detailed examination and pilot testing and it seems plausible to accomplish this in the initial stages of TALU implementation.

The key product of a TALU focused watershed assessment is a technical report that details the WQS use revisions including their location and the basis for any changes to existing assigned uses under the WQS. It also documents use attainment status in a logical array of how stream and river segments occur in the watershed and a summary of the causes and sources that are associated with the observed impairments. The assessment results can be arranged in a manner such that they are directly transferable to the 305b water body inventory (Assessment Database) and the Integrated Report. This information then supports the listing of impaired water bodies as required by the 303d process and the details of the assessment of biological, chemical, and physical data feeds into the development of TMDLs in response to the observed impairments. Ideally, TMDL implementation is followed afterward by follow-up assessments which then provide feedback to the TMDL listing and development process.

5.3.3 Water Quality Standards

While TALUs are a major aspect of state WQS once they are developed and adopted there are other parts of the WQS that can be affected by the TALU approach. This most commonly includes chemical and physical water quality criteria and the nondegredation policy.

5.3.3.1 Refined Water Quality Criteria

Both numeric and narrative water quality criteria can be affected by the adoption of TALUs in the state WQS. This mostly involves the “tiering” of criteria for selected parameters in accordance with the attributes ascribed by the TALU narratives. However, relying on the national criteria development methodology (Stephan et al. 1985) does not necessarily result in the derivation of tiered criteria for the different TALU tiers. The reason for this is that the Stephan et al. (1985) method relies on laboratory data for representative species that actually have data available and this never includes the entirety of an aquatic assemblage. In fact, these databases are usually overrepresented by species that are highly to intermediately tolerant of pollution, seldom including highly intolerant species members of these assemblages. In addition, the differences between TALU tiers are not completely explained by differences in species, but rather by shifts in the relative abundances between the same species. Because the representative species in the Stephan et al. (1985) all count as “equal” contributors, i.e., they are included on a presence/absence basis, the relative abundance influences are not accounted for in the traditional derivation of water quality criteria. Thus the species members of two adjacent TALU tiers may be similar enough that no differences are produced by the conventional method of deriving chemical criteria.

The alternate approach is to develop relationships between the biological criteria endpoints and field measurements of the parameter(s) of interest. Techniques to relate the response of the biological assemblages to single chemical/physical parameters have been developed and used to derive tiered criteria in concert with the adoption of TALUs. These include “wedge plot analysis” and more recently quantile regression (Terrell et al. 1996, Cade and Noon 2003, Bryce et al. 2008, Heiskary et al. 2010). An example using pricewise quantile regression or additive quantile regression smoothing is included in Figure 5-7 which was used as part of an analysis to develop nutrient criteria for rivers in Minnesota (Heiskary et al. 2010). A sufficiently robust spatial and temporal database of paired bioassessment and chemical/physical parameter specific data is needed to accomplish this type of criteria derivation. Furthermore, the full gradient of quality (excellent to very poor) as reflected by both the biological assemblage response and the chemical/physical parameter in question needs to be available. It is for this latter reason that only the most commonly occurring parameters are usually included in this type of process. This would include dissolved oxygen, ammonia-nitrogen, common heavy metals (Cu, Cd, Pb, Zn, Fe), and other parameters such as total suspended solids, total dissolved solids, sulfates, chlorides, and turbidity. This type of analysis is depicted in task 5 of the work plan described in section 1.

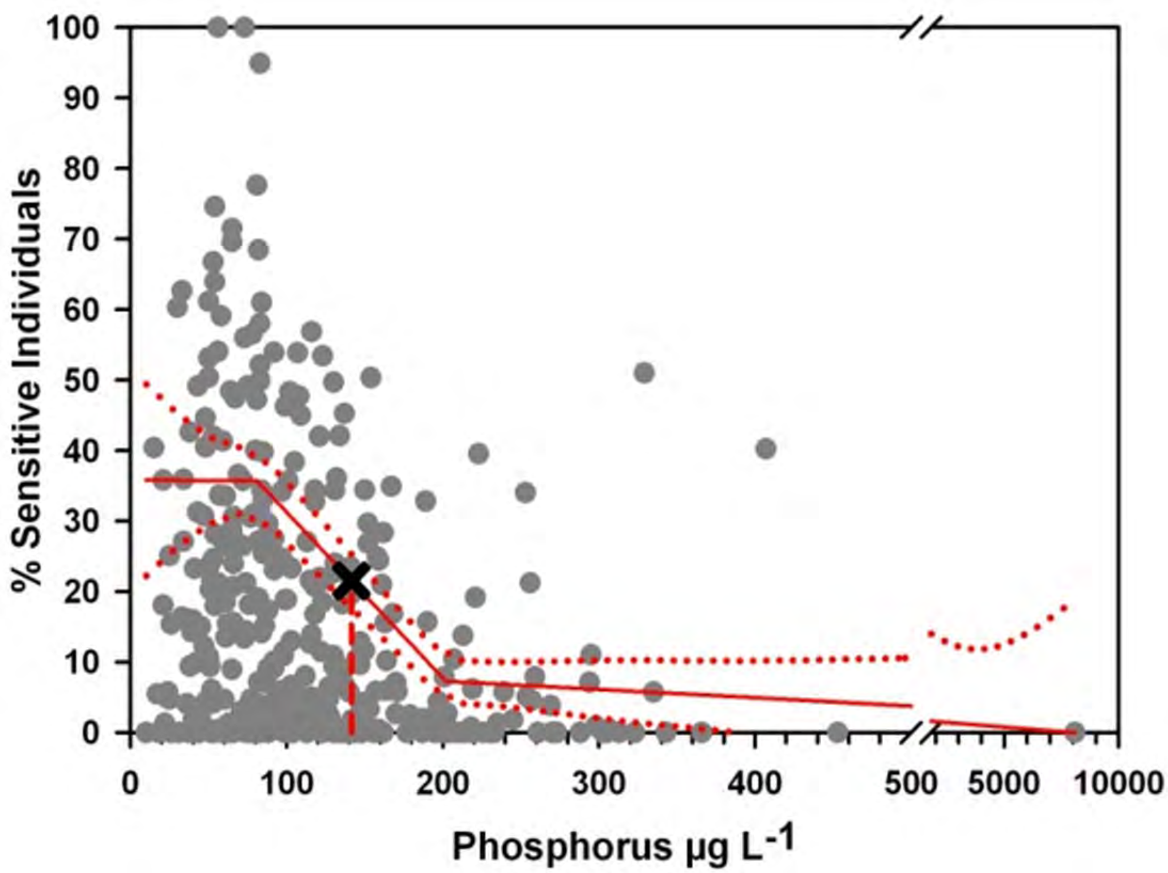


Figure 5-7. Example of 75th percentile additive quantile regression smoothing for percent sensitive fish for the Central Hardwood and Driftless Area ecoregions (solid line = AQRS fit; dotted lines = 90% confidence bands).

5.3.3.2 Antidegradation

TALU is also relevant to antidegradation in particular the assignment of specific water bodies to antidegradation tiers. The same biological data that is used to derive and implement the numeric biocriteria can be used for stratifying the antidegradation tiers while at the same time highlighting the occurrence of unique and sensitive species populations that otherwise may be "obscured" by the biocriteria indices alone.

5.3.3.3 Use Attainability Analysis (UAA)

Section 4.3.2 essentially described in detail a "UAA type" of process for using the results of bioassessment to determine if the currently applicable aquatic life use is both appropriate and attainable. In strict terms a UAA is employed when a use less than a CWA Section 101[a][2] use is being proposed, which in our case would be the Modified Warmwater Habitat (MWH) or Limited Resource Water use tiers (LRW). However, in a TALU-based approach the same data, tools, and stepwise process are used to answer the broader question about the applicability of the currently applicable use as defined by chapter 7050. As was discussed in Section 4.3, the starting point will almost always be class 2B (or class 2A in the case of cold water streams) which is roughly equivalent to the General Warmwater use tier. As such the same process will be used to assign a higher than CWA minimum use as it will to assign a less than CWA minimum use.

5.3.4 NPDES Permitting

The Nation's stream and rivers were grossly polluted by raw and under-treated wastewater discharges from industrial and municipal sources prior to the passage of the Federal Water Pollution Control Act (FWPCA) amendments of 1972. Referred to herein as the CWA it led to the institutionalization of a federal system of discharge permits known as the NPDES. This federal system of permitting developed out of a nearly quarter-century long legislative process that was spurred by an increasing recognition of visibly polluted rivers and streams both by the public and the research community. Pioneering works about the biological effects of water pollution included early studies by Bartsch (1948), Doudoroff and Warren (1951), and a series of studies compiled by the Federal Water Pollution Control Administration (Keup et al. 1967). These and many other investigations raised a keen public awareness about the grossly polluted state of many rivers and streams and spurred the development of legislation aimed at reducing and controlling the adverse impacts on public health, recreation, and aquatic ecosystem health.

The adoption of a TALU-based approach[10] by MPCA presents the opportunity to prioritize and streamline NPDES permit actions using ambient monitoring and assessment information with an emphasis on biological criteria as the key endpoint for determining overall permitting effectiveness. For the purposes of this project, permitting actions include the aggregate of permit development and issuance, compliance, and enforcement. Biological assessment includes the biological, chemical, and physical assessment of receiving waters on a river reach and/or watershed basis with biological criteria serving as the key response variable and as the arbiter of designated aquatic life use attainment. The process is generally illustrated in Figure 5-2 with a TALU-based approach representing the Resource End-Outcomes sequence. The current NPDES program represents the Administrative Outputs sequence with administrative outputs being used as the arbiter of program success.

Presently, the prioritization and effectiveness of NPDES permitting activities in Minnesota is based primarily on administrative processes, indicators, and measures. U.S. EPA and others have acknowledged the potential value of basing permitting and other priorities on ambient monitoring and assessment results *as they can be related to administrative actions*. The framework for a workable process (see Figure 5-4) first emerged out of prior U.S. EPA

[10] The "TALU based approach" includes tiered aquatic life uses (TALU) based on numeric biological criteria and implementation via an adequate monitoring and assessment program that includes biological, chemical, and physical measures, parameters, indicators and a process for stressor identification.

environmental indicators initiatives (U.S. EPA 1990, 1995) and selected pilot projects (Ohio EPA 1997). However, these frameworks have seen neither widespread application nor acceptance by EPA or the states. The lack of a broader and more creative use of ambient monitoring and assessment data and information for these purposes can be attributed to:

1) the lack of a sufficiently developed indicator process in the states;
2) the lack of sufficient and readily available monitoring and assessment data;
3) a cultural adherence to and preference for administrative measures and processes; and,
4) legislative mandates and management directives that reinforce and perpetuate a continued reliance on administrative processes.

In terms of the MPCA program, number 1 is being addressed via the adoption of biological indicators and numeric biocriteria. Number 2 is being addressed via the recommendation to add M&A designs that address specific point sources and in a manner that allows those assessments to serve as the environmental end outcomes in Figure 5-1. Number 3 can be addressed by more fully adopting an environmental end outcomes approach, but only if the right types of M&A data are brought to bear in receiving water assessments. If numbers 1-3 are addressed with MPCA, number 4 becomes a less relevant impediment especially since this new process is not a replacement of administrative measures. Those will continue to be a vital part of the overall NPDES permitting process. One of the first and most important baseline goals of a TALU-based approach is to provide direct support to NPDES permitting, thus the fundamental monitoring design will need to be sufficient for conducting retrospective analyses of the effectiveness of NPDES permitting over the preceding time period. Such an approach should serve as an important "reality check" on some of the administrative process improvements envisioned in the EPA report entitled *"Report on State-EPA Permit Re-engineering and Streamlining"* (October 28, 2002) and subsequent efforts to streamline NPDES permitting.

5.3.4.1 Spatial Survey Design

The key data and information requirements for a TALU-based approach are produced by adherence to the adequate monitoring and assessment framework that was previously described in Section 5.2. This underscores the multiple uses of the same data and indicators provided the spatial M&A design is adequate to the task. As such, multiple assessment issues can be simultaneously addressed by the same survey design. These include ensuring that the designated aquatic life use is appropriate and attainable, determining the severity and extent of impairments, and relating the relevance of sources to the observed impairments. If it is properly developed and executed a TALU-based approach should deliver assessments of specific point sources that fulfill the determination of the environmental effectiveness of NPDES permitting. Specific to this survey design is the recognition of how point source discharges affect the chemical/physical and biological characteristics of a receiving stream or river. Figure 5-8 illustrates a number of important concepts about how point sources of common constituents like oxygen demanding wastes (i.e., as measured by biochemical oxygen demand [BOD]) and ammonia-N react in a downstream direction via the process of pollutant fate and transport. At the same time, and depending on the discharged loadings and resulting instream concentrations, an effect on the dissolved oxygen (D.O.) regime is produced. Finally, the response of the aquatic assemblages can be measured against these chemical gradients and in proximity to the point source of these pollutants. Not only can the severity and extent of any impacts be measured, the type of response can also be visualized with this type of monitoring design. A response to toxicity is suggested by an immediate decline in the biological measures whereas a more D.O. driven response is suggested by a "delayed" response that corresponds to the D.O. "sag" that occurs some distance downstream as the effect of bacterial processing of excess oxygen demanding wastes occurs. The capacity to detect such "pollution gradients" is only possible by having an adequate survey design that employs a longitudinal pollution survey design as depicted in Figure 5-8. The typical "upstream/downstream" designs that have traditionally been used to assess NPDES permitted entities are simply inadequate for this level of characterization.

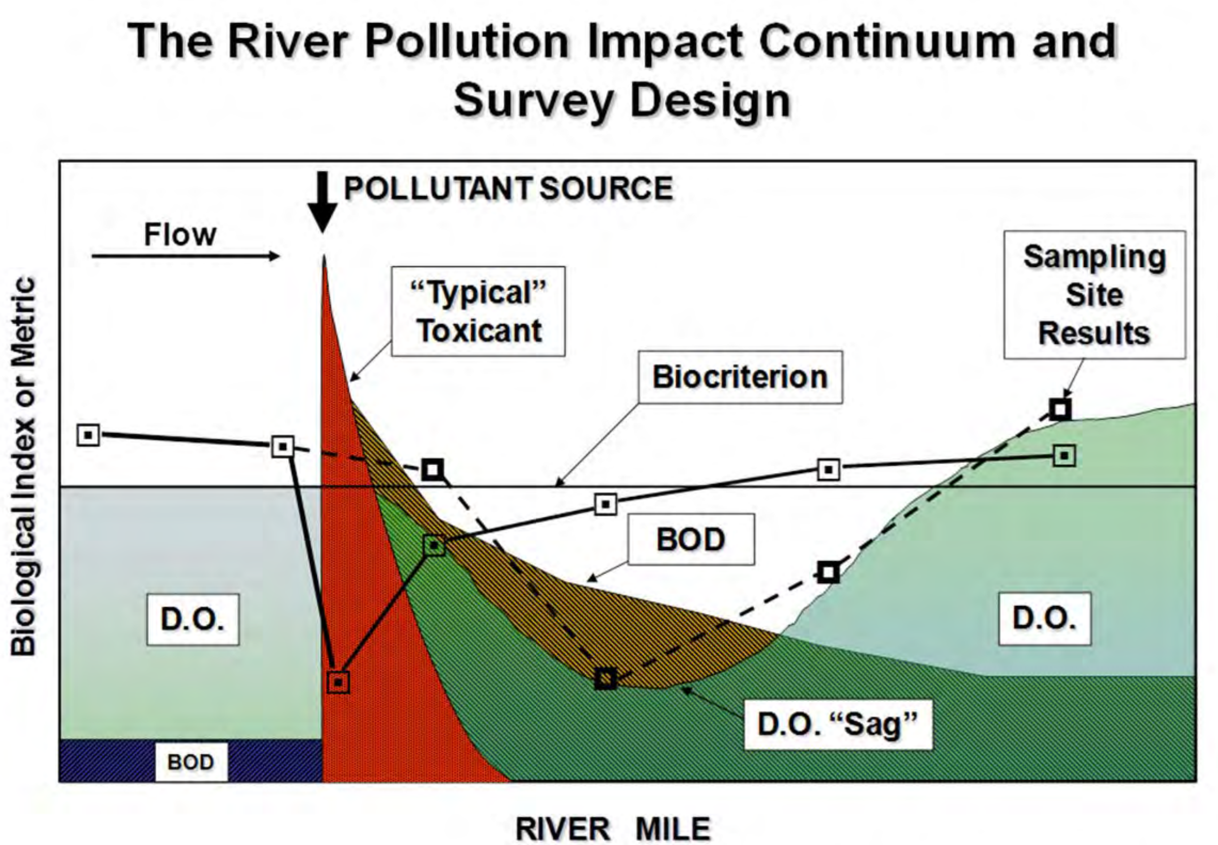


Figure 5-8. The river pollution impact continuum and survey design adapted from the original description of pollution zonation by Bartsch (1948). In addition to how pollutants typically react when discharged in a lotic system, suggested sampling design and two different biological responses are depicted.

Once an impact is characterized a stressor diagnosis process is then applied as part of a TALU-based approach. This consists of assessing multiple lines of evidence that relate to the observed biological impairment. This includes the process depicted in Figure 5-9 as an example of using affiliated tools such as biological response signatures (Simon 2003; Yoder and DeShon 2003; Riva-Murray et al. 2002; Yoder and Rankin 1995b) to categorically classify the type of biological response and then focusing in on key parameters that are either directly contributing or which serve as markers for the type of effluent process that is likely contributing. In addition, using facility information about effluent quality is vital to this diagnosis and includes information about trends in effluent quality and operational issues if any. Frequently, and depending on the type of discharge that is involved, knowledge from similar settings and assessments can be applied in support of the overall diagnosis. This lends support to taking any number of actions with a permit including enforcement, revisiting the water quality based effluent limits (WQBEL), and regulating previously under or unregulated activities.

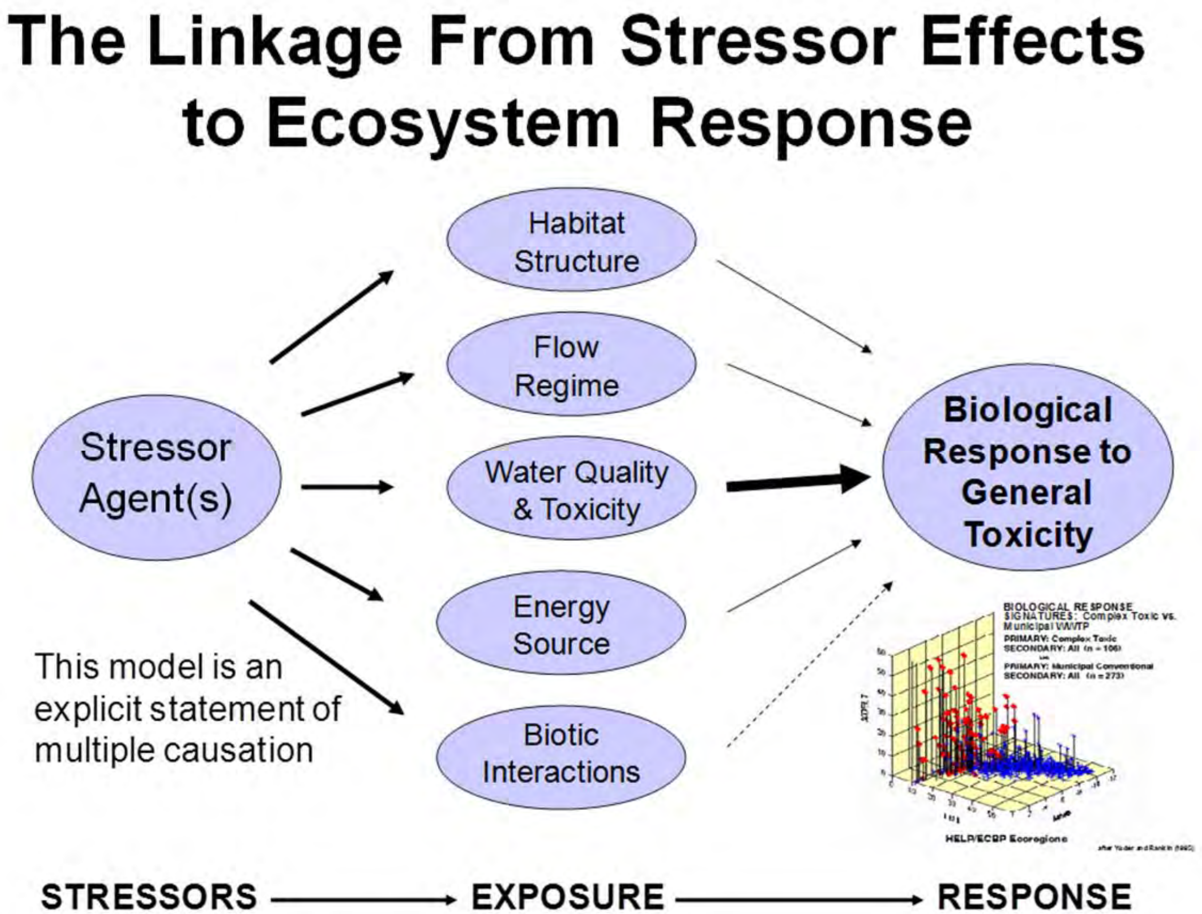


Figure 5-9. The process for relating a biological response indicative of generalized toxicity to the stressor source and via a lines of evidence approach supported by adequate monitoring and assessment data and information.

5.3.4.2 Designated Aquatic Life Use Impacts

Another anticipated impact of a TALU-based approach on NPDES permitting is the designated aquatic life use tier of the receiving stream or river. While this does affect the application of a bioassessment impact analysis by the numerical biocriteria that is applied in an impact assessment as just described, it can also directly affect the derivation of WQBEL if the pollutant specific water quality criteria vary by the different use tiers. However, this will be true only if the water quality criteria are indeed varied by the applicable use tiers.

In addition to the potential effect on WQBELs of differing chemical criteria by use tier is their application to an NPDES permit. A concern that has been expressed in Minnesota and which we have encountered elsewhere is situations where a permit was originally based on a lower tier and the bioassessment documents an upgrade to the current use tier. The assumption is that this automatically makes the WQBELs proportionately more stringent. However, if the biological impact assessment shows that the new use tier biocriteria are attained, then this brings in the biocriteria application language where full attainment is the finding. This could result in the maintenance of existing effluent quality in keeping with the finding of full attainment of the newly proposed use tier. As such, changes in use tiers do not necessarily nor automatically result in more stringent effluent limits. Table 5-2 outlines some general NPDES permit scenarios based on changes to the current designated use under the new TALU-based framework.

Table 5-2. Possible NPDES permit actions based on plausible use change scenarios under the new Minnesota TALU framework.

Current Use Class	New Use Class	Biology	Action
Class 7	Modified/General/Exceptional	Attains	Maintain Permit
Class 7	Modified/General	Does Not Attain	Review Permit[1]
Class 7	Limited Use	Attains	Maintain Permit
Class 2A/2B	Exceptional	Attains	Maintain Permit
Class 7/2B	General CW	Attains	Maintain Permit
Class 7/2B	General CW	Does Not Attain	Review Permit[1]
Class 2A	General WW	Attains	Maintain Permit
Class 2A	General WW	Does Not Attain	Review Permit[1]
Class 2A/2B	Modified	Attains	Maintain Permit
Class 2A/2B	Modified	Does Not Attain	Review Permit[1]
Class 2A/2B	Limited Use	Attains	Maintain Permit

[1] Permit review could result in more stringent effluent limits or if the discharge is not the cause of nonattainment then the effluent limits can be held at current levels.

5.3.4.3 Illustrating Permitting Effectiveness

Provided there is sufficient temporal data accomplished with the preceding M&A designs, bioassessments can be useful to demonstrate the environmental end outcomes of NPDES permitting. This is simply a manifestation of the processes previously described in Figures 5-2 through 5-4. The example in Figure 5-10 illustrates the full success of NPDES permitting over a nearly 30 year period of time for a major metropolitan wastewater treatment plant (WWTP) in Ohio. This especially illustrates the process depicted in Figure 5-4 where the initial actions of issuing and reissuing an NPDES permit (Level 1) coupled with actions taken by the regulated entity to reduce discharged loadings (Levels 2 and 3) improved water quality (Level 4) and assimilative capacity (Level 5) in the receiving river which was followed by an incremental improvement in biological assemblage condition to the full attainment of the designated TALU tier (Level 6). Furthermore, this illustrates an example where the biological improvement was

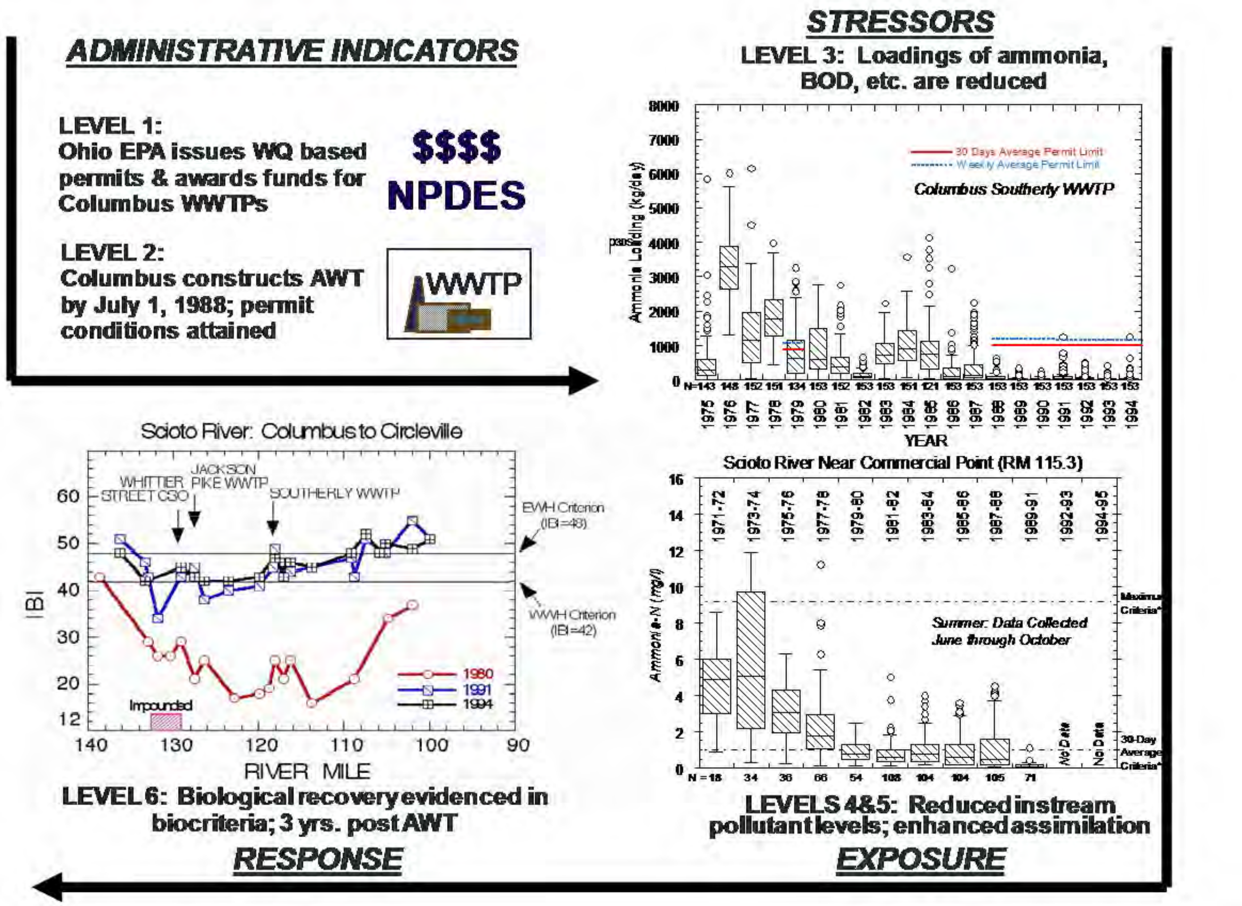


Figure 5-10. Example of using the hierarchy of indicators framework (see Figure 5-4) to demonstrate the sequence of events using level 1 through 6 indicators. This example is for the city of Columbus Southerly WWTP and bioassessment information from the receiving river (Scioto River) collected and assessed by Ohio EPA. It demonstrates a successful environmental outcome of NPDES permitting.

such that an upper TALU tier (Exceptional Warmwater) has been recommended for a portion of the receiving river. This same sequence of improvements in response to WQBELs for municipal WWTPs has been documented in multiple examples and has resulted in a 72% increase in full attainment of the biocriteria in Ohio non-wadeable rivers (Ohio EPA 2010). This level of documentation of full improvement does several things in addition to documenting the aggregate impact of WQBELs at Ohio WWTPs as follows:

1. It provides solid proof that advanced wastewater treatment is both implementable and assures environmental outcomes; and.
2. It provides proof that effluent dominated rivers can meet and exceed CWA goal uses.

The unheralded value of these observations is that the demonstrated successes herein have erased the historical debates about the efficacy of advanced wastewater treatment and the attainment of CWA goal uses in effluent dominated rivers. Prior to the push for WQBELs in the late 1970s and early 1980s, both were seen as barriers to that level of pollution control and at

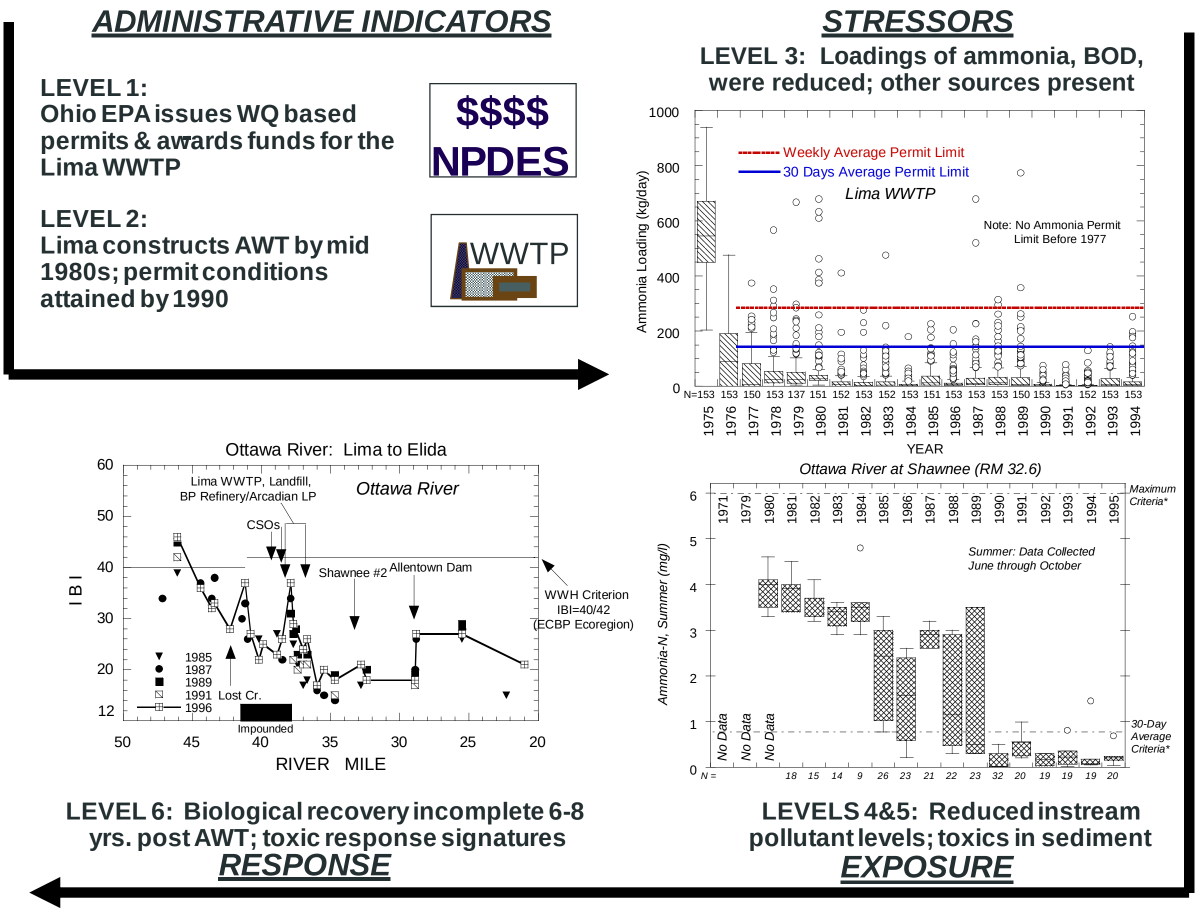


Figure 5-11. Example of using the hierarchy of indicators framework (see Figure 5-4) to demonstrate the sequence of events using level 1 through 6 indicators. This example is for the city of Lima WWTP and bioassessment information from the receiving river (Ottawa River) collected and assessed by Ohio EPA. It demonstrates an unsuccessful environmental outcome of NPDES permitting.

least temporarily resulted in the application of limited uses. Using a long term dataset produced by a sustained TALU-based M&A program illustrates the intangible benefits to a key water quality management program.

While the example in Figure 5-10 illustrates a virtually complete success of water quality based permitting for municipal WWTPs, there are some examples where this “conventional” approach for dealing with steady-state discharges was not completely successful. Figure 5-11 illustrates a municipal setting in Ohio where the same type of permitting and abatement actions were applied to a WWTP. In this case, biological impairment persisted despite attainment of WQBELs at the WWTP. Two adjacent industrial facilities with NPDES permits were suspected of contributing to the non-attainment, but neither was in “significant” noncompliance. The biological response furthermore indicated a toxic response which pointed to contaminants from either or both facilities. The lines of evidence approach (Figure 5-12) that is employed as part of the stressor identification process confirmed the presence of toxic substances in the effluents, water column, and sediments (Yoder and DeShon 2003). The question then became how did and do these substances enter the river if they are not being detected by the required effluent monitoring? Further investigations revealed on site contamination of the soils, legacy landfill disposal sites, and intermittent pulses via stormwater outfalls. As such, it took a lack of the expected biological attainment coupled with the type of biological response and the stressor identification process to guide the process of determining sources of the observed impairments. Preliminary data from Ohio EPA indicates that management interventions aimed at the categorical problems with toxicity have been followed by partial biological recovery, in particular the reduction in deformities, erosions, lesions and tumors (DELT) anomalies on fish which is a key part of the toxic response signature exhibited in the 1980s and 1990s.

Multiple Indicators Matrix: Ottawa River

	DES. USE	RESPONSE INDICATORS				EXPOSURE INDICATORS						STRESSORS				
SEGMENT	Attainment Status	QHEI	IBI	MIwb	ICI	Water Chem.	Sediment Chem.	Toxicity	% DELT	Fish Tiss.	Biomarker	# Dams/ Pools	Urban Indust. Landuse	Cumulative Loads	Spills	CSO SSOs
Ottawa River mainstem (1996)																
Thayer Rd to Sugar St.	FULL-PART	68	Fair-Good	Fair-Good	Good	Nitrates	Low	NA	Mod High	Mercury	Low	Mod-erate	Low	Low	Low	Low
Sugar St. to Lima WWTP dam	**NON**	47	**Poor** to Fair	**Poor** to Fair	**Poor** to M.G.	CBOD TSS D.O.	As,Cr Cd,Cu Ni,Zn	Moderate	**High**	Pesticides	BUN Naph B(a)p	**High**	**High**	Moderate	Moderate	**High**
Lima WWTP dam to Allentown dam	**NON**	72	**Poor**	**Poor** to Fair	Fair to Good	Amm. CBOD TSS D.O. Nitrates Phos Chrom PAH Pesticid	As,Cr Cd,Cu Ni,Zn PAH	Moderate	**Very High**	Selenium Pesticides	EROD Naph B(a)p BUN	Moderate	**High**	**High**	**High**	**High**
Allentown dam to Kalida	PARTIAL	69	**Poor**-Fair	Fair-Good	Good-Exc.	TSS	Low	NA	**High**	Pesticides	Low	Low	Low	**High**	Low	Low
Kalida to mouth	FULL	69	Good	Good	Exc.	TSS	Low	NA	**Very High**	Pesticides	Low	Low	Low	**High**	Low	Low

Figure 5-12. A matrix of stressor, exposure, and response indicators for the Ottawa River mainstem based on data collected in 1996 (after Ohio EPA 1998). The darkness of shading indicates the degree of severity in effect expressed by an indicator.

5.3.4.4 Other Types of NPDES Permitting

While the preceding examples were based on NPDES permitting of major point sources, the same principles can be applied to other types of permitting such as stormwater and CAFOs (Combined Animal Feeding Operations). This all applies provided that the design of the M&A is spatially adequate for these tasks, but the same pollution survey design at the watershed or mainstem river segment scale should satisfy the information needs of these applications.

5.3.5 Other Permitting and Review

Other permitting and review functions can also be supported by the TALU-based approach. An example is the review of projects that require a CWA Section 404 permit and a 401 certification by the state WQS agency. A 401 certification indicates that state WQS will be maintained by the subject activity. For rivers and streams these usually include the modification of in channel habitat which is jurisdictional under Section 404 reviews. Given that there is a sufficiently predictable relationship between the MPCA biological criteria endpoints and the MSHA, the effect of any activity subject to review under 404 and 401 will be predictable in terms of meeting and maintaining the Minnesota WQS, the aquatic life designated use in particular. Projects that are predicted to result in an impairment of the biologically based designated use cannot be allowed per the provisions of the existing use clause in the federal water quality regulations (40CFR Part 131). Such activities will need to be modified such that they are compatible with maintenance of the designated use. At the same time it is recognized that not every 404/401 decision will either have or require a review at this level of detail. Operationally this works best when the public notice is jointly reviewed by the 401 and biological monitoring staff. In addition to site-specific reviews, the administration of nationwide permits can also be influenced by the TALU-based approach. Some examples are exempting higher tier uses and antidegradation tiers from the nationwide permit, the effect of which is to require site-specific reviews for these waters.

5.3.6 Watershed Planning and Management

The information from a TALU-based approach is also valuable to watershed planning and management through any number of programs. TALU can affect these in the following ways:

1. The biological data and assessments can communicate about intrinsic condition and quality thus being useful for setting priorities for protection;
2. The biological measures employed in a TALU-based approach can measure incrementally thus providing a way to gauge progress as management programs are applied; and,
3. Indicator units that portray degradation units can be extracted and used in setting priorities for management and restoration projects.

Essential to using TALU-based data and information is the concept of incremental improvement. Incremental improvement is defined here to represent a measurable and technically defensible, positive change in the condition of an impaired water body within which an improvement has been measured, but which does not yet fully meet all applicable WQS. The general principles are defined as follows:

- ***measurement of incremental improvement*** can be accomplished in different ways, provided the measurement method is scientifically sound, appropriately used, and sufficiently sensitive enough to generate data from which signal can be discerned from noise;

- ***measurable parameters and indicators*** of incremental improvement may include biological, chemical, and physical properties or attributes of an aquatic ecosystem that can be used to reliably indicate a change in condition; and,

- ***a positive change in condition*** means a measurable improvement that is related to a reduction in a specific pollutant load, a reduction in total number of impairment causes, a reduction in an accepted non-pollutant measure of degradation, or an increase in an accepted measure of water body condition relevant to designated use support.

The methods, parameters, and tools to implement such an approach are an inherent part of the TALU-based approach and as such it is "ready" to support incremental measurement and comprehension.

A protocol for the documentation of incremental improvements in impaired waters is a major need of watershed management and other surface water protection programs. The evaluation of program success has almost exclusively focused on the full restoration of listed impairments. While this seems a straightforward process based on the removal of all impairment causes and meeting all WQS, it is presently difficult to account for improvements that have occurred as a result of project specific restoration actions, but which do not yet meet all WQS. This can result in the perception that the program seems staked to an "all or nothing" end result with no recognition of any positive movement towards full attainment of WQS. Furthermore, failing to recognize that waters are improving and are on a positive trajectory can lead to erroneous conclusions about the attainability of CWA goals and the viability of certain management practices. Hence, developing ways to measure and display incremental improvement would be beneficial to watershed management programs in a number of different ways. While the TMDL program is the primary water program that is dedicated to the delineation and tracking of the status of impaired surface waters and the progress of their restoration to meet CWA goals, other EPA water programs can also benefit from the measurement of incremental change. The TALU-based framework in development and use now should deliver that capability. Table 5-3 is a listing of the programmatic "clientele" that should benefit from this framework.

The significant challenges in addressing the need for a framework and protocol for measuring incremental change center on the inherently competing concepts of desiring a readily available and tractable process for reporting and the equally important, but frequently overlooked need to have it based on sound data and information (i.e., "credible scientific data"). A TALU-based approach emphasizes the integrity and strength of the underlying data and information upon which the incremental change indicators are founded. One problem with the current situation nationally is that a wide variety of different approaches are essentially homogenized by existing programmatic expressions of designated use attainment. This is commonplace within CWA program reporting and prior examples include state variability in 305[b] reporting from the previous 30 years and the litany of "lists" that have been produced from the same baseline data for a variety of purposes.

Table 5-3. "Clientele" for a framework that includes incremental improvement measurement concepts and methods (after Yoder and Rankin 2008).

Clientele	Reason for Interest
TMDL program managers (primary clientele)	Demonstrate partial recoveries as program results in outcomes potentially earlier and in larger numbers than full recovery (i.e., a recognition that all stressors cannot be remediated in the same time frames).
NPS program managers	Related to qualifying for NPS success stories recognition; also demonstrate more 319 progress and results.
Monitoring program managers	Once documented as partially recovered, help orient limited monitoring funds to measuring waters more likely to have completely recovered. Also documenting incremental improvement is a primary component of post- project effectiveness monitoring.
4b projects (controls other than TMDL are in place)	Demonstrate progress being made within a reasonable time period so as not to revert from 4b to 5/4a process.
EPA Surface Water Strategic Planners and Watershed Managers Forum	Clarify and help defensibility of counting rules on partial restoration measures (W, Y). Also, aid the consideration of possible new measures concerning incremental improvement.
States	Additional consideration in performance partnership agreements & reporting to EPA.
WQS program	Related to determination of highest attainable use for the purpose of designating aquatic life uses; essential in UAA considerations.

A fundamental problem with these past approaches has been the homogenization of technically different baseline inputs in designated use status reporting. Many states base their assessments of status either wholly or partially on chemical/physical parameters and indicators while others employ bioassessment results, yet each is distilled to a common terminology and "currency" expressed as the proportion of a water body unit that partially or fully attains designated aquatic life use support. As has been shown in prior comparability studies (Rankin and Yoder 1990; Rankin 2003; Karr and Yoder 2004) such assessments based on chemical/physical indicators can be substantially different than biologically based assessments, the differences being up to 50% in some cases. In such cases, biological assessment contributed to the avoidance of a type II assessment error that is inherently propagated in chemical/physical assessments, which results in the significant under-reporting of aquatic life use impairments. Current practice in effect obliterates these important differences by effectively homogenizing fundamentally different assessment protocols. There are additional differences in state programs that also contribute to the uncertainty about the reliability of status assessments and these include differences in spatial sampling design and the level of rigor of state M&A programs. These almost certainly contribute to an as yet undocumented degree of variability and uncertainty in consolidated measures of management program effectiveness. An advantage of the TALU-based approach is how it relates baseline chemical, physical, and biological measures and indicators in an integrated assessment process that will result in improved accuracy and consistency in the type of reporting that is to be accomplished by measures SP-11 and SP-12 (aka measures W and Y). This is an important prerequisite to assuring that “credible scientific data” are effectively used in the measurement of incremental change within these reporting frameworks.

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Appendix A: Detailed TALU Work Plan

March 29, 2011

The following are descriptions of the major tasks that are proposed as part of this project. A detailed work plan was developed in cooperation with MPCA and resulted in the following tasks:

Task 1 – Internal and External Stakeholder Meetings

MBI will lead a series of meetings with internal MPCA and external state and local agency and non-governmental stakeholders to coordinate and foster input and support for the principal objectives of this project. These meetings are described as follows:

Task 1a: Initial MPCA Coordination

MBI will participate in meetings and discussions with key MPCA managers and staff to discuss the specific tasks outlined in this detailed work plan and the projected timeline for various subtasks and final delivery of project work products. It includes detailed planning and consultation with MPCA staff in order to determine the key issues that are likely to be of the most interest to internal and external stakeholders. This task also includes the initial development of an implementation plan that communicates how the new biological criteria and WQS will affect their current stakeholder activities. We anticipate one introductory meeting at MPCA and follow-up conference calls as necessary.

Task 1b: Introductory external stakeholder meetings

MBI will lead discussions with stakeholders that include presentations and materials to communicate the scientific and regulatory foundation for biological criteria and TALUs and identifying the potential impacts to stakeholder interests. This task also includes communicating an implementation plan that communicates how the new biological criteria and WQS may affect their current activities. Approximately 7-10 stakeholder meetings are estimated by MPCA to take place mostly in year 1 of the project. As part of this task MBI and its subcontractor will provide on demand technical assistance to MPCA with external stakeholder issues as they arise.

To facilitate discussion and enhance the understanding of the new system MBI will develop a series of presentations to include at a minimum:

- an introduction to biological standards and tiered uses;
- the regulatory background that forms the foundation for biological standards and tiered uses;
- benefits of the new system of biological standards and uses;
- history and outcome of adopting biological standards and TALU by other states; and,
- the proposed Minnesota system of standards and uses.

Task 1c: Follow-up with MPCA Program
This task will involve interacting with the key MPCA staff and managers to foster their understanding about how the new biological criteria and TALUs will affect their principal areas of interest. MBI and Tetratech will apply their experience in this area with other state programs via the EPA national program. We anticipate 1-2 of these meetings at MPCA late in year 1 or during year 2.

Task 1d: Follow-up with external stakeholders
This task will involve conducting follow-up meetings with selected external stakeholders as the project develops and to answer their questions and concerns as the implementation plan, policies, and standards are developed. We anticipate 2-3 follow-up meetings to take place in various Minnesota locations to be determined at a later date.

Task 2 – Exploratory Data Analyses and Indicator Development

MBI will provide technical support that will include exploratory data analysis and summarization and a review of technical tools and products completed by MPCA staff including:

- a review of the statewide IBI for fish and invertebrates as well as the criteria used to define impairment thresholds;
- a review of technical elements and criteria used to define TALU categories;
- assist MPCA staff with calibration of the biological condition gradient for fish and invertebrates;
- data analysis and summarization of large river IBI fish protocols used by the MDNR and MPCA;
- data analysis and summarization of the MPCA qualitative habitat data to identify habitat attributes that are indicative of modified (i.e. less than Clean Water Act interim goal) and exceptional (greater than CWA goal) uses.

Each of these subtasks are further described as follows:

Task 2a – Review statewide indices & biocriteria
This task will involve first understanding the technical basis and characteristics of the MPCA biological indices including their calibration and derivation and spatial patterns across the state. This will next include examining index thresholds including sensitivity analyses for those thresholds. These in turn become the numeric biocriteria for different TALUs and other strata such as stream and river types, cold and warm water, etc.

Task 2b – Review TALU technical elements & criteria
This will include a review of the descriptiveness of the designated use narratives and suggestions for language that better ties the technical process for deriving numerical biological criteria to the designated use narratives.

Task 2c – Calibrate BCG for fish & macroinvertebrates
Calibrating a regionally applicable BCG requires adjustment of the generalized conceptual model (Davies and Jackson, 2006; U.S. EPA, 2005) to regional conditions. This includes components that construct a coherent ecological description of response to stressors in keeping with ecological theory and empirical observation that includes:

- Describe the native aquatic assemblages under natural, undisturbed conditions. The description of natural conditions requires biological knowledge of the region, a natural classification of the assemblages, and, if available, historical descriptions of the habitats and assemblages.
- Identify regional stressors. A description of regionally dominant stressors will help define expectations for biological responses that are likely to occur. This step considers sources of physical and chemical stressors and causes of land use disturbance.
- Assign taxa and other measurements (if available) in the state database to BCG attributes.
- Quantitative description of BCG levels that are the system responses to anthropogenic stressors.

The development process is iterative, and may require several passes through the process to converge on a coherent, locally calibrated BCG that is scientifically defensible.

Task 2d – Large rivers fish IBI data analysis; MPCA/MDNR protocols
This will include examining the data characteristics and methodological properties of the MPCA and MDNR large river fish sampling methods. We can bring the experience of the Region V comparability study to this task. This will include examining key data attributes in addition to the potential impact to the MPCA large river fish IBI.

Task 2e – Analysis of MPCA habitat data; relate to TALUs
An important aspect of a TALU approach is the task of determining if an existing designated use is appropriate and attainable. Key to this process is determining the realistic biological potential of a specific water body or segment. Habitat is a fundamental issue in that it governs the determination of potential for setting appropriate and attainable uses. Therefore a relationship between the indices used to determine attainment and the habitat assessment mechanism must be established in order to develop the required predictive tools and process. MBI proposes to subject the MPCA database to analyses similar to how Ohio EPA developed these relationships.

Task 3 – Develop plan for making transition to TALU

MBI will assist MPCA with the development of a detailed implementation plan for the eventual adoption of biocriteria and TALUs in the Minnesota WQS. Ideally, the implementation TALUs will be sequenced with the annual execution of river and stream assessments and the analysis of that data and information. This will involve anticipating the potential impacts to various stakeholder groups and their activities related to water resource usage. It will also include determining the impact to MPCA obligations such as the Integrated Report and the resulting list of impaired waters under Section 303d.

MBI will develop an implementation plan in the form of a report or reports that will guide stakeholders through the transition into the new system of standards and uses. The implementation plan will include at a minimum:

- identification of processes or procedures that will be impacted by the new system including a description of the process, an explanation of how the process will be affected by the new system and a recommendation of steps necessary to integrate into the new system; and,
- a report that will include a timeline that identifies the sequencing of action items to extend through the rulemaking process.

MBI will work with stakeholders throughout the process to ensure that each recommendation is both necessary and reasonable.

Task 4 – Lead stakeholder TALU implementation meetings

MBI will use the information learned and developed in the preceding tasks to communicate to stakeholders about the implications of the new biological criteria and TALUs. This will consist of 3-5 meetings with selected stakeholder groups.

Task 5 - Exploration and determination of relationships between key biological response variables and environmental stressors

Completion of this task requires that we understand the relationship between key biological response variables and environmental stressors including chemical, physical, hydrology, and watershed land use factors. The development of stressor-response models derived through this type of analysis would support MPCA objectives related to:

- WQS under a TALU framework. (e.g., specific tiered dissolved oxygen criteria derived through analysis of the class specific IBI data)
- Ecological flow modeling (e.g., association between specific biological attributes and hydrologic data will support the development of ecologically sustainable flows).
- Stressor ID to identify the likely stressors affecting the biology at impaired sites and suggest reasonable goals to move the water body back into compliance with CWA objectives.

The analysis phase of this work will consider various analysis techniques to investigate relationships between the stressor and response variables including the percentile method (commonly used by bioassessment programs to derive goal setting criteria), quantile regression, linear regression, logistic regression, species sensitivity distribution, conditional probability analysis, and Threshold Taxa Indicator ANalysis (TITAN). A description of each of these techniques as well as examples of the application of these techniques using field data is found in Cormier, et al (2008) Using Field Data and Weight of Evidence to Develop Water Quality Criteria. Integrated Environment Assessment and Management 4(4), pp 490-504.

Possible stressor variables data sources:

Chemical	Conventional parameters including Nutrients, DO, pH, conductivity. Primary data source is STORET
Physical variables	Stream habitat variables from MPCA quantitative habitat, MSHA, and Rosgen geomorphology variables Data sources include MPCA biological database for habitat data, MPCA and MDNR for geomorphology variables.
Land use	Human disturbance variables including ditching, land use percentages, prevalence of point sources, feedlots, etc. Data source includes MPCA biological database, MDNR, NRRI, etc.
Hydrology	Exploration of flow gauging data including minimum flows and measures of flow variability and timing. Data from Minnesota DNR, MPCA and USGS.

The nature of the stressor-response relationships as well as data limitations will determine when it is reasonable to develop a stressor-response model and which analytical techniques are most appropriate/illustrative for use in developing criteria or benchmarks. Close interaction between MPCA lead biologists and MBI throughout each sub task will maximize the potential benefits associated with the final product. Final products will include reports and associated materials (e.g., statistical coding, data files) for each subtask. The reports will be formatted to allow diagnosis of the cause of an impairment through evaluation of taxa, metrics, and IBI scores for response variables that were tested. When relationships are present graphics will be provided that describes the relationship between the biological measure and the stressor variable. This task also includes an assessment of the adequacy of the existing ambient databases to support such analyses. To complete this task, 2-3 meetings that require travel by MBI personnel are planned to discuss database development and to discuss and review the analyses and products.

Task 5a: Assessment of relationships between chemical and biological data and development of tiered water quality criteria

MPCA staff with consultation from MBI will develop databases with chemical data linked to biological data. The data analysis phase will be led by MBI with consultation from MPCA. Exploratory analyses will identify relationships between biological measures (e.g., indices, metrics, and taxa) and chemical measures. Additional statistical analyses described above will be used to develop models (e.g., regressions) and thresholds between biological and chemical parameters for use in stressor identification and the development of tiered water quality criteria.

The new biological standards and TALU framework will highlight the need to develop tiered water quality criteria for selected pollutants and parameters. This subtask contract will include data analysis of selected chemical parameters, summarization of findings, and recommendations for water quality criteria changes that correspond to the TALU framework.

Task 5b: Assessment of the relationships between physical and biological data
As with sub task 5a, MPCA staff with consultation from MBI will develop databases with biological data linked to biologically relevant physical measures (e.g., stream habitat and geomorphology). The data analysis phase will be led by MBI with consultation from MPCA. Exploratory analyses will identify relationships between biological measures (e.g., indices, metrics, and taxa) and physical measures. Additional statistical analyses will be used to develop models (e.g., regressions) and thresholds between biological and physical parameters for use in stressor identification. The objectives and analytical techniques for subtask 5b are slightly different than those under task 2e.

Task 5c: Exploratory assessment of the relationships between biological data and hydrology
This subtask will be a preliminary assessment of the relationship between flow and biological condition using available flow data (e.g., minimum flows, flow variability and timing). An element of this subtask will be to identify data needs for developing more complete models of the relationship between hydrology and biological condition. Although available flow data may not be sufficient to fully develop the association between specific biological attributes and hydrologic data to support the development of ecologically sustainable flows, this subtask will provide the groundwork to develop these tools.

Tiered Aquatic Life Uses Timeline

Task	2007	2008	2009	2010	2011	2012
1. Regional Framework Analysis						
1a. Literature review						
1b. Statistical analysis and selection of classification system			X			
1c. Calculation of Human Disturbance Score			X			
2. Data Gap Analysis and Sampling						
2a. Identify data gaps	X	X	X	X		
2b. Sample sites to fill data gaps	X	X	X	X		
3. Development of Biological Condition Gradient						
3a. Development of warmwater BCG models			XXX	XXXX		
3b. Development of cold water BCG models				XXX	X	
3c. Examine IBI/BCG relationship				XXXX	XXX	
4. Statewide IBI Development						
4a. Define temperature criteria for cold water streams	X					
4b. Metric selection and calibration – warmwater streams			XX	XX		
4c. Metric selection and calibration – cold water streams				XX	X	
4d. Determine warmwater IBI confidence intervals				X		
4e. Determine cold water IBI confidence intervals					X	
4f. Develop criteria for selection of reference sites				X		
4g. Develop biocriteria for General Use warmwater streams				XX		
4h. Develop biocriteria for General Use cold water streams					XXX	
4i. Assess IBIs				XX	XXXX	
4j. Write IBI development document(s)					XX	XX
5. Tiered Aquatic Life Use Development						
5a. Identify modified use "reference sites"				XX	XX	
5b. Develop biocriteria for modified uses					XXX	
5c. Examine characteristics of exceptional use class waters				XX	XX	
5d. Develop biocriteria for exceptional uses				X	XXX	
5e. Analyze and tier priority chemical criteria					X	XX
5f. Pilot assessment of tiered uses					XX	XX
5g. Write biocriteria development document					XXX	XX
6. Designation and Assessment of TALUs						
6a. Habitat analysis (UAA)				XX	XXXX	
6b. Develop use designation guidance for TALUs (including UAAs)					XXX	
6c. Develop and write assessment guidance for TALUs					XXX	
7. Begin Administrative Rule Process						XX

General Rule Making Timeline

2012	**Establish In-house workgroup to consider and amend proposal**
2013	**Take proposal to stakeholder groups**
	Draft rule language
	Solicitation of public opinion in state register
	Define impact to state agencies
	Complete SONAR
	Promulgation of proposed standards in state register
Summer 2014	**Public hearings, hearing dates in front of ALJ**
	Post hearing comment period and response
	Receive ALJ report
	MPCA board

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Adler R. (1995) Filling the gaps in water quality standards: legal perspectives on biocriteria. In: Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, FL (eds W. S. Davis & T. P. Simon) pp. 345-358. Lewis, Boca Raton, FL.

United States
Environmental Protection
Agency

Summary of Biological Assessment Programs and Biocriteria Development for States, Tribes, Territories, and Interstate Commissions: Streams and Wadeable Rivers

EPA-822-R-02-048
December 2002

Office of Environmental Information & Office of Water
U.S. Environmental Protection Agency
Washington, DC 20460

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http://www.epa.gov/bioindicators/

Foreword

We are pleased to release the 2002 ***Summary of Biological Assessment Programs and Biocriteria Development for States, Tribes, Territories, and Interstate Commissions: Streams and Wadeable Rivers.*** This summary, a joint project by the Office of Water and the Office of Environmental Information, provides an abundance of technical and programmatic information which illustrates the progress States, Tribes, Territories and Interstate Commissions are making in the utilization of biological assessments and criteria in their water programs.

Biological assessments and criteria are crucial tools for measuring the health of water bodies and for protecting aquatic life. Biological assessments evaluate the condition of a water body using surveys and other direct measurements of aquatic life—aquatic vegetation and algae, fish, insects, crayfish, salamanders, frogs, worms, snails, mussels, etc. Biological criteria are numeric or narrative targets that can be set to define the desired biological condition of a water body and can even be adopted into State and Tribal water quality standards. In combination with other available water quality tools, such as chemical pollutant criteria, the use of biological assessments and criteria give States, Tribes and Interstate Commissions better tools than ever before for restoring and maintaining the quality of our Nation's water bodies.

The progress made by the States, Tribes and Interstate Commissions as reported in this Summary is impressive. Since our previous assessments in 1995 and 1989, significant progress has been made by virtually every State and an increasing number of Tribes and Interstate Commissions. Biological assessments and criteria are in the mainstream of water management programs throughout the Country. More States than ever before are using biological criteria in their water quality programs as definitive standards.

We encourage you to take time to review this Summary to appreciate the progress that is being made. The information in the report is valuable to assess the progress of one program relative to other programs across the country. In addition, it may be possible to learn of new and different ways to employ biological assessments and criteria by better understanding what others have done. This Summary is another example of the value of public access to information and data. EPA firmly believes that analysis of and access to such information is the key to better environmental decision making. And lastly, since every State, Tribe and Interstate Commission reported in the Summary helped assemble the information, we thank you for your help and participation.

Geoffrey Grubbs, Director
Office of Science and Technology

Elaine Stanley, Director
Office of Information Analysis and Access

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Acknowledgments

Development and production of this document, *Summary of Biological Assessment Programs and Biocriteria Development for States, Tribes, Territories, and Interstate Commissions: Streams and Wadeable Rivers*, was coordinated by USEPA's Office of Environmental Information in partnership with the Agency's Biocriteria Team, comprised of members from the Office of Water (Office of Science & Technology, Office of Wetlands, Oceans, and Watersheds) and the Office of Environmental Information. The goal of the project was to obtain the current status of biological assessment programs and biocriteria development for streams and wadeable rivers.

The project team for this document was comprised of members from the USEPA offices listed above as well as members from the Midwest Biodiversity Institute (MBI); the Technology, Planning, and Management Corporation (TPMC); and Tetra Tech, Inc. (Tt). This work was completed under USEPA Contract No. 50-CMAA-900065 to Technology Planning and Management Corporation (TPMC).

The project team extends its most sincere appreciation to all of the State, Tribal, Territorial, and Interstate Basin Commission biological monitoring staffs for their willingness to complete surveys, participate in follow-up interviews, and review numerous interim drafts. Also, we would like to recognize the numerous personnel at EPA headquarters and Regional offices for their time in developing the initial survey and reviewing various drafts. We are particularly grateful to members of EPA's Biocriteria Team, as well as the EPA Regional Biocriteria Coordinators and Regional Indian Program Coordinators, who provided guidance on document structure and the process for gathering information. We also acknowledge the efforts of Brandon Peebles, an EPA intern with the Office of Water's Office of Science and Technology. In addition, the following Tetra Tech staff were essential in the progress and completion of this document: Catherine Cresswell, Brenda Decker, and Kristen Pavlik.

Most of all, we would like to recognize the spirit of collaboration evident throughout the development of this project.

Project team:

Elizabeth Jackson	USEPA Office of Environmental Information; Environmental Analysis Division
Wayne Davis	USEPA Office of Environmental Information; Environmental Analysis Division
Treda Smith	USEPA Office of Water; Office of Science and Technology
William Swietlik	USEPA Office of Water; Office of Science and Technology
James Campbell	Technology, Planning, and Management Corporation
Michael Barbour	Tetra Tech, Inc.
Abby Markowitz	Tetra Tech, Inc.
Margo Andrews	Tetra Tech, Inc.
Maggie Craig	Tetra Tech, Inc.
Chris Yoder	Midwest Biodiversity Institute, Inc.

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1. INTRODUCTION

1.1 Bioassessment and Biocriteria in Water Resource Assessment and Management

The Historical Context

During the last half of the 20th century, the terms "environmental protection" and "natural resource management" underwent a profound evolution both conceptually and as applied to decision-making. Two landmark pieces of legislation, the 1948 Federal Water Pollution Control Act (WPCA) and its 1972 amendments contained in the Clean Water Act (CWA), stand out as milestones in this process. Until 1948, water quality management decisions were based primarily on society's economic and public health priorities (Davis 1995). The passage of the 1948 WPCA marked the first time that the *propagation of fish and other aquatic life* was articulated as a stand-alone objective of water resource protection. It was a significant turning point because federal law recognized the importance of protecting waterbodies and aquatic life for their own intrinsic value, not just for their value to human society.

The 1972 Federal Water Pollution Control Act (the Clean Water Act) set far-reaching ideals for restoring the health of our Nation's waters, as outlined in Section 101(a) Declaration of Goals and Policy:

> The objective of this Act is to restore and maintain the chemical, physical, and biological integrity of the Nation's waters. In order to achieve this objective it is hereby declared that, consistent with the provisions of this Act –
>
> 1) it is the national goal that the discharge of pollutants into the navigable waters be eliminated by 1985;
> 2) it is the national goal that wherever attainable, an interim goal of water quality which provides for the protection and propagation of fish, shellfish and wildlife and provides for the recreation in and on the water be achieved by July 1, 1983…

Why Bioassessment?

Aquatic life (fish, insects, plants, shellfish, frogs, salamanders, etc.) integrate the cumulative effects of both point source and nonpoint source (NPS) pollution's multiple stressors. Biological assessments, or bioassessments, consisting of surveys and other direct measures of aquatic life, are the most effective way to measure the aggregate impact of these stressors on waterbodies. Bioassessments are an extremely useful tool to evaluate the biological integrity of a waterbody, commonly defined as

> "the ability to support and maintain a balanced, integrated, and adaptive community with a biological diversity, composition, and functional organization comparable to those of natural aquatic ecosystems in the region" (Frey 1977, Karr and Dudley 1981, and Karr et al. 1986).

Because biological communities are affected by all of the environmental factors to which they are exposed over time, bioassessments provide information on perturbations not always revealed by water chemistry measurements or toxicity tests. Thus, they are crucial for determining not only biological health but the *overall* health, or ecological integrity, of a waterbody.

In the mid-1980s, a national workgroup of EPA regional and state agency biologists was convened to provide oversight in the development of technical guidance for biological assessment. The result of the workgroup was the 1989 publication of EPA's Rapid Bioassessment Protocols (RBPs) (USEPA 1989). The RBPs provide a technical framework for using biological assemblage data as a direct indicator of ecological health. The RBPs synthesized existing methods for monitoring fish and benthic macroinvertebrates in streams and wadeable rivers, and presented some innovative ways to assess the biological and physical aspects of streams. The RBP methods were designed to be cost effective, reliable, efficient, applicable nationwide, and easily understood by various stakeholders (USEPA 1999). In addition, the 1990 publication of *Biological Criteria: National Program Guidance for Surface Waters* provided states with an organized approach for addressing their responsibilities as outlined in the CWA (USEPA 1990). In 1992, EPA issued procedures for initiating narrative biological criteria that explained how states and tribes could adopt narrative biocriteria in their water quality standards (USEPA 1992).

Since the 1989 RBPs were published, the use of bioassessments in water resource programs has continued to grow. In 1996, EPA published a guidance document for the development of biocriteria for streams and small rivers (USEPA 1996a). In 1998, EPA produced bioassessment technical guidance for lakes and reservoirs (USEPA 1998a), followed by similar guidance for estuarine and coastal marine waters in 2000 (USEPA 2000) and a series of guidance modules for biological assessments and index development for wetlands in March 2002 (USEPA 2002). The increased use of bioassessment in water monitoring programs nationwide led to the 1999 revision of the original RBPs for streams and wadeable rivers (USEPA 1999). Guidance for large rivers and coral reefs is currently under development.

Over the last 50 years, the science of environmental protection has come a long way both in theory and in practice. As a society, the United States has come to understand that protecting aquatic life is a critical resource management goal in its own right. We have adopted ecological integrity as a barometer of waterbody health. Resource management agencies at the local, state, tribal, and national levels have recognized the importance of biological assessments in the evaluation of water quality and ecological integrity. This evolution has brought us closer to realizing the CWA's goal of restoring and maintaining the physical, chemical, and biological integrity of the Nation's waters.

Current Legal Authority

The CWA and its amendments through 1987 provide the legal authority for the use of biological assessments and criteria in state and tribal water quality programs primarily under the provisions of sections 303 and 304. Under Section 303(c), states are required to have water quality standards that consist of designated uses, criteria to protect those uses, and an antidegradation policy. Also under section 303(c), states are required to review their standards every three years and revise them as needed to achieve the purposes of the Act, including the ecological integrity objective.

Section 303(c)(2)(B), enacted in 1987, requires states to adopt numeric criteria for toxic pollutants for which EPA has published 304(a)(1) criteria if such pollutants interfere with, or may be expected to interfere with, attainment of designated uses. The section further requires that, where numeric 304(a) criteria are not available, states adopt criteria based on biological assessment and monitoring methods consistent with information published by EPA under 304(a)(8).

Section 304(a)(8) directs EPA to develop and publish information on methods for establishing and measuring water quality criteria for toxic pollutants on bases other than pollutant-by-pollutant. This includes biological monitoring and assessment methods that evaluate:

> the effects of pollutants on aquatic community components ("...plankton, fish, shellfish, wildlife, plant life...") and community attributes ("...biological community diversity, productivity, and stability...");
>
> factors necessary "...to restore and maintain the chemical, physical, and biological integrity of all navigable waters..." for "...the protection of fish, shellfish, and wildlife for classes and categories of receiving waters..."
>
> appropriate "...methods for establishing and measuring water quality criteria for toxic pollutants on other bases than pollutant-by-pollutant criteria, including biological monitoring and assessment methods."

The Uses of Bioassessment and Biocriteria in the Clean Water Act

Biocriteria, derived from bioassessment data, are narrative descriptions and numeric values that describe the desired condition for the aquatic life inhabiting waters with a designated aquatic life use. Biocriteria are an effective tool for addressing water quality problems by providing regulatory mechanisms to assess and help protect the biological resources at risk from chemical, physical, or biological impacts. These narrative and/or numeric biocriteria may be formally adopted into water quality standards along with an antidegradation policy intended to protect waters from further deterioration.

As required in the Clean Water Act, states, tribes, and territories report on the quality of their waters through a biennial report referred to as the "305(b) report". USEPA compiles and analyzes this information in the *National Water Quality Inventory Report to Congress*, the primary vehicle for reporting water quality conditions throughout the United States. To assess water quality, states and other jurisdictions compare their monitoring results to the water quality standards they have set for their waters.

Bioassessments help states, tribes, and other entities develop expectations for acceptable biological conditions through a technical process of establishing aquatic life goals, referred to as *aquatic life uses* (ALUs). Designated uses to support aquatic life can cover a broad range of biological conditions; not only do they protect intact communities in a waterbody, but they also can establish restoration goals for compromised ecosystems. Using several types, or tiers, of ALUs allows the allocation of limited resources to waterbodies in proportion to their need for protection.

Although the 305(b) report includes information on the nationwide status of aquatic life use attainment (i.e., state water quality standards), the results reported do not consistently present the information necessary to determine the ecological/biological condition of the Nation's water resources. As currently reported in 305(b) water quality assessments, aquatic life use attainment may be determined solely by chemical parameters and in comparison to chemical water quality criteria. However, since attainment of chemical water quality standards alone may not ensure a healthy biological condition, most states are working to integrate a greater amount of biological information in their aquatic life use attainment determinations (Yoder and Rankin 1995).

Under Section 303(d) of the CWA, a second reporting mechanism requires states, tribes, and territories to provide lists of all impaired waters. These lists are then used to prioritize restoration activities through the development of Total Maximum Daily Loads (TMDLs). TMDLs are calculations of the amount of a pollutant that a waterbody can receive and still meet water quality standards. Bioassessments and biocriteria play a critical role in enabling states, tribes, and territories to develop and implement protection and management strategies needed to fulfill these, and other, requirements of the Clean Water Act, including:

- determining impacts from nonpoint sources [i.e., Section 304(f) "(1) guidelines for identifying and evaluating the nature and extent of nonpoint sources of pollutants, and (2) processes, procedures, and methods to control pollution..."];
- developing lists of waters unable to support "balanced population(s) of shellfish, fish and wildlife..." [(304(l)];
- conducting assessments of lake trophic status and trends, [Sec. 314];
- listings of waters that cannot attain designated uses without nonpoint source controls, [Sec. 319];
- developing management plans and conducting monitoring in estuaries of national significance [Sec. 320];
- determining the impacts and efficacy of NPDES permit controls [Section 402];
- issuing permits for ocean discharges and monitoring ecological effects [Sec. 403(c) and 301(h)(3)]; and,
- determining acceptable sites for disposal of dredge and fill material [Sec. 404].

The 2001 Bioassessment Summary

During 1994-1995, EPA prepared an inventory of state bioassessment programs for streams and wadeable rivers, *Summary of State Biological Assessment Programs for Streams and Rivers* (USEPA

1996b). The purpose of the document was to determine how many states, and in what fashion, were using biological assessments and criteria in water management programs. EPA used the information from that report to evaluate state bioassessment/biocriteria capabilities and their needs for technical support.

During the second half of the 1990s as additional methods, guidance, and information on the use of biological assessments and criteria were issued by EPA, the Office of Water made it a national priority for state and tribal water quality standards programs to adopt biocriteria to better protect aquatic life in all waters where biological assessments methods were available (USEPA 1998b). In 1999, EPA's Office of Water declared the following goals and objectives for the biocriteria program:

- All states/tribes will use bioassessments/biocriteria to evaluate the health of aquatic life in all waterbodies.
- Bioassessment data will be used by all states/tribes to better define aquatic life uses.
- Numeric biocriteria will be adopted in all state/tribal water quality standards to protect aquatic life uses.
- Biocriteria/bioassessments will be used in ongoing regulatory programs.
- Biocriteria/bioassessments will be used to assess the effectiveness of water quality management efforts.
- Bioassessment data and biocriteria will be used to better communicate the health of the Nation's waters.

In the late 1990s, momentum to develop and adopt biocriteria grew, and pressures increased from the Total Maximum Daily Load (TMDL) Program to have well-established biocriteria in water quality standards to support listings of impaired waterbodies. The Office of Water and the Office of Environmental Information determined it would be valuable to re-assess the progress states were making in developing and adopting biological assessments and criteria into their water quality management programs. In 2001, Geoffrey Grubbs, Director of the Office of Water, Office of Science and Technology, stated that the key goal of the biocriteria program should be to accelerate the adoption of biocriteria in state and tribal water quality standards programs to better support regulatory programs. Therefore, in late 2001, the Office of Environmental Information and the Office of Water initiated this effort to update the 1994-95 survey information. This project was also supported by the Office of Wetlands, Oceans, and Watersheds and was coordinated through USEPA Regional Offices.

The goal of the 2001 update was to compile a comprehensive re-assessment of state use of bioassessments and biocriteria for protecting streams and wadeable rivers. The update also illustrates changes and improvements in bioassessment capabilities over the past six years, and serves as an important measure of program advancement and EPA's bioassessment technical transfer efforts. This documentation will enable USEPA to better focus its water quality standards and criteria development and implementation strategy for the next several years, target new program priorities, and assess the present technical support needs of states, tribes, territories, and interstate commissions. EPA will also use this documentation to prepare a summary report card of national progress in adopting biocriteria into water quality standards.

As you will see from this report, the use of biological assessment and criteria for managing the Nation's waterbodies has progressed significantly in the past six years and is equipping states, tribes, territories, interstate commissions, and EPA with a more effective set of monitoring and standards tools for determining and protecting the health of the Nation's waters.

1.2 Introduction to the Process

This project was coordinated by EPA's Office of Environmental Information in partnership with the Agency's Biocriteria Team, composed of members from the Office of Water (Office of Science & Technology, Office of Wetlands, Oceans, and Watersheds) and the Office of Environmental Information. The goal of the project was to obtain the current status of biological assessment programs and biocriteria development for streams and wadeable rivers. The project team also coordinated with EPA Regional Biocriteria Coordinators and Regional Indian Program Coordinators. Because identical information would be solicited from all 50 states, the District of Columbia, US territories, selected tribes, and selected interstate commissions, this project was covered under the Water Quality Standards Program Information Collection Request (ICR No. 0988.07) in compliance with the 1995 Paperwork Reduction Act.

In June 2001, the project team developed a “checklist” of 57 questions covering six different categories (Appendix C contains a blank copy of the checklist):

- contact information (including points of contact for biological programs for other waterbody types – nonwadeable rivers, lakes, reservoirs, estuaries/near coastal marine, and wetlands)
- programmatic elements
- ALU decision making process
- field and lab methods
- data analysis and interpretation
- information management

Throughout the autumn of 2001, email “packets” were distributed to over 75 points of contact in states, tribes, territories, and interstate commissions (provided by EPA Regional offices). These packets consisted of an introductory memo, the checklist, and relevant excerpts from each entity’s water quality standards (where applicable). Recipients were asked to complete the checklist and review the standards excerpts for completeness and accuracy. As completed checklists were returned, members of the project team followed-up by phone and email with each entity to clarify, verify, and document information and to fill in gaps where necessary. Contacts from a total of 65 entities responded and provided the information included in this document.

As was done for the 1996 document, the project team created a template “program summary” used to translate and display the information gathered from each entity. The summary pages for each responding entity consist of a narrative program description, documentation and further information, as well as a three page fact sheet. Program summaries for all 65 entities are found in Chapter 3 (there are only 64 actual program summaries because Puerto Rico and the U.S. Virgin Islands are combined into one).   The information in the program summaries was organized into several sections as shown below (Appendix D contains a blank program summary coded with the corresponding sections of the original checklist):

Contact Information

Program Description

Documentation and Further Information

Programmatic elements
- Uses of bioassessment within overall water quality program
- Applicable monitoring designs

Stream Miles
- Total miles
- Total perennial miles
- Total miles assessed for biology
  - fully supporting for 305(b)
  - partially/non-supporting for 305(b)
  - listed for 303(d)
  - number of sites sampled
  - number of miles assessed per site

Aquatic Life Use (ALU) Designations and Decision Making

- ALU designation basis
- ALU designations in water quality standards
- Narrative Biocriteria in WQS
- Numeric Biocriteria in WQS
- Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)
- Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU

Reference Site/Condition Development

- Number of reference sites
- Reference site determinations
- Reference site criteria
- Characterization of reference sites within a regional context
- Stream stratification within regional reference conditions
- Additional information

Field and Lab Methods

- Assemblages assessed (no. of samples/year, level of rigor)
- Benthos (sampling gear, habitat selection, subsample size, taxonomy)
- Fish (sampling gear, habitat selection, sample processing, subsample, taxonomy)
- Periphyton (sampling gear, habitat selection, sample processing, taxonomy)
- Habitat assessments
- Quality assurance program elements

Data Analysis and Interpretation

- Data analysis tools and methods
- Multimetric thresholds
  - transforming metrics into unitless scores
  - defining impairment in a multimetric index
- Multivariate thresholds
  - defining impairment in a multivariate index
- Evaluation of performance characteristics
- Biological data
  - Storage
  - Retrieval and analysis

In addition, selected relevant excerpts from state, tribal, territorial and interstate commission water quality standards excerpts were compiled into a separate chapter for inclusion in the document (see Chapter 4: Relevant Excerpts from Water Quality Standards and Biocriteria Language).

In April 2002, a preliminary draft of the document containing the Definition of Terms and Acronyms, Program Summaries, Water Quality Standards and Biocriteria Language, Literature Cited, and List of Contacts was distributed to the full Biocriteria Team for an editorial and technical review. Individual program summaries and water quality excerpts were distributed to the relevant EPA Regional contacts and the point of contact for each responding entity for review and comment. During the summer of 2002, the project team compiled, organized, and incorporated the feedback received from all reviewers.

This document, *Summary of Biological Assessment Programs and Biocriteria Development for States, Tribes, Territories, and Interstate Commissions*: *Streams and Wadeable Rivers*, represents this project's final product. The document's value lies not only in the wealth of information it contains but also in the lessons learned from the process. In the near future, EPA hopes to initiate similar projects to assess the status of bioassessment and biocriteria programs for lakes, reservoirs, estuaries, and wetlands. The effectiveness and efficiency of those efforts will be enhanced by the development of this reference document.

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2. SUMMARY OF FINDINGS

2.1 Summary of Current Biological Assessment Programs and Biocriteria Development

This report summarizes the national breadth of biological monitoring and assessment in stream and wadeable river management programs based on 2001 program information (Table 1). Since this summary pertains to more than just "states," the term "entity" is used to refer to the combination of states, tribes, territories, and interstate commissions. Survey responses were received from 65 entities (50 states, District of Columbia, four territories, six tribes, and four interstate commissions – see Appendix A for a complete list).

Although ranging across a wide spectrum – from initial pilot studies to comprehensive assessment – 57 of the 65 entities have bioassessment programs for streams and wadeable rivers, and two (Puerto Rico and the Nez Perce Tribe) have programs under development. Nearly 440,000 river and stream miles nationwide are assessed using biological data (see Figure 1a for state-by-state percentages). More importantly, as shown in Table 1, 40 entities use bioassessment to help determine aquatic life use support (ALUS) for their 305(b) reporting (Figure 1b), and six states (AK, CA, HI, MT, NV, OK) are developing processes for using biological data to interpret ALU. Thirteen entities, including seven states (AZ, AR, CO, DE, LA, SD, UT) either don't have *comprehensive* statewide bioassessment programs in place, or they don't yet use bioassessment data to determine the condition of their waters.

A total of 29 entities have incorporated narrative biocriteria into their WQS (Figure 2a). The 11 entities (AZ, CO, HI, IL, IN, IA, MD, MT, NV, WA, Pyramid Lake Paiute Tribe) in a developmental phase of adopting narrative biocriteria into their WQS are at various stages in this process. While some may have already developed biocriteria and are working on promulgating the statements into their WQS, others are awaiting state or federal approval, or are in the earlier stages of developing narrative biocriteria to be submitted for review. Although 20 entities do not have narrative biocriteria in their WQS, several of these have incorporated general aquatic life statements. The following five entities – ICPRB, SRBC, Nez Perce Tribe, Oneida Nation of Wisconsin and Passamaquoddy Tribe - Pleasant Point Reservation – do not have federally approved WQS and are not currently working toward that end. Therefore, these entities are not included in any biocriteria counts.[1]

Of the 29 entities with narrative biocriteria incorporated into their WQS, 22 have also developed quantitative implementation procedures or translators, and eight are working to develop them (Figure 2b). These procedures can be found in various documents including WQS, SOPs, 305(b) guidelines, and other agency documents. While numeric procedures are not numeric *biocriteria* per se, they do provide a quantitative basis for assessing attainment of specific designated aquatic life uses and are an important step in biocriteria development.

[1] While the Oneida Nation does not have federally approved water quality standards, the Tribe is currently using bioassessments to implement their water quality program under tribal law. Inclusion of narrative and numeric biocriteria into the Tribe's WQS is under development.

Table 1. National summary of bioassessment programs for streams and wadeable rivers in 2001

PROGRAMMATIC ELEMENT	NUMBER OF ENTITIES			
	In-place	Under development	None	Not applicable
Use of Bioassessments				
Water resource management	57	2	6	0
Interpret aquatic life use attainment	40	6	13	6[2]
Narrative biocriteria in WQS	29	11	20	5[3]
Narrative biocriteria in WQS with quantitative implementation procedures or translators	22	8	30	5[4]
Numeric biocriteria in WQS	4	11	45	5[4]
Assemblage Used				
Fish	41	0	16	8[4]
Benthic macroinvertebrates	56	1	0	8[5]
Algae (periphyton, diatoms)	20	5	32	8[5]
More than one assemblage	45	5	7	8[5]
Reference Conditions				
Ecoregional	42	2	12	9[5]
Site-specific	19	1	37	8[6]
State-wide or basin-specific	7	1	46	11[6]
Analysis				
Biological metrics	54	1	1	9[7]
Multivariate	22	2	32	9[8]
Assessment				
Multimetric index	41	3	12	9[8]
Habitat assessment	57	0	0	8[3]

[2] DRBC and ICPRB are not regulatory authorities. Nez Perce Tribe, Oneida Nation of Wisconsin, Passamaquoddy Tribe - Pleasant Point Reservation, and Pyramid Lake Paiute Tribe do not have federally approved WQS.

[3] ICPRB, SRBC, Nez Perce Tribe, Oneida Nation of Wisconsin and Passamaquoddy Tribe - Pleasant Point Reservation do not have federally approved WQS and are not currently working toward that end.

[4] The following entities do not use biological assessment methods as a means to assess stream and river water quality: American Samoa (AS), Puerto Rico (PR), U.S. Virgin Islands (USVI), Confederated Tribes of the Colville Reservation, Nez Perce Tribe, Passamaquoddy Tribe - Pleasant Point Reservation, and Seminole Tribe of Florida. The Commonwealth of Northern Mariana Islands (CNMI) has a bioassessment program for marine systems only; bioassessment for freshwater is not applicable.

[5] Virginia did not provide complete reference condition information. American Samoa, CNMI, Puerto Rico, U.S. Virgin Islands, Confederated Tribes of the Colville Reservation, Nez Perce Tribe, Passamaquoddy Tribe - Pleasant Point Reservation, and Seminole Tribe of Florida do not have bioassessment programs.

[6] AS, CNMI, PR, USVI, Confederated Tribes of the Colville Reservation, Nez Perce Tribe, Passamaquoddy Tribe - Pleasant Point Reservation, and Seminole Tribe of Florida do not have bioassessment programs.

[7] Pyramid Lake Paiute Tribe has not yet analyzed or evaluated their biological data. AS, CNMI, PR, USVI, Confederated Tribes of the Colville Reservation, Nez Perce Tribe, Passamaquoddy Tribe - Pleasant Point Reservation, and Seminole Tribe of Florida do not have bioassessment programs.

Four entities (FL, OH, OK, DRBC) have numeric biocriteria incorporated into their WQS (Figure 2c).[8] And of the 11 entities for which numeric biocriteria is categorized as "under development," Maine and Wyoming have developed and incorporated numeric biocriteria into other program documents, such as SOPs and monitoring guidance manuals, and have been using the numeric limits to maintain designated uses.

The three major groups of biological organisms or assemblages monitored as part of comprehensive biological assessment programs are fish, benthic macroinvertebrates, and algae (periphyton). Macroinvertebrates are the most common indicator assemblage used by state water quality agencies and are a part of all but Hawai`i's bioassessment program, where it is currently under development (Figure 3a). The second most common assemblage monitored is fish, followed by periphyton (Figures 3b and 3c). Forty-five entities monitor for at least two assemblages, and another five (AK, HI, NV, UT, WY) currently use one, but are developing the capability of using a second (Figure 3d).

One of the key elements in bioassessment programs is the establishment of reference conditions to help discern human impacts from natural variation. The two types of reference conditions currently used in biological surveys are regional and site-specific. The Ecoregion Concept, a common regionalization approach, recognizes geographic patterns of similarity among ecosystems and the subsequent distribution of biological communities grouped on the basis of environmental variables such as climate, soil type, physiography, and vegetation. Forty-two entities have adopted this method of stream stratification/ characterization in developing reference conditions (Figure 4). Site-specific reference conditions typically consist of condition measurements taken upstream of a point source discharge or from a "paired" watershed. However, their usefulness is limited since they have only site-specific value (USEPA 1999). Only nine entities primarily use this approach to determine reference conditions.

Biological metrics and multivariate analysis are two types of data analysis tools/methods used to reduce a wealth of raw data into workable indicators of biological condition. Nearly all of the entities with bioassessment programs have developed biological metrics. In addition, just under half use multivariate analysis (techniques that look at the pattern of relationships among several variables simultaneously, such as principal components analysis (PCA) and non-metric multidimensional scaling (NMS)). Of the 54 entities that select and calculate biological metrics, 41 aggregate these metrics into a multimetric index (such as fish or macroinvertebrate IBIs) to assess biological condition and water quality, and to discriminate between impaired and unimpaired conditions (Figure 5). Finally, all entities with bioassessment programs also assess the physical habitat quality at their sample sites, usually employing visual based methods (such as QHEI and RBPs) in combination with other measurements.

2.2 Bioassessment Program Success from 1989 to 2001

In 1989, when developing the *Rapid Bioassessment Protocols for Use in Streams and Rivers*, USEPA summarized the bioassessment and biomonitoring capabilities in state regulatory programs (USEPA 1989). While the 1989 summary did not determine the actual use of the bioassessment data for all states, it did provide an estimate based upon past knowledge of state programs and on the documentation gathered during its development.

The *Summary of State Biological Assessment Programs for Streams and Rivers,* based on 1995 data, compiled a more comprehensive assessment of state uses of bioassessments and biocriteria in water management programs (USEPA 1996). The document serves as the baseline for determining changes and improvements in bioassessment capabilities over the past six years. Table 2 presents a summary of the 1989 and 1995 results alongside the 2001 data from Table 1. The incremental change (from 1989 to

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[8] Florida has made substantial progress in developing new multimetric indices for streams (Stream Condition Index and BioRecon), lakes (Lake Condition Index), and wetlands for eventual inclusion in the Florida Administrative Code. When the new indices are adopted as water quality standards, the role of Shannon-Weaver diversity as a numeric standard will be re-evaluated.

Macroinvertebrate biocriteria were developed for DRBC's Special Protection Waters rules issued in 1990, but the criteria were later found to be based upon inconsistent and non-representative methods and have not been used as envisioned during development of the Commission's antidegradation policies. Program redesign recommendations were recently made to improve effectiveness and applicability of the criteria.

1995, and 1995 to 2001) appears in parentheses, and an additional column indicates the net change from 1989 to 2001. For the purposes of comparison, Table 2 only contains program information from the original 52 entities surveyed in 1989 and 1996 (50 states, the District of Columbia, and ORSANCO). Refer to Table 1, Chapter 3, and Appendix A for programmatic information on the additional entities surveyed for this document.

There has been extensive progress in the development and use of biological assessments and criteria as revealed by virtually all measures of the survey as shown in Table 2. All 52 entities contained in this table have incorporated bioassessment in their water resource management programs. This is up over 30% from a count of 37 in 1989. Although the number of states that used bioassessments to determine aquatic life use attainment in 1989 is unknown, these numbers did increase noticeably from 1995 to 2001. And despite the fact that the number of entities with numeric biocriteria in their WQS has only increased by two over the past 12 years, 18 entities have developed and implemented quantitative procedures or translators for use in their water quality management programs (Figure 2b), and sixteen are in the process of developing narrative and/or numeric biocriteria for their standards.

Since 1989, the number of entities sampling at least one of the three major assemblages has steadily grown. Almost every entity surveyed in 1995 now conducts benthic macroinvertebrate assessments (Figure 3a). Even periphyton sampling, which declined from 1989 to 1995, rose sharply from 1995 to 2001. Studies have found that assessing only one assemblage can only achieve roughly 80 to 85% effectiveness at identifying aquatic life use attainment or nonattainment. Thus, since 1995, USEPA has recommended the use of multiple assemblages, especially in larger streams (USEPA 1996). The number of entities using more than one assemblage in 2001 reached 41 (an increase of 15 in just five years); and 20 of these 41 entities sample for at least three, and even four, assemblages, such as phytoplankton, macrophytes and zooplankton (Figure 3d).

One of the major advancements since 1989, and especially since 1995, has been the increased use of regional reference conditions as a basis for making comparisons and detecting use impairment. Only four states were actively using ecoregional reference conditions in 1989, and still only 15 in 1995. However, by 2001, 39 entities characterized reference conditions using a composite or aggregation of least or minimally impaired sites within distinct ecoregions (Figure 4). And conversely, 11 fewer entities used a site-specific approach alone to determine reference conditions.

The number of entities using biological metrics for data analysis increased by eight in 2001, in step with a sharp increase of 39 between 1989 and 1995. Today, all but two of the surveyed entities contained in Table 2 have developed biological metrics.

Finally, for the 2001 survey, we narrowed the definition of what constitutes narrative biocriteria in WQS to exclude general aquatic life statements. We adhered to the definition of narrative biocriteria as "narrative expressions that describe biological integrity of aquatic communities inhabiting waters of a given classification or designated aquatic life use." We also required entities to clarify how the criteria were operationally defined in their WQS. This examination yielded a count of 28 entities with narrative biocriteria in their WQS, one entity less than was reported in 1995. However, had we used the 1995 definition of narrative biocriteria, these 28 entities would grow to 40, resulting in an increase of 11 between 1995 and 2001.

Refer to Appendix A for a summary of pertinent information for each entity surveyed. This information is captured in greater detail and clarity in the individual program summaries found in Chapter 3.

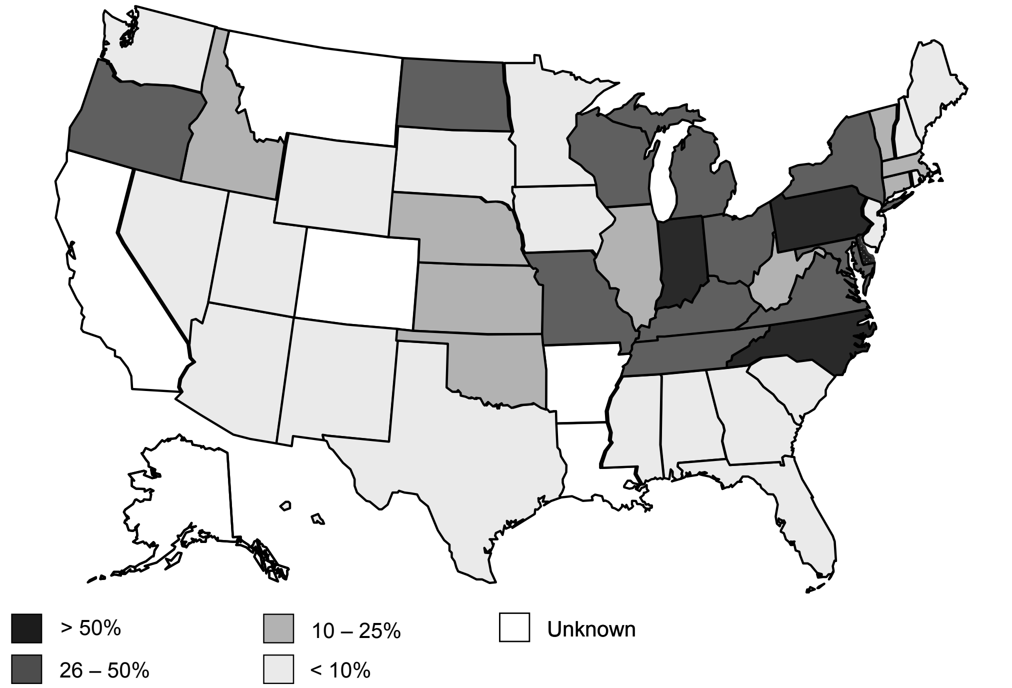
Table 2. National summary of bioassessment programs for streams and wadeable rivers in 1989, 1995, 2001 and the interim change [9]

PROGRAMMATIC ELEMENT	NUMBER OF ENTITIES (see note below)											
	In-place				Under Development				None			
	1989	1995	2001	net change	1989	1995	2001	net change	1989	1995	2001	net change
Use of Bioassessments												
Water resource management	37	41 (+4)	52 (+11)	+11	7	8 (+1)	0(-8)	-3	8	3 (-5)	0(-3)	-8
Interpret aquatic life use attainment	unk	31	39 (+8)	+8	unk	8	6 (-2)	-2	unk	13	7 (-6)	-6
Narrative water quality standard	unk	29	28 (-1)	-1	unk	11	10 (-1)	-1	unk	12	14 (+2)	+2
Numeric water quality standard	1	2 (+1)	3 (+1)	+2	unk	15	10 (-5)	-7	49	35 (-14)	39 (+4)	-8
Organism Group Used												
Fish	23	29 (+6)	37 (+8)	+15	1	5 (+4)	0 (-5)	-1	28	18 (-10)	15 (-3)	-13
Benthic macroinvertebrates	39	44 (+5)	51 (+7)	+12	3	5 (+2)	1 (-4)	-2	10	3 (-7)	0 (-3)	-10
Algae (periphyton, diatoms)	7	4 (-3)	19 (+15)	+12	0	3 (+3)	5 (+2)	+5	45	45 (+0)	28 (-17)	-16
More than one assemblage	24	26 (+2)	41 (+15)	+17	4	10 (+6)	5 (-5)	+1	26	16 (-10)	6 (-10)	-20
Reference Conditions												
Ecoregional	4	15 (+11)	39 (+24)	+35	2	26 (+24)	2 (-24)	0	44	11 (-33)	11[10] (0)	-33
Site-specific	unk	31	19 (-12)	-12	unk	0	1 (+1)	+1	unk	21	32[10] (+11)	+11
State-wide or basin-specific	unk	6	6 (0)	0	unk	0	0	0	unk	46	46[10] (0)	0
Multiple Metrics for Data Analysis												
Biology	3	42 (+39)	50 (+8)	+47	11	6 (-5)	1 (-5)	-10	35	4 (-31)	1 (-3)	-34

NOTE: The same 52 entities were used for each of the years for the most accurate comparison of changes over time.

[9] The incremental change (from 1989 to 1995, and 1995 to 2001) appears in parentheses, and the "net change" column indicates the total change from 1989 to 2001, or 1995 to 2001 where 1989 data is unknown.

[10] The *Ecoregional* and *State-wide or basin-specific* elements are not applicable to New York and Virginia's programs (Virginia did not complete this section). The *Site-specific* element is not applicable to Utah's program. For the purposes of comparison, each has been counted as *None* in this table.



*The use of various monitoring designs, i.e. targeted vs. probabilistic, influences the derivation of these numbers.

Figure 1a. Percent of total stream/river miles assessed in each state using bioassessments

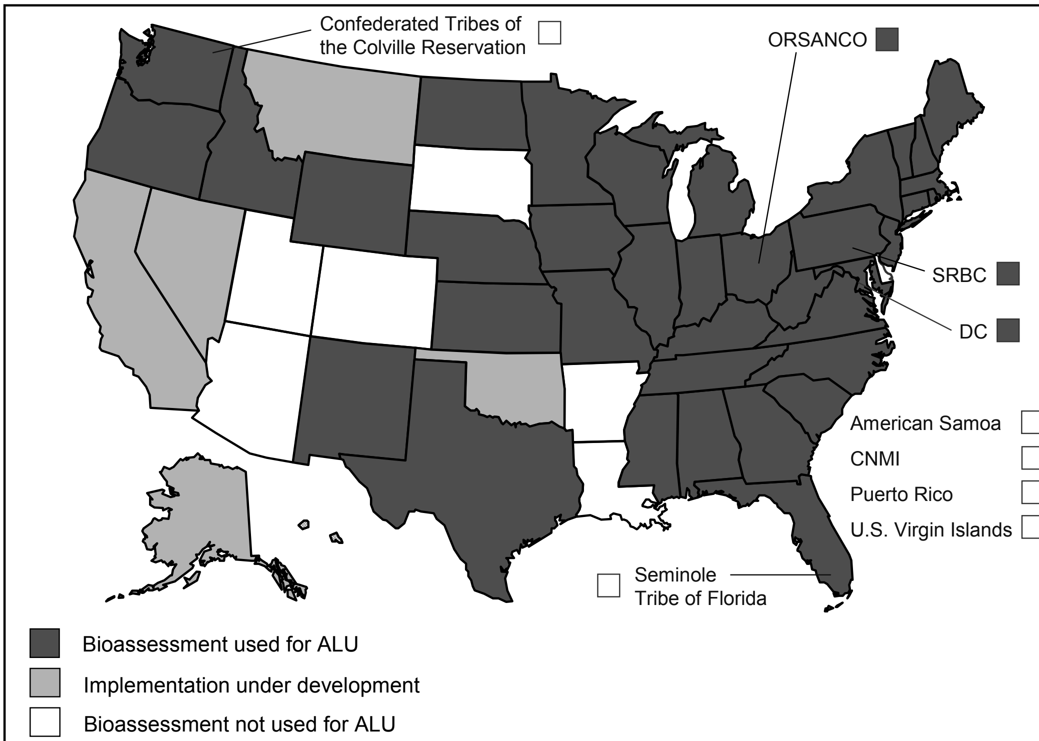


Figure 1b. Use of bioassessment to determine aquatic life use (ALU) for 305(b) reporting

Figure 1. Use of bioassessments to assess water quality

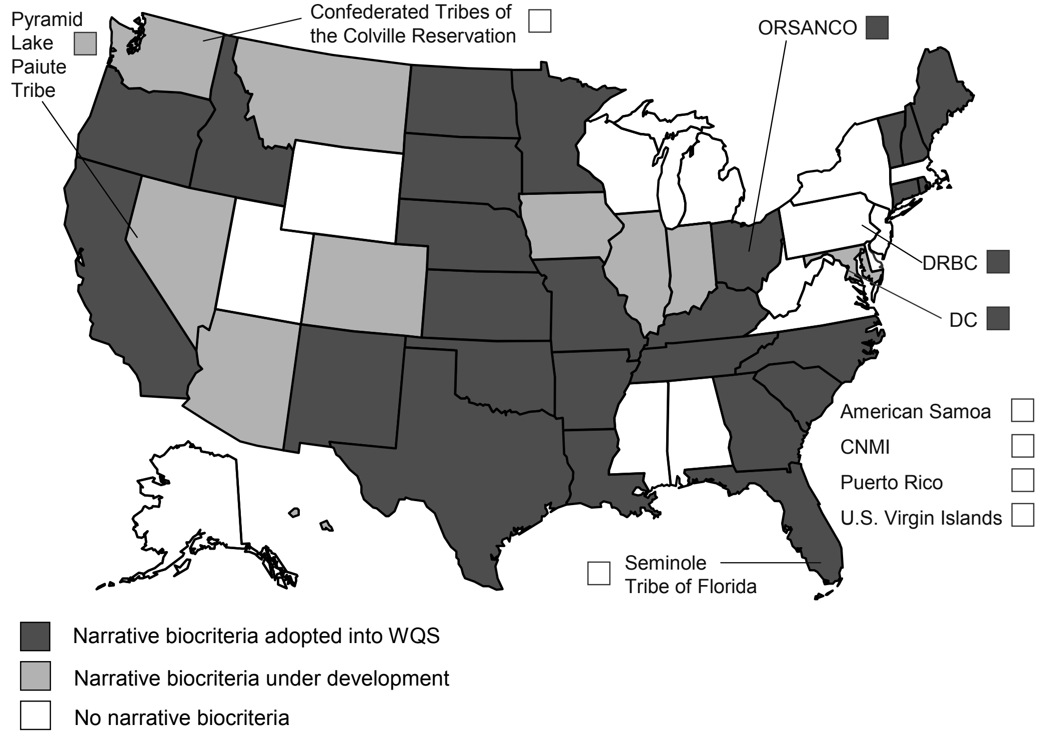


Figure 2a. Narrative biocriteria development

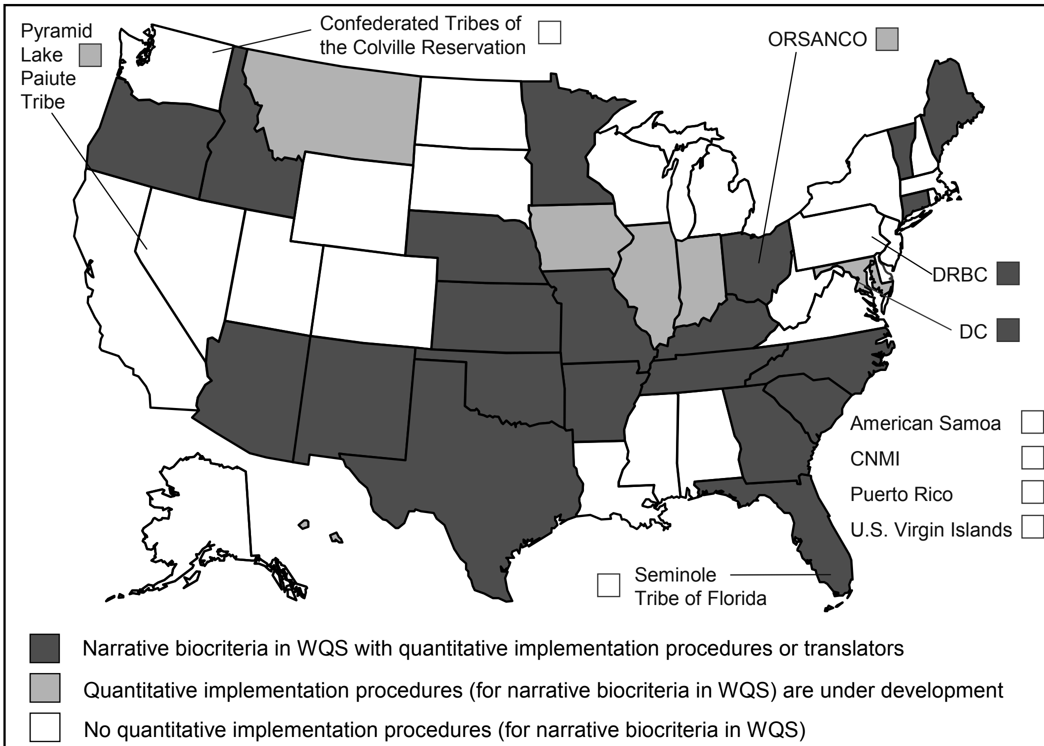


Figure 2b. Narrative biocriteria in WQS with quantitative implementation procedures

Figure 2. Biocriteria development

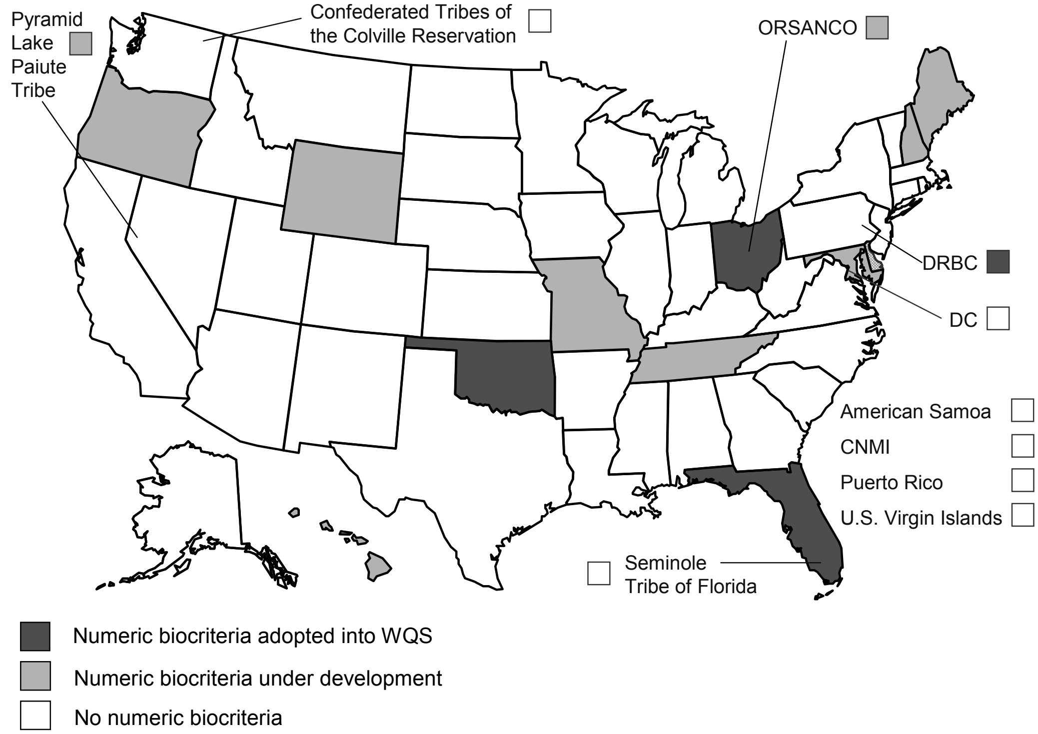


Figure 2c. Numeric biocriteria development

Figure 2 (cont). Biocriteria development

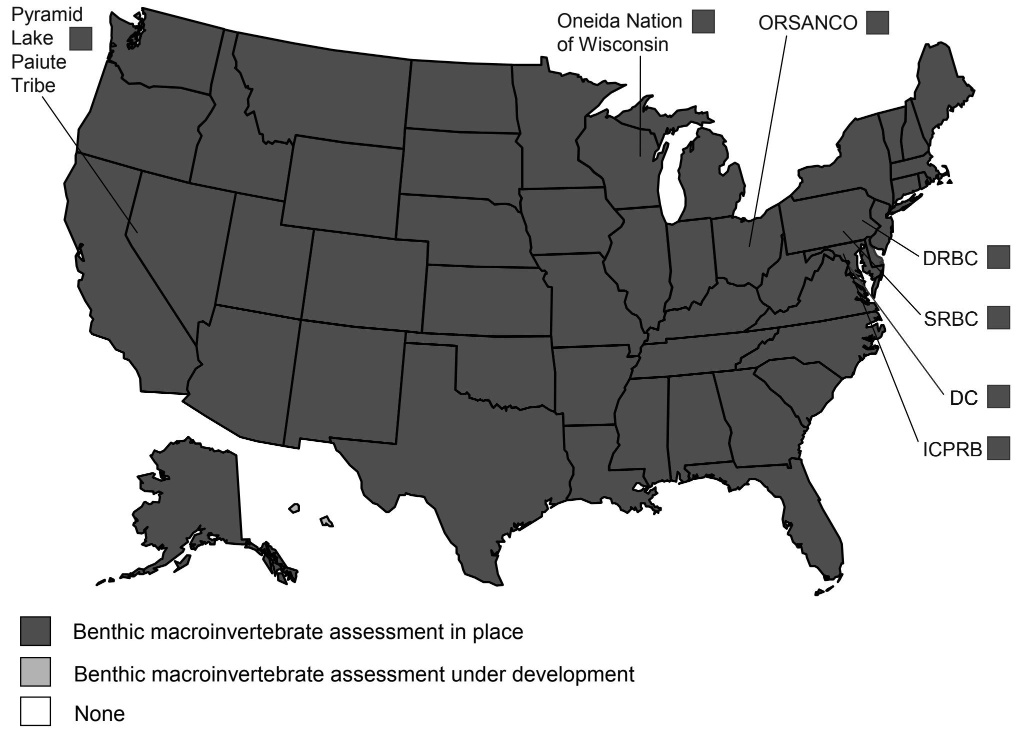


Figure 3a. Benthic macroinvertebrates

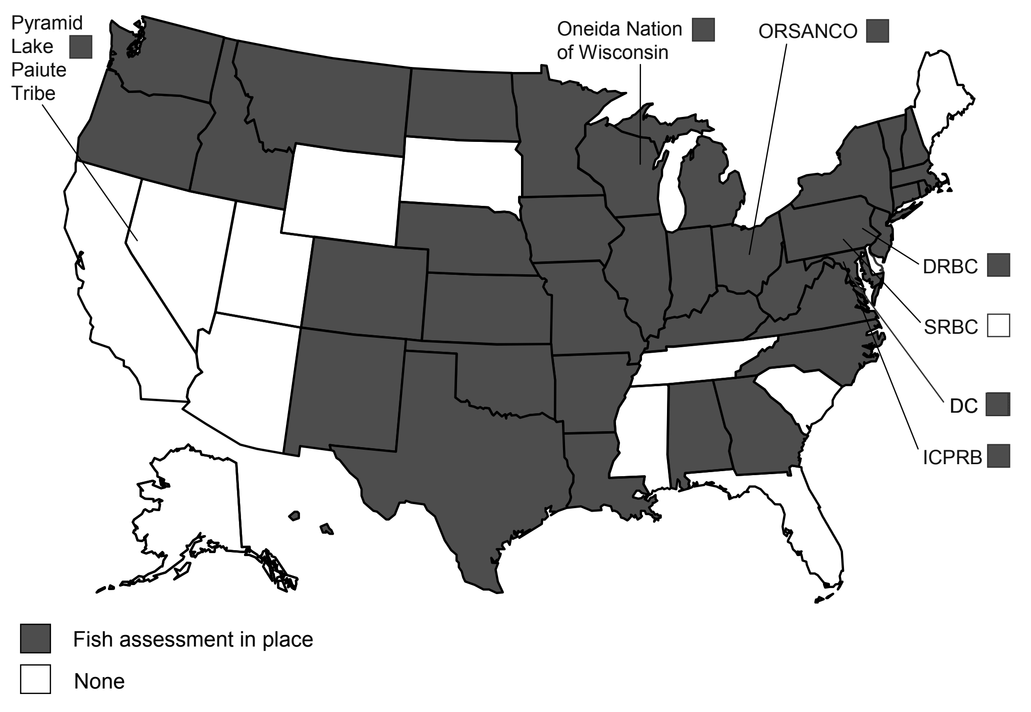


Figure 3b. Fish

Figure 3. Assemblages assessed

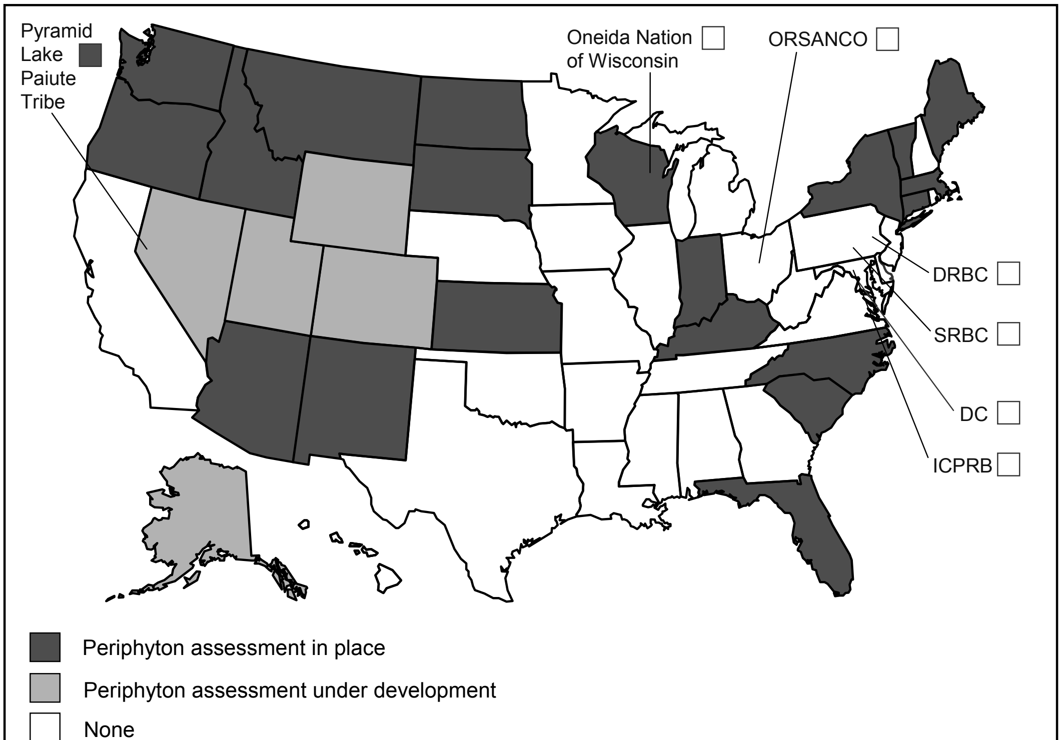


Figure 3c. Periphyton

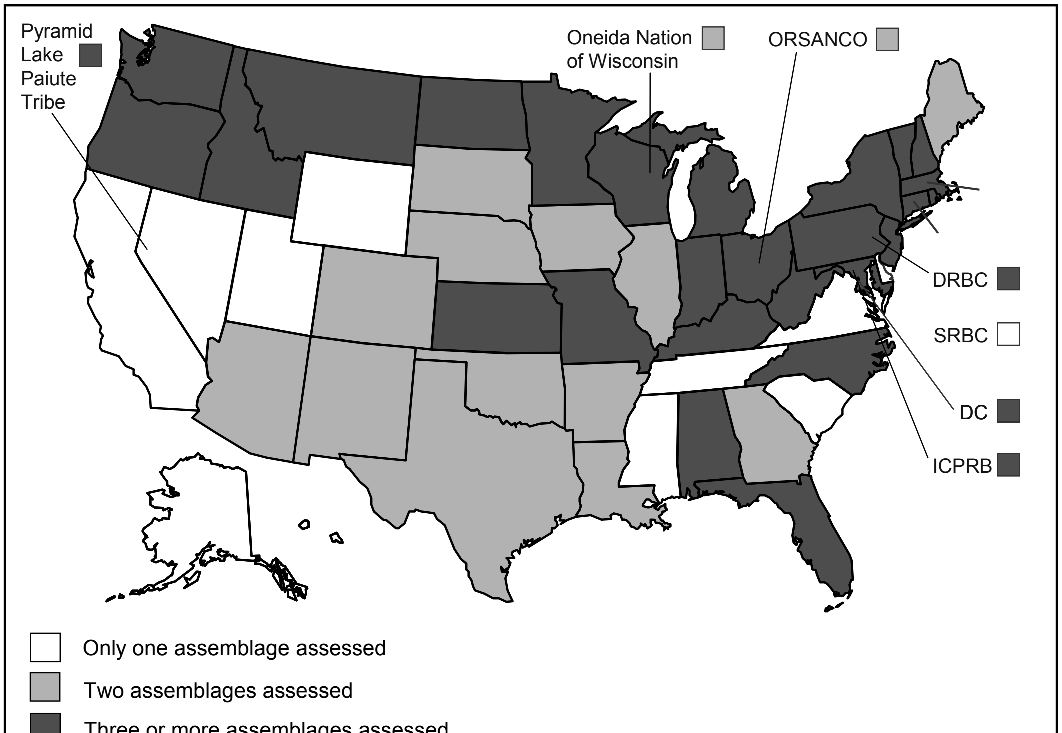


Figure 3d. Number of assemblages assessed

Figure 3 (cont). Assemblages assessed

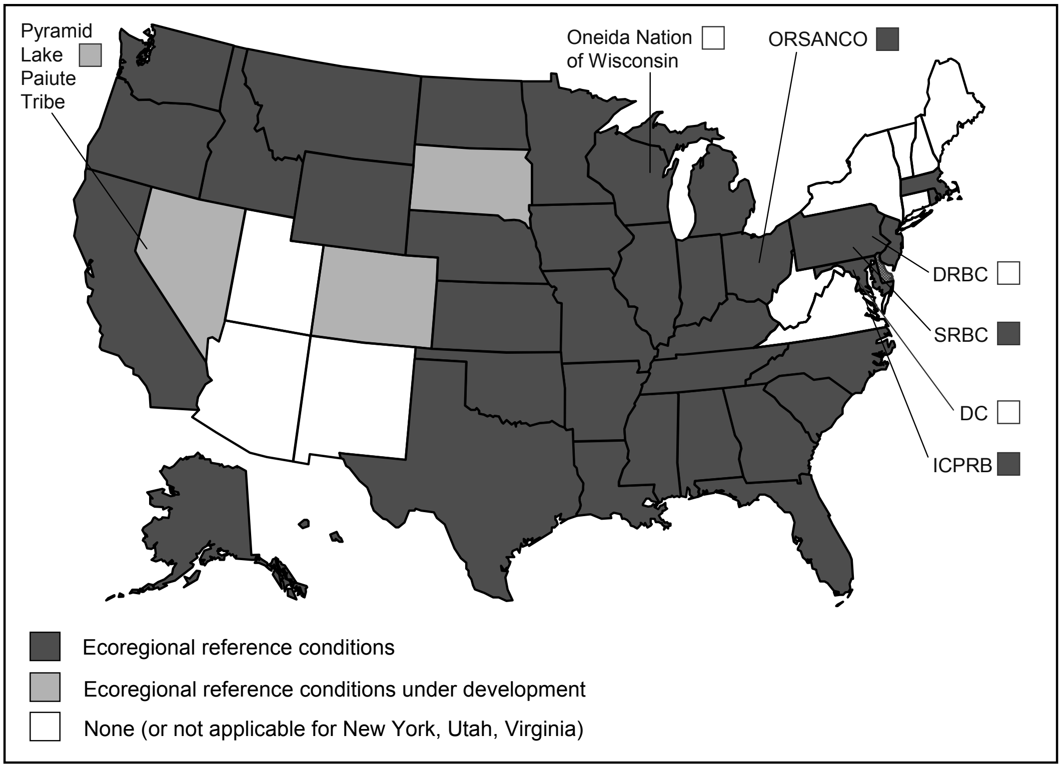


Figure 4. Use of ecoregional reference conditions

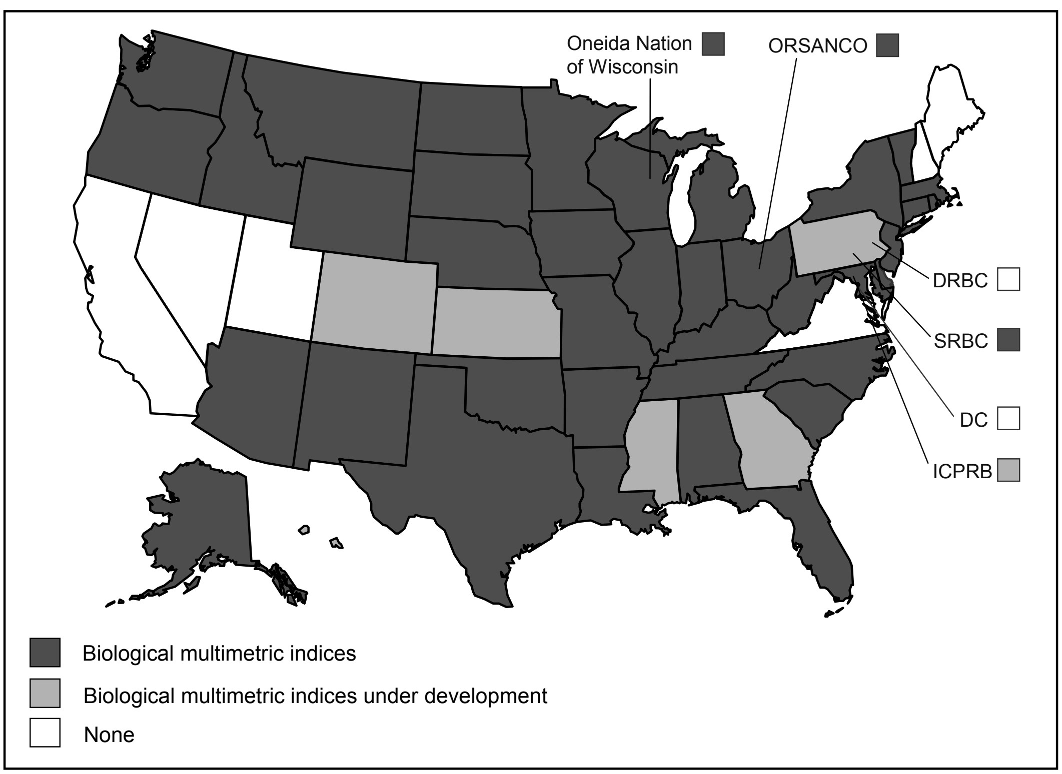


Figure 5. Development of biological multimetric indices

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3. PROGRAM SUMMARIES

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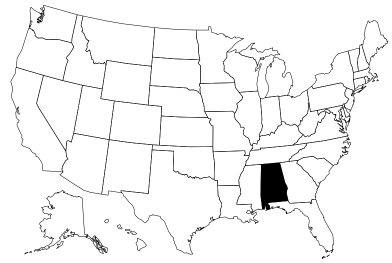
ALABAMA



Contact Information

Fred Leslie, Chief - Aquatic Assessment Unit
Alabama Department of Environmental Management (ADEM)
P.O. Box 301463 ■ Montgomery, AL 36130-1463
Phone 334/260-2752 ■ Fax 224/272-8131
email: fal@adem.state.al.us
ADEM Water Quality homepage:
http://www.adem.state.al.us/WaterDiv/Water%20Quality%20Info/WQMainInfo.htm

Program Description

In the last five years the Alabama Department of Environmental Management (ADEM) has assessed more than 1,100 river and stream locations as a part of six major long-term riverine-focused monitoring programs:

- Nonpoint Source Assessment Program
- Source Assessment Program
- Ecoregion Reference Assessment Program
- Upland Alamap Monitoring and Assessment Program
- Clean Water Act §303(d) Support Assessment/Monitoring Program
- Fixed Ambient Trend Monitoring Program

The Field Operations Division's (FOD) benthic macroinvertebrate assessment program is an integral part of the Department's biological monitoring effort. A Multihabitat Bioassessment Protocol is currently utilized to sample wadeable and nonwadeable streams. All methods utilized are documented in the Department's *Standard Operating Procedures* and *Quality Control Assurance Manual, Volume II* (ADEM 1999).

The Department has developed assessment criteria based on a ten-year ecoregional reference database. These assessments are then used to determine the Aquatic Life Use Designations. These comparisons have aided the Department in evaluating the "best attainable biotic community" within an ecoregion. The Department uses macroinvertebrates and a multi-habitat fish community assessment to evaluate water quality. Periphyton bioassessment methods are currently being tested as a more direct assessment of nutrient enrichment.

Biological integrity and water quality are directly affected by physical habitat. In addition, the assessment of habitat quality is an important step in documenting the adverse impacts of nonpoint source pollution. The Department utilizes the Habitat Assessment Matrices developed by EPA (USEPA 1989) and Barbour and Stribling (1994) in conjunction with physical characteristics and water quality parameters to evaluate and document the habitat quality of each wadeable bioassessment sampling site. More intensive assessment of geomorphological survey methods are currently being implemented (in 2002) to evaluate sedimentation impacts.

Through contracts and cooperative efforts, other agencies have contributed valuable information, time, data, and other resources to the surface and ground water management program. These contributions have included sampling and analysis efforts; flow information; data contribution and management; and GIS development. The Alabama Water Watch (AWW) Program and Association routinely provides quality citizen volunteer monitoring data to ADEM. With so much water to manage and diminishing program funds, the "Alabama Water Watchers" play a key role in identifying waters that need immediate or long-term attention.

Documentation and Further Information

2000 Water Quality Report to Congress, 305(b) Report:
http://www.adem.state.al.us/WaterDiv/Water%20Quality%20Info/305b/WQ305bReport.htm

1996, 1998 and 2000 303(d) lists, listing and delisting criteria, and maps of listed waters:
http://www.adem.state.al.us/WaterDiv/Water%20Quality%20Info/303d/WQ303d.htm

ADEM. 1999. *Standard Operating Procedures and Quality Control Assurance Manual Volume II – Freshwater Macroinvertebrate Biological Assessment*. Field Operations Division ADEM, Montgomery, Alabama.

O'Neil, P.E., and T.E. Shepard. 1998. *Standard operating procedure manual for sampling freshwater fish communities and application of the index of biotic integrity for assessing biological condition of flowing, wadeable streams in Alabama*. ADEM Contract No. AGY7042. Geological Survey of Alabama, Tuscaloosa, Alabama.

Barbour, M.T., and J.B. Stribling. 1994. A technique for assessing stream habitat structure. Pages 156-178 in *Conference proceedings, Riparian ecosystems in the humid U.S.: Functions, values, and management.* National Association of Conservation Districts, Washington, D.C. March 15-18, 1993, Atlanta, Georgia.

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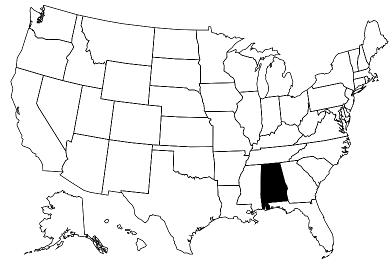


Contact Information

Fred Leslie, Chief - Aquatic Assessment Unit
Alabama Department of Environmental Management (ADEM)
P.O. Box 301463 ■ Montgomery, AL 36130-1463
Phone 334/260-2752 ■ Fax 224/272-8131
email: fal@adem.state.al.us

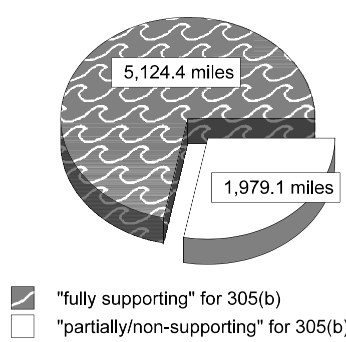
Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
	✓	monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
		promulgated into state water quality standards as biocriteria
	✓	support of antidegradation
	✓	evaluation of discharge permit conditions
	✓	TMDL assessment and monitoring
		other:
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(special projects and specific river basins or watersheds)*
	✓	fixed station (i.e., water quality monitoring stations) *(special projects and comprehensive use throughout jurisdiction)*
		probabilistic by stream order/catchment area
		probabilistic by ecoregion, or statewide
	✓	rotating basin *(special projects and specific river basins or watersheds)*
		other:

Stream Miles

Total miles	**77,274**
Total perennial miles	47,077
Total miles assessed for biology*	**7,103.5**
fully supporting for 305(b)	5,124.4
partially/non-supporting for 305(b)	1,979.1
listed for 303(d)	1,979.1
number of sites sampled *(on an annual basis)*	200
number of miles assessed per site	–

7,103.5 Miles Assessed for Biology



*The above miles are the total river and stream miles assessed for biological *and* other (chemical, physical, etc.) effects. Strictly biological miles are as follows: 2,992.1 *monitored* miles and 5,524 *evaluated* miles were determined as "fully supporting" for 305(b) using bioassessment data. These miles do not include fish tissue monitoring data from streams and rivers.

Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Fishery Based Uses	
ALU designations in state water quality standards	Three designations: Outstanding Alabama Water, Fish & Wildlife, Limited Warmwater Fishery	
Narrative Biocriteria in WQS	none - A narrative scale of condition is used to support criteria decisions. Draft guidelines, based upon ecoregional reference conditions, are used in the evaluation of aquatic macroinvertebrate community assessments.	
Numeric Biocriteria in WQS	none	
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
	✓	cause and effect determinations
	✓	permitted discharges
	✓	monitoring (e.g., improvements after mitigation)
	✓	watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	none	

Reference Site/Condition Development

Number of reference sites	**48 total**	
Reference site determinations		site-specific
		paired watersheds
	✓	regional (aggregate of sites)
		professional judgment
		other:
Reference site criteria	Local Soil and Water Conservation District (SWCD) estimates of landuse, animal densities, and sedimentation rates, etc. and departmental databases are used to identify potentially least-impaired sub-watersheds.	
Characterization of reference sites within a regional context		historical conditions
	✓	least disturbed sites
		gradient response
		professional judgment
		other:
Stream stratification within regional reference conditions	✓	ecoregions (or some aggregate)
		elevation
		stream type
		multivariate grouping
		jurisdictional (i.e., statewide)
		other:
Additional information	✓	reference sites linked to ALU
		reference sites/condition referenced in water quality standards
	✓	some reference sites represent acceptable human-induced conditions

Field and Lab Methods

Assemblages assessed	✓	benthos *(100-500 samples/year; multiple seasons, multiple sites - broad coverage for watershed level)*
	✓	fish *(<100 samples/year; multiple seasons, multiple sites - broad coverage for watershed level)*
		periphyton *(currently being tested for assessment of nutrient enrichment)*
	✓	other: phytoplankton *(100-500 samples/year; multiple seasons, multiple sites - broad coverage for watershed level)*

Benthos	
sampling gear	wash bucket, dipnet and kick net (1 meter); 500-600 micron mesh
habitat selection	multihabitat
subsample size	100 per habitat
taxonomy	family and genus
Fish	
sampling gear	backpack electrofisher and seine; 3/16" mesh
habitat selection	pool/glide and riffle/run (cobble)
sample processing	biomass - batch
subsample	none
taxonomy	species
Habitat assessments	visual based; performed both with, and independent of, bioassessments
Quality assurance program elements	standard operating procedures, quality assurance plan, periodic meetings and training for biologists, sorting and taxonomic proficiency checks, specimen archival

Data Analysis and Interpretation

Data analysis tools and methods	✓	summary tables, illustrative graphs
		parametric ANOVAs
		multivariate analysis
	✓	biological metrics *(aggregate metrics into an index and return single metrics)*
		disturbance gradients
		other:

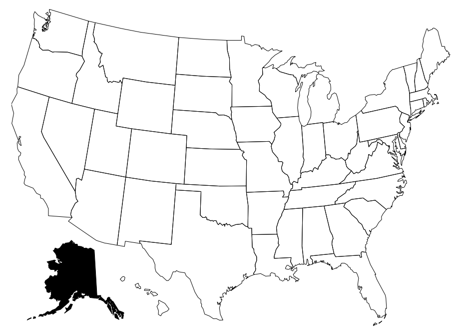
Multimetric thresholds	
transforming metrics into unitless scores	95th percentile of reference population
defining impairment in a multimetric index	The 2000 305(b) report states that sampling results equal to or less than fair/moderately impaired for the macroinvertebrate index and chemical/physical field data indicate an impairment ("excellent, good, fair, poor, very poor" or "unimpaired, slightly impaired, moderately impaired, severely impaired") and will be considered non-support and placed on the 303(d) list.

Evaluation of performance characteristics	✓	repeat sampling *(sampling - multiple crews same site/same day)*
	✓	precision *(sampling, assessment and identification)*
	✓	sensitivity *(sampling and assessment; standard level of identification)*
	✓	bias *(identification - 10% peer review)*
	✓	accuracy *(identification - 10% peer Quality Assurance; lab pick - 100% recheck; field pick - 10% returned to lab for re-check)*

Biological data*	
Storage	Aquatic macroinvertebrate data from 1990 to present are stored in a PACE mainframe database. ADEM has very recently developed an MS Access Fish IBI database and will begin data entry of this information as time allows. Historical macroinvertebrate data are stored in paper files. Fish IBI data are mostly in spreadsheets, but will eventually be included in the Access database.
Retrieval and analysis	Both databases mentioned above include automated metric calculation. The macroinvertebrate database also allows some comparison of taxa lists between stations.

*Additional resources are necessary to develop an in-house biological database module in Oracle that would be compatible with the Oracle Surface Water Quality Database currently under development. The current aquatic macroinvertebrate dataset and the fish community data would be migrated into this database module. STORET will not be used as the primary biological data storage and retrieval system.

ALASKA



Contact Information

Kent Patrick-Riley, Section Leader - NPS Protection and Impairment
Alaska Department of Environmental Conservation (ADEC)
555 Cordova Street ■ Anchorage, AK 99501
Phone 907/269-7554 ■ Fax 907/269-7508
email: kent_patrick-riley@envircon.state.ak.us
ADEC Division of Air and Water Quality homepage:
http://www.state.ak.us/local/akpages/ENV.CONSERV/dawq/dec_dawq.htm

Program Description

The State of Alaska is in the early stages of using bioassessments in water quality management. The lead agency funding bioassessment work is the Alaska Department of Environmental Conservation (ADEC); with the bulk of the development work done by the University of Alaska (UAA) Environment and Natural Resources Institute (ENRI). To date, bioassessments have not been used for biocriteria. Key accomplishments of Alaska's program include:

- method development and testing, resulting in the Alaska Stream Condition Index
- successful interagency involvement and supplemental funding
- extensive outreach and educational opportunities
- development of regional reference conditions for the Cook Inlet Ecoregion
- stream type differences incorporated into the framework for assessment
- index development incorporating multiple community attributes
- water quality assessments for Cook Inlet Ecoregion
- database development compatible with STORET for the water quality information
- relationship between degradation and habitat quality
- nutrient enrichment issues
- impervious surface areas influences to water quality

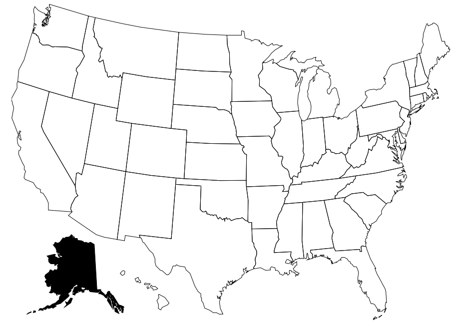
Documentation and Further Information

Alaska's bioassessment program is being developed in conjunction with UAA-ENRI. For consistency and to avoid duplicate information, refer questions on protocols and reference sites to them. Their web site is:
http://www.uaa.alaska.edu/enri/bmap

Alaska Stream Condition Index: Biological Index Development for Cook Inlet, Summary 1997 - 2001, August 2001:
http://www.uaa.alaska.edu/enri/bmap/pdfs/AK_SCI_2001.pdf

Quality Assurance Project Plan, Alaska Biological Monitoring and Assessment Program, February 2002:
http://www.uaa.alaska.edu/enri/bmap/pdfs/ENRI_QAPP_2-02.pdf

ALASKA



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Alaska Department of Environmental Conservation (ADEC)
555 Cordova Street ■ Anchorage, AK 99501
Phone 907/269-7554 ■ Fax 907/269-7508
email: kent_patrick-riley@envircon.state.ak.us

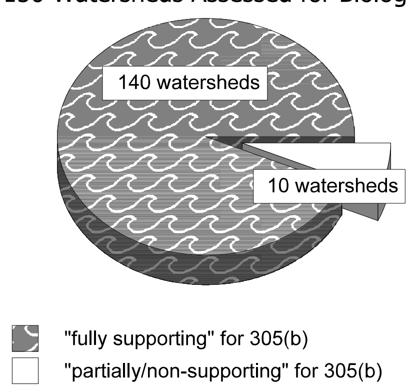
Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
		monitoring the effectiveness of BMPs
		ALU determinations/ambient monitoring
		promulgated into state water quality standards as biocriteria
		support of antidegradation
		evaluation of discharge permit conditions
	✓	TMDL assessment and monitoring
		other:
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(comprehensive use throughout jurisdiction, special projects and specific river basins or watersheds)*
		fixed station (i.e., water quality monitoring stations)
		probabilistic by stream order/catchment area
		probabilistic by ecoregion, or statewide
		rotating basin
		other:

Stream Miles

Total miles *(determined using National Hydrography Database)*	**>3 million**
Total perennial miles	unknown
Total watersheds assessed for biology	**150**
watersheds fully supporting for 305(b)	140
watersheds partially/non-supporting for 305(b)	10
watersheds listed for 303(d)	10
number of sites sampled	300
number of miles assessed per site*	10

150 Watersheds Assessed for Biology



*For the purposes of decision making, a 100 meter reach represents approximately 10 stream miles.

Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Class system (A,B,C)–Every AK stream is designated for ALL uses (including drinking water) unless specifically exempted.	
ALU designations in state water quality standards	One designation in A: 3) aquaculture; One designation in C: 1) growth and propagation of fish, shellfish, other aquatic life, and wildlife	
Narrative Biocriteria in WQS	none	
Numeric Biocriteria in WQS	none	
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
		cause and effect determinations
		permitted discharges
	✓	monitoring (e.g., improvements after mitigation)
	✓	watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	Alaska is just beginning to use bioassessment information to help with assessment/monitoring and in management decisions.	

Reference Site/Condition Development

Number of reference sites	**43 total**	
Reference site determinations	✓	site-specific
		paired watersheds
		regional (aggregate of sites)
	✓	professional judgment
		other:
Reference site criteria	no channelization; no upstream impoundments; no known point-source discharges; DO > 5 ppm; urban land use <15% in catchment; mining or logging in <15% of catchment; forest or natural land use >50% in catchment; riparian buffer width >18m	
Characterization of reference sites within a regional context		historical conditions
		least disturbed sites
		gradient response
		professional judgment
	✓	other: minimally disturbed*
Stream stratification within regional reference conditions	✓	ecoregions (or some aggregate)
		elevation
	✓	stream type
		multivariate grouping
		jurisdictional (i.e., statewide)
		other:
Additional information	✓	reference sites linked to ALU
		reference sites/condition referenced in water quality standards
		some reference sites represent acceptable human-induced conditions

*Alaska's reference sites are considered "minimally" disturbed; variation in results is due to natural and environmental influences.

Field and Lab Methods

Assemblages assessed	✓	benthos *(100 to 500 samples/year; single and multiple seasons, multiple sites - broad coverage)*
		fish
	UD	periphyton
		other:

Benthos	
sampling gear	d-frame; 200 - 400 micron mesh
habitat selection	multihabitat
subsample size	300-count target
taxonomy	genus level
Habitat assessments	visual based, hydrogeomorphology; performed with bioassessments
Quality assurance program elements	standard operating procedures, quality assurance plan (in progress), periodic meetings and training for biologists, sorting and taxonomic proficiency checks, specimen archival

Data Analysis and Interpretation

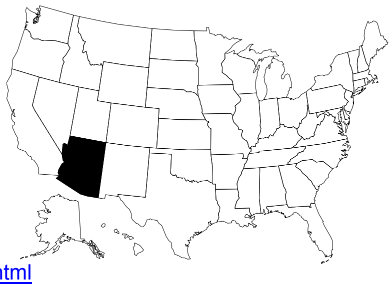
Data analysis tools and methods	✓	summary tables, illustrative graphs
		parametric ANOVAs
		multivariate analysis
	✓	biological metrics *(aggregate metrics into an index)*
		disturbance gradients
		other:

Multimetric thresholds	
transforming metrics into unitless scores	95^{th} percentile of all sites
defining impairment in a multimetric index	first quartile from the 95^{th} percentile

Evaluation of performance characteristics		repeat sampling
	✓	precision *(sampling replicates)*
		sensitivity
		bias
		accuracy

Biological data	
Storage	EDAS
Retrieval and analysis	EDAS

ARIZONA



Contact Information

Patti Spindler, Aquatic Ecologist
Arizona Department of Environmental Quality (ADEQ)
1110 West Washington St. 5415A-1 ■ Phoenix, AZ 85007
Phone 602/771-4543 ■ Fax 602/771-4528
email: phs@ev.state.az.us
ADEQ Water Quality Division homepage: http://www.adeq.state.az.us/environ/water/index.html

Program Description

The Biocriteria Program at the Arizona Department of Environmental Quality (ADEQ) has been sampling benthic macroinvertebrates since 1992. Data has been collected for biocriteria standards development and 305(b) assessment purposes for the past ten years. ADEQ has only one dedicated biocriteria staff person, however six other water quality monitoring staff assist in biological data collection during the spring as part of the ambient watershed monitoring program.

ADEQ does not yet have narrative or numeric biocriteria. However, sampling methods and Indexes of Biological Integrity have been developed with the assistance of USEPA and contractor support. The cold and warm water Indexes of Biological Integrity will be used to support two designated uses, Aquatic and Wildlife (cold water fishery) (A&Wc) and Aquatic and Wildlife (warm water fishery) (A&Ww), which are currently listed in Arizona's surface water quality standards. ADEQ plans to develop a narrative biocriterion for the next triennial review of standards and these indexes will serve as the implementation guidance for such a standard. ADEQ has also developed an approach to using bioassessments plus habitat assessments to implement the narrative bottom deposit standard, which will be proposed during a separate rulemaking on implementation guidance documents for all narrative standards during 2002.

In the water quality standards rules that are currently under review by USEPA, ADEQ has updated definitions for A&Wc and A&Ww based upon "macroinvertebrate regions" identified in Spindler 2001. The 5000' elevation contour marks the threshold for a change in community type from warm to cold, as determined by statistical analysis of empirically derived statewide biological data. These macroinvertebrate regions will be used instead of ecoregions for predicting community types in Arizona. Addition of the elevation range in the A&Wc and A&Ww standards definitions allows Arizona to use the elevation model to better predict the correct A&W use type. Revisions to the "list of surface waters and designated uses" have correspondingly been made in the 2001 standards rule.

ADEQ does not have a biocriteria standard and has subsequently been unable to assess biological integrity in Arizona's 305(b) report or 303(d) list. As a result of a lawsuit, ADEQ is preparing an "impaired waters rule" this year which will specifically outline assessment and listing procedures. Rules for conducting bioassessments will also have to be developed as part of this impaired waters rule, in addition to the surface water quality standard before bioassessments can be fully implemented in our assessment and listing process in Arizona. ADEQ is also partnering with the US Forest Service and Bureau of Land Management to standardize macroinvertebrate sample collection and analysis methods in order to share data on this important ecosystem indicator.

Future program directions include refining narrative bottom deposit standard implementation guidance for rule development, developing narrative biocriterion, starting a diatom bioassessment pilot project, refining reference condition, and developing bioassessments for intermittent streams and large rivers.

Documentation and Further Information

Status of Water Quality In Arizona - Clean Water Act Section 305(b) Report: June 2000:
http://www.adeq.state.az.us/environ/water/assess/305/index.html

Draft Status of Water Quality in Arizona - 2002, Arizona's Integrated 305(b) Assessment and 303(d) Listing Report:
http://www.adeq.state.az.us/environ/water/assess/hsa.html#draft

WQD Biocriteria Program information: http://www.adeq.state.az.us/environ/water/assess/monit.html

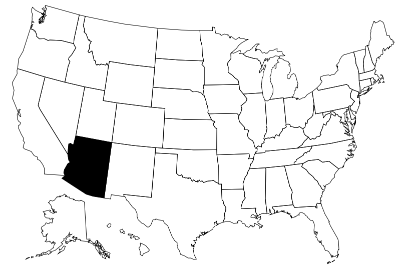
ADEQ. 2001. *DRAFT Quality Assurance Program Plan for the Biocriteria Program. ADEQ*, Phoenix, AZ.

Spindler, P.H. 2001. *DRAFT Narrative bottom deposit standard implementation guidelines for Arizona*. ADEQ, Phoenix, AZ.

Spindler, P.H., 1996. *Using ecoregions for explaining macroinvertebrate community distribution among reference sites in Arizona*, 1992. ADEQ OFR-95-7, Phoenix, AZ.

Other accomplishments include macroinvertebrate community distribution among reference sites in AZ (2001), development of Arizona EDAS biological database (2001), development and testing of a biological index for coldwater streams of AZ (2000), development and testing of a biological index for warmwater streams of AZ (1998), and Macroinvertebrate Photocatalog on CD (1998).

ARIZONA



Contact Information

Patti Spindler, Aquatic Ecologist
Arizona Department of Environmental Quality (ADEQ)
1110 West Washington St. 5415A-1 ■ Phoenix, AZ 85007
Phone 602/771-4543 ■ Fax 602/771-4528
email: phs@ev.state.az.us

Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	UD	nonpoint source assessments
	UD	monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
	UD	promulgated into state water quality standards as biocriteria
		support of antidegradation
	✓	evaluation of discharge permit conditions
	✓	TMDL assessment and monitoring
		other:
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(special projects, specific river basins or watersheds)*
	✓	fixed station (i.e., water quality monitoring stations) *(comprehensive use throughout* jurisdiction)
		probabilistic by stream order/catchment area
		probabilistic by ecoregion, or statewide
	✓	rotating basin *(specific river basins or watersheds)*
		other:

Stream Miles

Total miles	**127,505**
Total perennial miles	4,980
Total miles assessed for biology*	**0**
fully supporting for 305(b)*	n/a
partially/non-supporting for 305(b)*	n/a
listed for 303(d)*	n/a
number of sites sampled	324
number of miles assessed per site	site specific

*Arizona does not have formal biocriteria and will not be using bioassessments in the 2002 305(b) or 303(d) reports. However, a proposal to use bioassessment plus habitat assessment as the implementation procedure for the narrative bottom deposit standard will be considered during a rulemaking (2002-03), which is separate from the just completed triennial review of standards. The next 305(b) report may include bioassessments in support of the narrative bottom deposit standard, if this implementation procedure is approved.

Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Warm water vs. Cold Water
ALU designations in state water quality standards	Aquatic and Wildlife (A&W) cold, A&W warm, A&W-effluent dependent water, A&W-ephemeral (AZ has acute and chronic categories for each except ephemeral in which only acute applies.)
Narrative Biocriteria in WQS	under development – ADEQ has developed a cold water and warm water Index of Biological Integrity to support these two designated uses, which are currently listed in the surface water quality standards. However ADEQ does not yet have established biocriteria. These indexes will become the implementation guidance for proposed biocriteria in the next triennial review of standards.
Numeric Biocriteria in WQS	none

Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	UD	assessment of aquatic resources
	UD	cause and effect determinations
	UD	permitted discharges
	✓	monitoring (e.g., improvements after mitigation)
		watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	none	

Reference Site/Condition Development

Number of reference sites	**89 total**	
Reference site determinations		site-specific
		paired watersheds
	✓	regional (aggregate of sites)
		professional judgment
		other:
Reference site criteria	For initial site selection, the following guidelines were used in the early 1990s: a site must be accessible (within a 2-hour walk or 3-4 miles from nearest 4-wheel drive road), > 0.5 km downstream of road crossings, no known discharges upstream, no major impoundments upstream, no channel alterations at the site, and be only minimally impacted by land use activities and nonpoint sources. All of the following criteria must be attained in the field assessment of potential sites for a site to be accepted as reference: site should be truly perennial (indicators: fish, univoltine insects, riparian indicators), site should be free of local land use impacts, site should be free of channel alterations, no violations of pH or dissolved oxygen water quality standards, and habitat assessment index score > 14 using ADEQ's 2001 5-parameter habitat index.	
Characterization of reference sites within a regional context		historical conditions
	✓	least disturbed sites
		gradient response
	✓	professional judgment
	✓	other: minimally disturbed
Stream stratification within regional reference conditions		ecoregions (or some aggregate)
	✓	elevation
		stream type
		multivariate grouping
		jurisdictional (i.e., statewide)
		other:
Additional information	✓	reference sites linked to ALU
		reference sites/condition referenced in water quality standards
	✓	some reference sites represent acceptable human-induced conditions

Field and Lab Methods

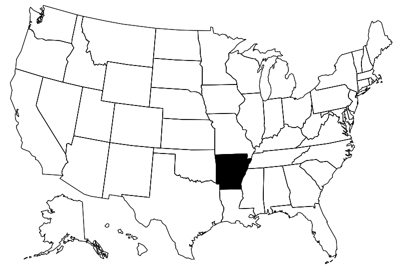
Assemblages assessed	✓	benthos *(<100 samples/year; single season, multiple sites - watershed level)*
		fish
	✓	periphyton *(<100 samples/year; single season, multiple sites - watershed level)*
		other:
Benthos		
sampling gear		d-frame net; 500 micron mesh
habitat selection		riffle/run (cobble)
subsample size		500 - 600 count target
taxonomy		combination level; EPT taxa are identified to genus or species
Periphyton		
sampling gear		**natural substrate**: brushing/scraping device (razor, toothbrush, etc.) **artificial substrate**: microslides or other suitable substratum
habitat selection		riffle/run (cobble); artificial substrate
sample processing		taxonomic identification
taxonomy		diatoms only; identified at species level
Habitat assessments		visual based, quantitative measurements, hydrogeomorphology; performed with bioassessments
Quality assurance program elements		standard operating procedures, quality assurance plan, periodic meetings, training for biologists, sorting and taxonomic proficiency checks, and specimen archival

Data Analysis and Interpretation

Data analysis tools and methods		summary tables, illustrative graphs
		parametric ANOVAs
		multivariate analysis
	✓	biological metrics *(aggregate metrics into an index)*
		disturbance gradients
		other:
Multimetric thresholds		
transforming metrics into unitless scores		95th percentile of reference population
defining impairment in a multimetric index		25th percentile of reference population
Evaluation of performance characteristics*	✓	repeat sampling *(duplicate samples collected for 10% of sites annually)*
		precision
	✓	sensitivity (*standard level of identification used by lab)*
	✓	bias *(ADEQ uses a standard mesh size, the lab locates small organisms, using a 6-12x dissecting microscope and a Caton tray to randomly obtain fractions of the total sample)*
	✓	accuracy *(any questionable identifications are sent to nationally recognized taxonomic experts for confirmation and a voucher specimen collection is maintained*)
Biological data		
Storage		AZ-EDAS
Retrieval and analysis		Systat, EDAS

*Though multiple performance characteristics are evaluated, ADEQ has not incorporated this information into a QA/QC document.

ARKANSAS



Contact Information

William Keith, Water Quality Planning Branch Manager
Jim Wise, Program Manager
Chris Davidson, Water Quality Specialist
Arkansas Department of Environmental Quality (ADEQ)
P.O. Box 8913 ■ Little Rock, AR 72219-8913
Phone 501/682-0656 ■ Fax 501/682-0910
email: Keith@adeq.state.ar.us, Wise@adeq.state.ar.us and Davidson@adeq.state.ar.us
ADEQ Water Division homepage: http://www.adeq.state.ar.us/water/

Program Description

As part of the Water Division of the Arkansas Department of Environmental Quality (ADEQ), the Water Quality Planning Branch has seven biologists/ecologists and two geologists on staff. This branch deals with a variety of issues related to water quality monitoring, standards development, and groundwater and wasteload allocations. The Branch is responsible for conducting water quality surveys, assessing the State's water quality for surface and ground water, and 305(b) reporting. The Branch is also responsible for the development of water quality and biological criteria for water quality use attainability analysis and for water quality standards development. In addition, the Branch is responsible for developing TMDLs (303d) for those waters not meeting water quality standards. Finally, the Branch is responsible for the biomonitoring aspect of the NPDES program.

Biological and habitat monitoring are currently restricted to special project needs associated with synoptic watershed surveys or for the development of additional data to support the establishment of biological criteria. For the 2000 305(b) report, portions of 106 stream segments from 17 planning segments were assessed for aquatic life use support using biological communities. These stream segments were either located above or below a point source discharge, or were part of intensive water quality surveys. Survey objectives were to determine the impacts of the discharge, evaluate the biological community in ecoregional reference streams, determine use attainment in previously listed water bodies of concern or those waters not currently meeting all designated uses.

Macroinvertebrates were collected and evaluated following EPA's *Rapid Bioassessment Protocols (*USEPA 1989). Habitat considerations were used in the evaluation of the macroinvertebrate communities through percent comparability evaluation techniques at all sites. An upstream-downstream comparison of the communities, and a comparison of the community to a least disturbed reference stream were also used to make the assessments. Fish communities were analyzed following EPA's *Technical Support Manual: Waterbody Surveys and Assessments for Conducting Use Attainability Analysis* (USEPA 1983). Direct comparisons were made with ecoregional fish community data outlined in the Department's *Physical, Chemical, and Biological Characteristics of Least-Disturbed Reference Streams in Arkansas' Ecoregions, 1987.* In addition, an upstream-downstream comparison of the communities was made and compared to a least-disturbed reference stream.

Documentation and Further Information

Water Quality Inventory Report 2000, 305(b) Report:
http://www.adeq.state.ar.us/water/pdfs/documents/305(b)_2000.pdf

2002 Proposed 303(d) List: http://www.adeq.state.ar.us/water/pdfs/documents/303(d)_list_proposed_020426.pdf

1998 Arkansas 303(d) List: http://www.adeq.state.ar.us/water/303drprt.htm

Water Quality Standards for Surface Waters, effective Feb.1998, amended January 2001:
http://www.adeq.state.ar.us/regs/files/reg02_final_010917.pdf

Physical, Chemical, and Biological Characteristics of Least-Disturbed Reference Streams in Arkansas' Ecoregions, Volume 1: Data Compilation, and *Volume 2: Data Analysis*. ADEQ Water Division. 1987.

Water Quality Planning Branch, list of publications: http://www.adeq.state.ar.us/water/pdfs/documents/publist.pdf

ARKANSAS

Contact Information

William Keith, Water Quality Planning Branch Manager
Jim Wise, Program Manager
Chris Davidson, Water Quality Specialist
Arkansas Department of Environmental Quality (ADEQ)
P.O. Box 8913 ■ Little Rock, AR 72219-8913
Phone 501/682-0656 ■ Fax 501/682-0910
email: Keith@adeq.state.ar.us, Wise@adeq.state.ar.us and Davidson@adeq.state.ar.us

Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
	✓	monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
	✓	promulgated into state water quality standards as biocriteria
	✓	support of antidegradation
	✓	evaluation of discharge permit conditions
	✓	TMDL assessment and monitoring
		other:
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(special projects and specific river basins or watersheds)*
	✓	fixed station (i.e., water quality monitoring stations)
		probabilistic by stream order/catchment area
		probabilistic by ecoregion, or statewide
	✓	rotating basin
		other:

Stream Miles

Total miles *(determined using RF3 and the National Hydrography Database)*	**87,617**
Total perennial miles	28,408
Total miles assessed for biology*	**245 stream segments**
fully supporting for 305(b)	n/a
partially/non-supporting for 305(b)	n/a
listed for 303(d)	n/a
number of sites sampled *(on an annual basis)*	~450
number of miles assessed per site	–

*Currently, biological monitoring occurs as either 1) part of intensive watershed survey where water quality problems have been previously identified; 2) part of a site specific survey, wasteload allocation; and 3) most recently as part of expanding ecoregion reference stream data. Biological data are not used to list any 303(d) waters.

Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Single Aquatic Life Use, Fishery Based Uses and Warm Water vs. Cold Water	
ALU designations in state water quality standards	Two designations: Ecologically sensitive waterbodies protecting endangered, threatened, and endemic aquatic species. Fisheries are divided into Trout, Lakes and Reservoirs, and Streams (further subdivided by ecoregion).	
Narrative Biocriteria in WQS	Procedures used to support narrative biocriteria are currently found in the project specific QAPP. Additional methods and SOPs are being developed. NOTE: The development of criteria and standards is ongoing.	
Numeric Biocriteria in WQS	none	
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
	✓	cause and effect determinations
	✓	permitted discharges
		monitoring (e.g., improvements after mitigation)
	✓	watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	Currently, baseline data has been collected from numerous locations prior to BMP implementation and NPDES limit changes. Follow-up monitoring has occurred at some locations below point sources. No follow-up monitoring has occurred at nonpoint source locations.	

Reference Site/Condition Development

Number of reference sites	**75 total**	
Reference site determinations	✓	site-specific
	✓	paired watersheds
	✓	regional (aggregate of sites)
	✓	professional judgment
	✓	other: upstream/downstream
Reference site criteria	Water quality and habitat is typical of background ecoregion conditions. Watershed is somewhat undisturbed.	
Characterization of reference sites within a regional context	✓	historical conditions
	✓	least disturbed sites
		gradient response
	✓	professional judgment
		other:
Stream stratification within regional reference conditions	✓	ecoregions (or some aggregate)
		elevation
	✓	stream type
		multivariate grouping
		jurisdictional (i.e., statewide)
	✓	other: watershed size, habitat, water quality
Additional information	✓	reference sites linked to ALU
	✓	reference sites/condition referenced in water quality standards *(found in ADPC&E 1987 - WQ87-06-01 & 02)*
	✓	some reference sites represent acceptable human-induced conditions

Field and Lab Methods

Assemblages assessed	✓	benthos *(100-500 samples/year; single season, multiple sites - watershed level and broad coverage; multiple seasons, multiple sites)*
	✓	fish *(<100 samples/year; single season, multiple sites - watershed level and broad coverage)*
		periphyton
		other:

Benthos	
sampling gear	D-frame; 200-400 micron mesh
habitat selection	riffle/run (cobble), multihabitat and woody debris
subsample size	100 count
taxonomy	combination - family, genus and species
Fish	
sampling gear	backpack and boat electrofisher, pram unit (tote barge) and seine; 3/16" and 1/4" mesh
habitat selection	pool/glide, riffle/run (cobble), and multihabitat
sample processing	anomalies
subsample	whole samples are sorted and identified to species
taxonomy	species and life stage
Habitat assessments	visual based with limited quantitative measurements and hydrogeomorphology, pebble counts, flows and canopy cover; performed with bioassessments
Quality assurance program elements	quality assurance plan, periodic meetings and training for biologists, sorting and taxonomic proficiency checks, specimen archival, and standard operating procedures (in development stage)

Data Analysis and Interpretation

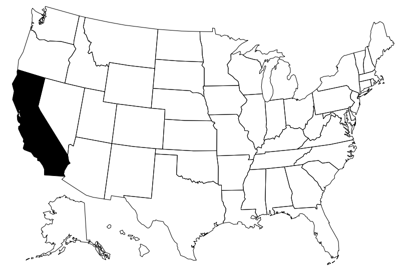
Data analysis tools and methods	✓	summary tables, illustrative graphs
		parametric ANOVAs
	✓	multivariate analysis
	✓	biological metrics *(aggregate metrics into an index and return single metrics - use endpoint for each single metric)*
	✓	disturbance gradients
		other:

Multimetric thresholds	
transforming metrics into unitless scores	As a percent of either the reference site or based on ecoregion data dependent upon standard deviation units
defining impairment in a multimetric index	As a percent of either the reference site or based on ecoregion data dependent upon standard deviation units
Multivariate thresholds	
defining impairment in a multivariate index	As a percent of either the reference site or based on ecoregion data dependant upon standard deviation units

Evaluation of performance characteristics *Not currently evaluated*		repeat sampling
		precision
		sensitivity
		bias
		accuracy

Biological data	
Storage	Microsoft databases
Retrieval and analysis	none

CALIFORNIA



Contact Information

Del Rasmussen, TMDL Section
California State Water Resources Control Board (SWRCB)
1001 I Street, P.O. Box 944213 ■ Sacramento, CA 95812
Phone 916/341-5545 ■ Fax 916/341-5550
email: rasmd@dwq.swrcb.ca.gov
website: http://www.swrcb.ca.gov/quality.html

Jim Harrington, State Water Quality Biologist
California Department of Fish and Game (CA DFG)
2005 Nimbus Road ■ Rancho Cordova, CA 95670
Phone 916/358-2862 ■ Fax 916/985-4301
email: jharring@ospr.dfg.ca.gov
California Aquatic Bioassessment Workgroup homepage: http://www.dfg.ca.gov/cabw/cabwhome.html

Program Description

Historically, the use of bioassessment data in California water regulations and decision-making has not been a high priority. California's tremendous range of ecological diversity and its equally complex history of land and water use have confounded progress towards implementation of a state-wide bioassessment program. The recent organization of California's Surface Water Ambient Monitoring Program (SWAMP) is providing the impetus to implement a better organized and standardized biological assessment and monitoring program throughout the state. Current concerns over hydroaugmentation and use attainability analyses of targeted waterbodies will foster a greater dependence upon bioassessment information in making informed decisions regarding the protection and restoration of California's streams.

Nine regional boards are essentially independent regulatory entities within the California State Water Resources Control Board (SWRCB). Not all regional boards are at the same level of development regarding bioassessment. One of the first management actions advancing bioassessment in CA was in 1993 when the Lahontan Regional Water Quality Control Board (RWQCB 6) required the use of EPA's Rapid Bioassessment Protocols in a fish hatchery permit. Since that time, the use of bioassessment in water resource decision-making has steadily increased. Presently, bioassessment is used by several RWQCBs for a variety of purposes, including to: assess the impacts of human activities on the biological integrity of streams and rivers; evaluate the effectiveness of restoration efforts, BMP implementation, and permit conditions; develop narrative and numeric biocriteria; establish reference conditions; provide baseline data on the benthic macroinvertebrate community in regional streams; determine the biological health of streams relative to land use in specific watersheds; help identify aquatic life stressors and associated development of ecological indicators in agriculturally dominated and effluent dominated waterbodies; and as an additional tool to NPDES and stormwater permitting to supplement the chemical and toxicological information obtained to address chemical standards.

The California Department of Fish and Game's (CA DFG) Water Pollution Control Laboratory and its Aquatic Biological Assessment Laboratory (ABAL) perform macroinvertebrate sampling and identification, fish surveys, physical/habitat surveys, toxicity testing, sedimentation studies, and tissue and water chemistry. Since 1992, the ABAL has conducted projects covering many different applications of biological monitoring throughout California. These projects have demonstrated bioassessment and promoted the effectiveness of bioassessment in the State.

In 1993, ABAL distributed a set of standard protocols for assessing biological and physical conditions of wadeable streams. The California Stream Bioassessment Procedures (CSBP) are regional adaptations of the national USEPA Rapid Bioassessment Protocols. The DFG, in cooperation with the SWRCB and USEPA Region 9, also established the California Aquatic Bioassessment Workgroup (CABW) to provide input and guidance for the development of a state-wide bioassessment program. The Workgroup was formed in 1994 to coordinate scientific and policy-making efforts towards implementing aquatic bioassessment in California. Members of the CABW consist of biologists from universities, consulting firms, industry, and representatives of state and federal agencies responsible for assessing, monitoring and protecting the biological integrity of surface waters. Through its Steering Committee and annual meetings, CABW participants develop objectives and strategies for implementing aquatic bioassessment in California.

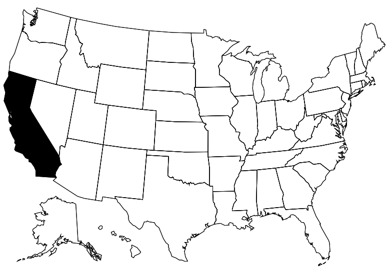
Documentation and Further Information

State Water Resources Control Board. October 2000. *2000 California 305(b) Report on Water Quality*. Sacramento, CA: SWRCB.

Status of Aquatic Bioassessment in California and the Development of a State-wide Bioassessment Program, prepared by the California Department of Fish and Game Aquatic Biological Assessment Laboratory: http://www.dfg.ca.gov/cabw/status.html

California Stream Bioassessment Procedure (CSBP): http://www.dfg.ca.gov/cabw/protocols.html

CALIFORNIA



Contact Information

Del Rasmussen, TMDL Section
California State Water Resources Control Board (SWRCB)
1001 I Street, P.O. Box 944213 ■ Sacramento, CA 95812
Phone 916/341-5545 ■ Fax 916/341-5550
email: rasmd@dwq.swrcb.ca.gov

Jim Harrington, State Water Quality Biologist
California Department of Fish and Game (CA DFG)
2005 Nimbus Road ■ Rancho Cordova, CA 95670
Phone 916/358-2862 ■ Fax 916/985-4301
email: jharring@ospr.dfg.ca.gov

Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
	✓	monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
	✓	promulgated into state water quality standards as biocriteria
	✓	support of antidegradation
	✓	evaluation of discharge permit conditions
	✓	TMDL assessment and monitoring
		other:
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(specific river basins or watersheds)*
	✓	fixed station (i.e., water quality monitoring stations) *(specific river basins or watersheds)*
	✓	probabilistic by stream order/catchment area *(specific river basins or watersheds)*
	✓	probabilistic by ecoregion, or statewide *(specific river basins or watersheds)*
	✓	rotating basin *(comprehensive use throughout jurisdiction)*
		other:

Stream Miles

Total miles	**211,513**
Total perennial miles	64,438
Total miles assessed for biology*	**unknown**
fully supporting for 305(b)	unknown
partially/non-supporting for 305(b)	unknown
listed for 303(d)	unknown
number of sites sampled	unknown
number of miles assessed per site	unknown

*Due to a comprehensive, statewide overhaul of California's database system, SWRCB was unable to break out numbers for stream miles assessed using biology.

Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Fishery Based Uses, Warm Water vs. Cold Water	
ALU designations in state water quality standards	Regional Water Quality Boards have a Basin Planning function. Therefore, water quality standards are regionally specific for establishing functional uses, criteria, and implementation plans.	
Narrative Biocriteria in WQS	Regional water quality standards contain generic statements for the overarching protection of biological communities with an emphasis on, but not limited to, fisheries. Procedures to support narrative biocriteria are regionally specific.	
Numeric Biocriteria in WQS	none	
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
	✓	cause and effect determinations
	✓	permitted discharges
	✓	monitoring (e.g., improvements after mitigation)
	✓	watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	Limited to select studies where biological data are used for management decisions regarding urban development.	

Reference Site/Condition Development

Number of reference sites	**~ 200 - 300 total**	
Reference site determinations		site-specific
		paired watersheds
		regional (aggregate of sites)
	✓	professional judgment
	✓	other: CA DFG is in the process of developing a more quantitative method of selecting reference sites on a regional basis using GIS land use analyses and quantitative physical habitat measures.
Reference site criteria	under development	
Characterization of reference sites within a regional context		historical conditions
	✓	least disturbed sites
		gradient response
		professional judgment
		other:
Stream stratification within regional reference conditions	✓	ecoregions (or some aggregate)
		elevation
		stream type
		multivariate grouping
		jurisdictional (i.e., statewide)
	✓	other: stream order
Additional information		reference sites linked to ALU
	✓	reference sites/condition referenced in water quality standards *(varies by region)*
	✓	some reference sites represent acceptable human-induced conditions

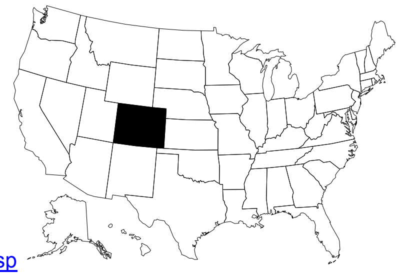
Field and Lab Methods

Assemblages assessed	✓	benthos *(>500 samples/year; varying levels of rigor)*
		fish
		periphyton
		other:
Benthos		
sampling gear		D-frame; 200 - 400 micron mesh (Sierra Nevada Aquatic Research Laboratory), 500 - 600 micron mesh (California Stream Bioassessment Procedure)
habitat selection		riffle/run (cobble)
subsample size		300 - 500 count (Sierra Nevada Aquatic Research Laboratory), 300 count (CSBP)
taxonomy		lowest possible, usually genus or species
Habitat assessments		visual based; performed with bioassessments
Quality assurance program elements		standard operating procedures, sorting and taxonomic proficiency checks

Data Analysis and Interpretation

Data analysis tools and methods		summary tables, illustrative graphs
	✓	parametric ANOVAs
	✓	multivariate analysis
	✓	biological metrics *(return single metrics – use endpoint for each single metric)*
		disturbance gradients
		other:
Multimetric thresholds		
transforming metrics into unitless scores		bar graph distribution function
Multivariate thresholds		
defining impairment in a multivariate index		under development
Evaluation of performance characteristics		repeat sampling
	✓	precision
		sensitivity
		bias
		accuracy
Biological data		
Storage		Central Coast Ambient Monitoring Program (CCAMP) regional database
Retrieval and analysis		CalEDAS

COLORADO



Contact Information

Robert McConnell, Monitoring Unit Manager
Colorado Department of Public Health and Environment (CDPHE)
4300 Cherry Creek Drive South ■ Denver, CO 80246
Phone 303/692-3578 ■ Fax 303/782-0390
email: robert.mcconnell@state.co.us
CDPHE Water Quality Control Division website: http://www.cdphe.state.co.us/wq/wqhom.asp

Program Description

The Monitoring Unit of the Water Quality Control Division, Colorado Department of Public Health and Environment (CDPHE), is responsible for designing studies and collecting chemical, physical, and biological data from a statewide network of sampling stations. Personnel from the Assessment Unit of the Water Quality Control Division evaluate this information, along with data from other agencies. Using a watershed-specific approach, the seven major watersheds within the State of Colorado are assessed sequentially as part of the triennial review of water quality standards and classifications. In addition, specific waterbodies are assessed as part of targeted synoptic studies, site-specific studies, and as required for evaluating waterbodies listed on the State of Colorado's 303(d) list.

Most biological assessments are performed to evaluate aquatic life use classifications and to support standards development. Biological assessments have occasionally been used to determine attainment of aquatic life uses or attainment of provisional sediment standards. However, chemical information from surface water samples is primarily used to assess use support determinations as reported in the State of Colorado's biennial Status of Water Quality report. Biologists in the Monitoring Unit are actively developing biocriteria to more effectively utilize biological information as part of the State of Colorado's water quality standards program. Initially, biocriteria will be developed for benthic macroinvertebrates. Over the last four years, biologists in the Monitoring Unit have collected benthic macroinvertebrate samples from approximately 300 potential reference/least impaired sites from all dominant ecoregions within the State of Colorado. This data is currently being evaluated. Combined with information on physical habitat and water chemistry, this benthic macroinvertebrate data will be used to develop provisional region-specific biocriteria. Once developed, these provisional biocriteria will be evaluated using new benthic macroinvertebrate information, and further refined as needed. It is anticipated that benthic macroinvertebrate biocriteria will be used as an assessment tool to support the water quality standards and classification programs within the State of Colorado. Biocriteria based on fishery information may be developed in the future.

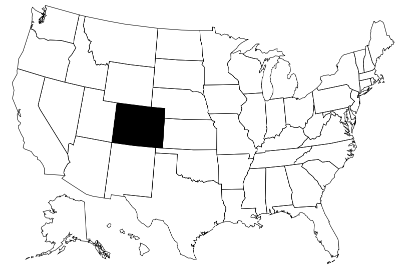
Documentation and Further Information

Colorado's 2002 305(b) report and 1998 303(d) list: http://www.cdphe.state.co.us/op/wqcc/wqresdoc.html

Draft 2001 Unified Assessment Methodology, *Guidance on Data Requirements and Data Interpretation Methods Used in Stream Standards and Classification Proceedings*, July 1993:
http://www.cdphe.state.co.us/wq/Assessment/assessment_practices_and_methods.htm

Water Quality in Colorado 2000: http://www.cdphe.state.co.us/wq/waterqualitybooklet.pdf

COLORADO



Contact Information

Robert McConnell, Monitoring Unit Manager
Colorado Department of Public Health and Environment (CDPHE)
4300 Cherry Creek Drive South ■ Denver, CO 80246
Phone 303/692-3578 ■ Fax 303/782-0390
email: robert.mcconnell@state.co.us

Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
	✓	monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
	UD	promulgated into state water quality standards as biocriteria
		support of antidegradation
	✓	evaluation of discharge permit conditions
	✓	TMDL assessment and monitoring
	✓	other: determine attainment of narrative sediment (clean) standard
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(comprehensive use throughout jurisdiction, specific river basins or watersheds, and special projects)*
	✓	fixed station (i.e., water quality monitoring stations) *(specific river basins or watersheds)*
		probabilistic by stream order/catchment area
		probabilistic by ecoregion, or statewide
	✓	rotating basin *(comprehensive use throughout jurisdiction)*
		other:

Stream Miles

Total miles *(determined using RF3)*	**107,403**
Total perennial miles	31,415
Total miles assessed for biology*	**n/a**
fully supporting for 305(b)	n/a
partially/non-supporting for 305(b)	n/a
listed for 303(d)	85.1
number of sites sampled *(on an annual basis)*	~70 -100
number of miles assessed per site	–

*Colorado does not use bioassessment in 305(b) assessments with some exceptions. Since Colorado's water quality standards are chemically oriented, the majority of use support determinations are based on chemical data. Bioassessments are conducted as part of the Triennial Standards Review process for Colorado's seven major watersheds; a few are used in the determination of aquatic life use and sediment standards attainment. The majority of CDPHE's work in the field is spent conducting bioassessments in preparation for the review process. During the review process, the Water Quality Control Commission uses biological data to determine the appropriate aquatic life use classification for 636 stream segments. Once classifications are set, all further water quality monitoring and assessment is chemical.

Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Class System, Warm Water vs. Cold Water	
ALU designations in state water quality standards	Three classifications: Class 1 Cold Water Aquatic Life, Class 1 Warm Water Aquatic Life, Class 2 Cold and Warm Water Aquatic Life	
Narrative Biocriteria in WQS	under development*	
Numeric Biocriteria in WQS	none*	
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
	✓	cause and effect determinations
	✓	permitted discharges
		monitoring (e.g., improvements after mitigation)
		watershed based management
Uses of bioassessment/ biocriteria uses in making management decisions regarding restoration of aquatic resources to a designated ALU	Bioassessment endpoints are used as targets in the attainment of the sediment standard (e.g. TMDL development).	

*ALU classifications are defined in Colorado's water quality standards but are not considered to be formal narrative biocriteria in the CO regulatory process. Colorado is presently developing biocriteria through a stakeholder workgroup process.

Reference Site/Condition Development**

Number of reference sites	**300 total potential reference/least impaired sites**	
Reference site determinations	✓	site-specific
		paired watersheds
		regional (aggregate of sites)
	✓	professional judgment
		other:
Reference site criteria	The condition of candidate sites is verified through field evaluation using a "checklist" of stream attributes that include, but are not limited to, measures of riparian condition, Rosgen channel type, land use, basin characteristics, physical habitat, substrate, chemistry, geology, vegetation, and climate.	
Characterization of reference sites within a regional context	✓	historical conditions
	✓	least disturbed sites
		gradient response
	✓	professional judgment
	✓	other: minimally disturbed***
Stream stratification within regional reference conditions	UD	ecoregions (or some aggregate)
		elevation
	✓	stream type
		multivariate grouping
		jurisdictional (i.e., statewide)
		other:
Additional information	n/a	reference sites linked to ALU
	n/a	reference sites/condition referenced in water quality standards
	n/a	some reference sites represent acceptable human-induced conditions

**Reference condition is used on a limited basis in Colorado. Currently, it is used as a key component in determining sediment deposition impacts to aquatic life and has been used in the first stages of biocriteria development, to locate sampling sites, as part of various EMAP studies underway in CO, and in the development of regional nutrient criteria. The reference condition approach is not developed enough to be an established part of biological assessments or the standards setting process in Colorado. Most, if not all, assessments are conducted on a case-by-case or site-specific basis, and although CO does attempt to characterize the "expected condition" for a particular waterbody, it is not treated as a formal reference condition.

***Sediment guidance suggests 3 tiers for reference conditions like those described in the 1996 EPA technical guidance for biological criteria: 1) minimally disturbed, 2) best available (least disturbed), and 3) none acceptable ("hypothetical explanation"). These can be considered individually and in combination.

Field and Lab Methods*

Assemblages assessed	✓	benthos *(100 - 500 samples/year; single season, multiple sites - watershed level)*
	✓	fish *(<100 samples/year; single season, multiple sites - not at watershed level)*
	UD	periphyton *(<100 samples/year; single season, multiple sites - watershed level)*
		other:

Benthos	
sampling gear	Surber, dipnet; 500 - 600 micron mesh
habitat selection	riffle/run (cobble) or most productive habitat if riffle/run is not available
subsample size	300 count
taxonomy	lowest possible level with positive identification
Fish	
sampling gear	backpack electrofisher
habitat selection	multihabitat
sample processing	length measurement
subsample	none
taxonomy	species
Periphyton	
sampling gear	**natural substrate**: brushing/scraping device (razor, toothbrush, etc), collect by hand
habitat selection	riffle/run (cobble)
sample processing	chlorophyll *a*/ phaeophytin, taxonomic identification
taxonomy	all algae, species level
Habitat assessments	visual based, hydrogeomorphology, pebble counts; performed with bioassessments
Quality assurance program elements	standard operating procedures, periodic meetings and training for biologists, specimen archival

*Field and lab methods reported are those used by the Monitoring Unit of the CDPHE Water Quality Control Division and are patterned after the EPA RBP approach. They do not apply to any of the other agencies collecting biological data in Colorado.

Data Analysis and Interpretation

Data analysis tools and methods	✓	summary tables, illustrative graphs
		parametric ANOVAs
		multivariate analysis
	✓	biological metrics *(return single metrics)*
		disturbance gradients
		other:

Multimetric thresholds	
transforming metrics into unitless scores	impairment thresholds determined on case-by-case basis as part of site-specific analyses
defining impairment in a multimetric index	Colorado is currently exploring possible metrics and indices through a workgroup process.

Evaluation of performance characteristics		repeat sampling
	✓	precision *(replicate samples collected at 10% of sites)*
		sensitivity
		bias
		accuracy

Biological data	
Storage	Currently moving all biological and habitat data into EDAS
Retrieval and analysis	EDAS, Excel, Minitab

CONNECTICUT

Contact Information

Ernest Pizzuto, Jr., Supervising Environmental Analyst
Guy Hoffman, Environmental Biologist
Connecticut Department of Environmental Protection (CT DEP)
79 Elm Street ■ Hartford, CT 06106-5127
Phone 860/424-3715 ■ Fax 860/424-4055
email: ernest.pizzuto@po.state.ct.us
CT DEP Bureau of Water Management website: http://dep.state.ct.us/wtr/index.htm

Program Description

The Connecticut Ambient Biological Monitoring Program characterizes water quality by evaluating the biological integrity of resident communities of aquatic organisms. This information is used as the primary indicator to meet reporting requirements for assessment of aquatic life use support and impairment under Sections 305(b) and 303(d) of the Clean Water Act. There are currently about 3.5 full time employees dedicated to biological assessment of rivers. Biological monitoring has been conducted by the CT DEP Bureau of Water Management since the early 1970s and has focused primarily on the benthic invertebrate community of wadeable stream segments. Narrative criteria for benthic invertebrates were incorporated into the CT water quality standards in 1987. Assessments are based on community structure characteristics using techniques intended to minimize the influence of variables such as habitat, seasonality and sampling method. Since 1989, methodology has followed a modified version of the USEPA Rapid Bioassessment Protocol (RBP) III (USEPA 1989).

A total of 302 sites on 153 rivers have been monitored to date (February 2002). Pursuant to the five-year rotating basin monitoring strategy that began in 1996, benthic invertebrate monitoring was conducted at approximately 50 sites each year for the five-year period ending in 2000. Since biological monitoring integrates environmental conditions over an extended time period, each site was sampled only once, primarily during the fall. Spring sampling is conducted on a limited basis for special studies or to supplement fall sampling. Sampling site selection is based on a targeted approach that considers sub-basin size, location of wastewater discharges, land use, and resource value. In addition to the rotating basin schedule, approximately ten regional reference sites located across the State are sampled annually, as well as a limited number of sites to support special projects.

The Bureau of Water Management recognizes the need to obtain a broader perspective of biological integrity by incorporation of fish community assessment data into the biological monitoring process. This has been accomplished to a limited degree by a cooperative working relationship with the CT DEP Division of Inland Fisheries. Fish sampling information obtained by fisheries biologists for purposes consistent with the fisheries management program has been utilized in the form of best professional judgment assessments which CT DEP considers to be generally equivalent to USEPA RBP IV (USEPA 1989). Funds obtained through an EPA 104(b)(3) grant have supported part of a Fisheries Division staff position since 1999. This effort has provided for approximately 24 fish community surveys, roughly equivalent in effort to annual RBP V assessment. This project is intended to support development of fish community structure metrics that will provide a more quantitative approach to the assessment process.

The CT DEP also promotes and directs a monitoring program for volunteers from which usable assessment information is obtained. The details of this program, *A Tiered Approach to Citizen-Based Monitoring of Wadeable Streams and Rivers*, can be obtained from the CT DEP Bureau of Water Management or viewed online at http://dep.state.ct.us/wtr/volunmon/tierapp.pdf

Section 305(b) of the CWA requires that states provide a description of the water quality of all navigable waters within their boundaries. Even with program improvements resulting from the rotating basin approach and incorporation of volunteer data, a complete census of State waters is not possible based on this focused approach to monitoring. To accomplish the goal of comprehensive monitoring, CT DEP is currently utilizing funds and technical assistance from USEPA to conduct a pilot statewide probabilistic monitoring program during 2002-2003. This project will sample the benthic invertebrate, fish, and periphyton communities at approximately 60 randomly selected sites. Through probabilistic monitoring, this statistically valid sample of wadeable streams in Connecticut will provide an estimate of conditions of all wadeable streams in the State. During this two-year period, the rotating basin approach will be suspended. However, limited focused monitoring will continue for reference sites, special projects, intensive surveys and to support TMDL development.

Documentation and Further Information

DRAFT *2002 List of Connecticut Waterbodies Not Meeting Water Quality Standards*, 303(d) list, May 2002: http://dep.state.ct.us/wtr/wq/implist.pdf

Draft Consolidated Assessment and Listing Methodology for 305(b) and 303(d) Reporting, April 2002: http://dep.state.ct.us/wtr/wq/method.pdf

Quality Assurance Project Plan for Ambient Biological Monitoring, March 1996. CT DEP Bureau of Water Management, Planning and Standards Division, CT06106.

Beauchene, M. 2002. *Quality Assurance Project Plan, Ambient Biological Monitoring -- Fish Community Structure*. CT DEP Bureau of Water Management.

Ambient Monitoring Strategy for Rivers and Streams, Rotating Basin Approach. CT DEP 1999.

CONNECTICUT

Contact Information

Ernest Pizzuto, Jr., Supervising Environmental Analyst
Guy Hoffman, Environmental Biologist
Connecticut Department of Environmental Protection (CT DEP)
79 Elm Street ■ Hartford, CT 06106-5127
Phone 860/424-3715 ■ Fax 860/424-4055
email: ernest.pizzuto@po.state.ct.us

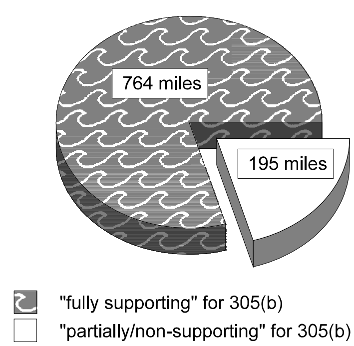
Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
	✓	monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
	✓	promulgated into state water quality standards as biocriteria
	✓	support of antidegradation
	✓	evaluation of discharge permit conditions
	✓	TMDL assessment and monitoring
		other:
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) (*special projects, specific river basins and watersheds, and comprehensive use throughout jurisdiction)*
	✓	fixed station (i.e., water quality monitoring stations) (*special projects, specific river basins and watersheds, and comprehensive use throughout jurisdiction)*
		probabilistic by stream order/catchment area
	✓	probabilistic by ecoregion, or statewide *(comprehensive use throughout jurisdiction beginning in 2002 and 2003)*
	✓	rotating basin (*comprehensive use throughout jurisdiction)*
		other:

Stream Miles

Total miles *(State based determinations)*	**5,830**
Total perennial miles	5,484
Total miles assessed for biology	**961**
fully supporting for 305(b)	764
partially/non-supporting for 305(b)	195
listed for 303(d)*	n/a
number of sites sampled*	311
number of miles assessed per site*	site specific

961 Miles Assessed for Biology



*The existing 303(d) doesn't use mileage, although it contains a subset of partially/non-supporting stream miles listed in the 305(b). These numbers will be the same in the next report. Of the 311 sites sampled, 221 were sampled by the state, 30 by contractors and 60 by volunteers. The number of miles assessed per site is site specific and varies according to land use, geomorphology, etc.

Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Class System (A,B,C)	
ALU designations in state water quality standards	"Fish and Wildlife Habitat" is the only ALU designation, but narrative criteria are provided for "benthic invertebrates which inhabit lotic waters" for classifications AA, A, and B while more general descriptive narrative is provided for C and D.	
Narrative Biocriteria in WQS	Procedures used to support narrative biocriteria located in *SOPs for ambient biological monitoring*	
Numeric Biocriteria in WQS	none	
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
	✓	cause and effect determinations
	✓	permitted discharges
	✓	monitoring (e.g., improvements after mitigation)
	✓	watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	Bioassessment/biocriteria have been used in specific cases to determine if formerly impaired waters are meeting ALU.	

Reference Site/Condition Development

Number of reference sites	**12 total**	
Reference site determinations	✓	site-specific
		paired watersheds
		regional (aggregate of sites)
		professional judgment
	✓	other: within major drainage basin
Reference site criteria	Least impacted by human influence. Size: ± one stream order or one order of magnitude in drainage area with similar gradient.	
Characterization of reference sites within a regional context		historical conditions
	✓	least disturbed sites
		gradient response
		professional judgment
		other:
Stream stratification within regional reference conditions		ecoregions (or some aggregate)
		elevation
		stream type
		multivariate grouping
		jurisdictional (i.e., statewide)
	✓	other: major drainage basin, gradient
Additional information		reference sites linked to ALU
		reference sites/condition referenced in water quality standards
	✓	some reference sites represent acceptable human-induced conditions

Field and Lab Methods

Assemblages assessed	✓	benthos *(<100 samples/year; single season, multiple sites - watershed level; multiple seasons, multiple sites - broad coverage for watershed level)*
	✓	fish *(<100 samples/year; single season, multiple sites - broad coverage)*
	✓	periphyton *(<100 samples/year; single season, multiple sites - broad coverage)*
	✓	other: phytoplankton and macrophytes *(<100 sample/year; single season, multiple sites - not at watershed level)*

Benthos	
sampling gear	Rectangular kick net, 1.5 ft. wide, 800-900 micron mesh. Surber and multiple plate samplers used prior to 1989. Rock baskets used for special projects.
habitat selection	richest habitat, riffle/run (cobble)
subsample size	200 count
taxonomy	benthic identification is primarily to species
Fish	
sampling gear	backpack electrofisher, pram unit (tote barge)
habitat selection	multihabitat
sample processing	length measurement, anomalies
subsample	none
taxonomy	species
Periphyton	
sampling gear	**natural substrate**: brushing/scraping device (razor, toothbrush, etc.)
habitat selection	riffle/run (cobble)
sample processing	chlorophyll *a*/ phaeophytin; biomass; taxonomic identification; semi-quantitative field-based rapid periphyton survey
taxonomy	all algae, species level if possible
Habitat assessments	visual based; performed with bioassessments
Quality assurance program elements	standard operating procedures, quality assurance plan, periodic meetings and training for biologists, sorting and taxonomic proficiency checks, specimen archival

Data Analysis and Interpretation

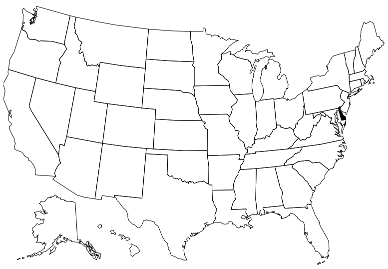
Data analysis tools and methods	✓	summary tables, illustrative graphs
		parametric ANOVAs
		multivariate analysis
	✓	biological metrics *(aggregate metrics into an index)*
		disturbance gradients
		other:

Multimetric thresholds	
transforming metrics into unitless scores	Use scoring criteria table from 1989 Rapid Bioassessment Protocol (RBP) guidance (Figure 6.3-4). CT DEP recognizes the need to refine scoring criteria and impairment thresholds.
defining impairment in a multimetric index	Use biological condition table from 1989 RBP guidance (Figure 6.3-4): >54% of reference score = non-impaired for purposes of 305(b)/303(d)

Evaluation of performance characteristics	✓	repeat sampling *(duplicate samples at reference sites)*
		precision
		sensitivity
		bias
		accuracy

Biological data	
Storage	Initial sample data is entered into an Excel spreadsheet then transferred to MS Access. Currently working on migration from MS Access to STORET.
Retrieval and analysis	Spreadsheet used for metric calculation. Formerly used SAS. Currently shopping for less expensive statistical package.

DELAWARE



Contact Information

Ellen Dickey, Environmental Scientist
Delaware Department of Natural Resources and Environmental Control (DNREC)
89 Kings Highway ■ Dover, DE 19901
Phone 302/739-4771
email: ellen.dickey@state.de.us
DNREC Surface Water Quality Management homepage:
http://www.dnrec.state.de.us/dnrec2000/Divisions/Water/WaterQuality/WQM.htm

Program Description

Water quality and biological data for Delaware's surface waters are collected under Delaware's Ambient Surface Water Quality Monitoring Program and Biological Monitoring Program within the Delaware Department of Natural Resources and Environmental Control (DNREC). Several active citizen monitoring programs have also been developed throughout Delaware that augment the data collected by DNREC. The purpose of the Ambient Surface Water Quality Monitoring Program is to collect data on the chemical, physical, and biological characteristics of Delaware's surface waters. The information collected under this program is used to:

- Describe general water quality conditions in the State;
- Identify long-term trends in water quality;
- Determine the suitability of Delaware's waters for water supply, recreation, fish and aquatic life, and other uses;
- Monitor achievement of water quality standards;
- Identify and prioritize high quality and degraded waters;
- Support Total Maximum Daily Load Program; and
- Evaluate the overall success of Delaware's water quality management efforts.

DNREC recognizes the need to use its personnel and financial resources efficiently and effectively. To that end, surface water quality monitoring is conducted in a manner that focuses available resources on the Whole Basin Management concept. This program calls for the Department, in partnership with other governmental entities, private interests, and all stakeholders, to focus its resources on specific watersheds and basins (groups of watersheds) within specific time frames. The Whole Basin Management Program in Delaware operates on a 5-year rotating basis. In addition to the planning and preliminary assessment steps, Whole Basin Management will include intensive basin monitoring, comprehensive analyses, management option evaluations, and resource protection strategy development. Public participation and ongoing implementation activities will occur throughout the Whole Basin Management process. This new approach enables DNREC to comprehensively monitor and assess the condition of the State's environment with due consideration to all facets of the ecosystem.

Biological assessment monitoring is one of five major components of Delaware's Surface Water Quality Monitoring Program. The biological monitoring program is a major tool used by the Department to assess the conditions of surface waters. It includes the assessment of indigenous biological communities and physical habitats of streams, ponds, estuaries and wetlands. The goal of the program is to establish numeric biological criteria in State water quality standards to complement both existing chemical criteria and other assessments focused on fish tissue monitoring and bioassay testing. Standard methods have been developed and tested for assessing the biological community and habitat quality of nontidal streams, and draft numeric criteria are under development. Efforts over the next few years will focus on the development of methods for assessing estuaries and ponds and for assessing the quality and quantity of wetlands.

Documentation and Further Information

State of Delaware 2000 Watershed Assessment 305(b) Report and 1998 303(d) List:
http://www.dnrec.state.de.us/water2000/Sections/Watershed/TMDL/305and303.htm

DE Surface Water Quality Standards: http://www.dnrec.state.de.us/water/wqs1999.pdf

State of Delaware Fiscal Year 2000 Surface Water Quality Monitoring Plan:
http://www.dnrec.state.de.us/dnrec2000/Library/Water/swmonpro.pdf

Division of Water Resources 2000 Annual Report: http://www.dnrec.state.de.us/water2000/Public/2000AnnualReport/index.htm

DELAWARE

Contact Information

Ellen Dickey, Environmental Scientist
Delaware Department of Natural Resources and Environmental Control (DNREC)
89 Kings Highway ■ Dover, DE 19901
Phone 302/739-4771
email: ellen.dickey@state.de.us

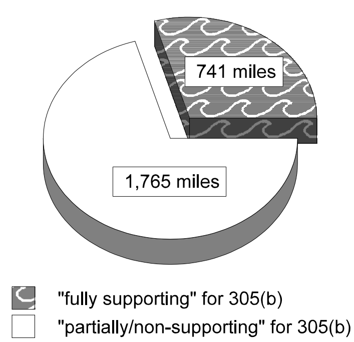
Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
		nonpoint source assessments
	✓	monitoring the effectiveness of BMPs
		ALU determinations/ambient monitoring
		promulgated into state water quality standards as biocriteria
		support of antidegradation
		evaluation of discharge permit conditions
	✓	TMDL assessment and monitoring
		other:
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(special projects only)*
	✓	fixed station (i.e., water quality monitoring stations) *(specific riverbasins or watersheds)*
		probabilistic by stream order/catchment area
		probabilistic by ecoregion, or statewide
		rotating basin
	✓	other: probabilistic by specific county *(used comprehensively throughout state)*

Stream Miles

Total miles *(determined using RF3)*	**2,506**
Total perennial miles	1,778
Total miles assessed for biology*	**2,506**
fully supporting for 305(b)*	741
partially/non-supporting for 305(b)*	1,765
listed for 303(d)*	1,173
number of sites sampled *(1991 - 2001)***	195
number of miles assessed per site	–

2,506 Miles Assessed for Biology



*All of DE's streams were assessed for the 2000 305(b) Report. These numbers represent the miles assessed for aquatic life support using a combination of physical, chemical, and biological data.

**These sampling stations were EMAP based. Of the 195 total sites sampled, 49 sites have not yet been assessed. Of the 146 sites assessed, 27 are fully supporting and 119 are partially/non-supporting.

Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Single Aquatic Life Use and Warm Water vs. Cold Water	
ALU designations in state water quality standards	Two designations: 1) Fish, Aquatic Life, and Wildlife; 2) Cold Water Fish	
Narrative Biocriteria in WQS	none - Procedures used to support general aquatic life statements in WQS are those developed by the Mid Atlantic Coastal Streams (MACS) Workgroup.	
Numeric Biocriteria in WQS	Draft numeric criteria are under development.	
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
		cause and effect determinations
		permitted discharges
		monitoring (e.g., improvements after mitigation)
		watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	Some streams have been placed on the State's 303(d) list for poor biology/habitat.	

Reference Site/Condition Development

Number of reference sites	**13 total**	
Reference site determinations		site-specific
		paired watersheds
	✓	regional (aggregate of sites)
	✓	professional judgment
		other:
Reference site criteria	Least impacted, land use, habitat score >110 out of 140, no point source discharge, no known direct discharge from animal feedlots or urban runoff, professional judgment.	
Characterization of reference sites within a regional context		historical conditions
	✓	least disturbed sites
		gradient response
		professional judgment
		other:
Stream stratification within regional reference conditions	✓	ecoregions (or some aggregate)
		elevation
		stream type
		multivariate grouping
		jurisdictional (i.e., statewide)
		other:
Additional information		reference sites linked to ALU
		reference sites/condition referenced in water quality standards
	✓	some reference sites represent acceptable human-induced conditions

Field and Lab Methods

Assemblages assessed	✓	benthos *(<100 samples/year; single season, multiple sites - broad coverage)*
		fish
		periphyton
		other:

Benthos	
sampling gear	D-frame and kick net (1 meter); 500-600 micron mesh
habitat selection	riffle/run (cobble) in Piedmont ecoregion, and multihabitat in Coastal Plain ecoregion
subsample size	200 count
taxonomy	genus
Habitat assessments	visual based; performed with bioassessments
Quality assurance program elements	standard operating procedures, periodic meetings and training for biologists, sorting proficiency checks, specimen archival, and a QAPP for biological work is under development

Data Analysis and Interpretation

Data analysis tools and methods		summary tables, illustrative graphs
		parametric ANOVAs
		multivariate analysis
	✓	biological metrics *(aggregate metrics into an index)*
		disturbance gradients
		other:

Multimetric thresholds	
transforming metrics into unitless scores	95^{th} percentile of all sites
defining impairment in a multimetric index	< 67% of reference is impaired to some degree

Evaluation of performance characteristics	✓	repeat sampling *(replicate samples are collected at every 10 sites by the same team, at the same reach or an adjacent reach)*
		precision
		sensitivity
		bias
		accuracy

Biological data	
Storage	MS Access and Excel
Retrieval and analysis	Excel

DISTRICT OF COLUMBIA

Contact Information

Nicoline Shulterbrandt, Water Quality Division
Department of Health (DC DOH)
51 N Street, NE, 5th Floor■ Washington, DC 20002
Phone 202/535-2194 ■ Fax 202/535-1363
email: nicoline.shulterbrandt@dc.gov
DOH Water Quality Division homepage:
http://dchealth.dc.gov/services/administration_offices/environmental/services2/water_division/index.shtm

Program Description

The mission of DC's Department of Health (DC DOH), Environmental Health Administration, Water Quality Division is to restore and protect the surface and ground waters of the District of Columbia. The program, established under the authorities of the DC Water Pollution Control Act and the federal Clean Water Act (CWA), has three principal components:

Water Quality Control
The Water Quality Control component fulfills the function of policy planning as well as regulatory control. In addition, it conducts special studies on pollutant fate and transport to identify probable sources and impacts, river/stream sediment and water column quality not covered by ambient monitoring, wet weather nonpoint source runoff quantity and quality, and discharge-related facility inspections. It also tracks permit violations.

Water Quality Monitoring
Water Quality Monitoring functions encompass waterbody assessment; collection of ambient water quality data; periodic fish tissue analysis for parameters of concern such as PCB, chlordane, and DDT; periodic submerged aquatic vegetation survey; and bioassessment of wetlands and river fringes.

Environmental Laboratory
The Environmental Laboratory is charged with the analysis of samples for a variety of chemical parameters.

Documentation and Further Information

District of Columbia 2000 305(b) Report, Executive Summary:
http://dchealth.dc.gov/services/administration_offices/environmental/services2/water_division/pdf/00-305bexsumm.shtm

District of Columbia Water Quality Standards:
http://dchealth.dc.gov/services/administration_offices/environmental/services2/water_division/pdf/WaterQualityStandards.shtm

District of Columbia Water Quality Monitoring Regulations (Chapter 19 of DC Municipal Regulations):
http://dchealth.dc.gov/services/administration_offices/environmental/services2/water_division/pdf/WaterQualityMonitoring.shtm

DISTRICT OF COLUMBIA

Contact Information

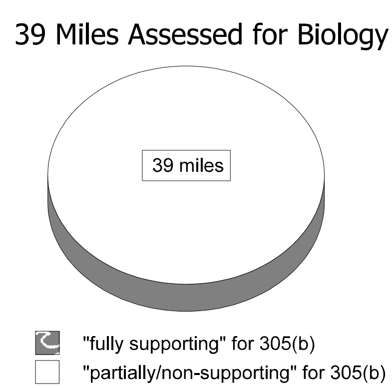
Nicoline Shulterbrandt, Water Quality Division
Department of Health (DC DOH)
51 N Street, NE, 5th Floor■ Washington, DC 20002
Phone 202/535-2194 ■ Fax 202/535-1363
email: nicoline.shulterbrandt@dc.gov

Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
		nonpoint source assessments
		monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
	✓	promulgated into state water quality standards as biocriteria
		support of antidegradation
		evaluation of discharge permit conditions
	✓	TMDL assessment and monitoring
		other:
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(special projects only)*
	✓	fixed station (i.e., water quality monitoring stations) *(comprehensive use throughout jurisdiction)*
		probabilistic by stream order/catchment area
		probabilistic by ecoregion, or statewide
		rotating basin
		other:

Stream Miles

Total miles *(determined using state based GIS coverage)*	**39**
Total perennial miles	–
Total miles assessed for biology	**39**
fully supporting for 305(b)	0
partially/non-supporting for 305(b)	39
listed for 303(d)	unknown
number of sites sampled	unknown
number of miles assessed per site	unknown



Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Single Aquatic Life Use	
ALU designations in state water quality standards	One designation: Protection and propagation of fish, shellfish and wildlife	
Narrative Biocriteria in WQS	Formal/informal numeric procedures are used to support narrative biocriteria	
Numeric Biocriteria in WQS	none	
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)		assessment of aquatic resources
		cause and effect determinations
		permitted discharges
		monitoring (e.g., improvements after mitigation)
		watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	unknown	

Reference Site/Condition Development

Number of reference sites	**2 total**	
Reference site determinations		site-specific
		paired watershed
		regional (aggregate of sites)
	✓	professional judgment
		other:
Reference site criteria	DC DOH does not have reference site criteria. All streams in DC are contaminated. DC DOH compares streams to reference streams in Prince Georges and Montgomery Counties in Maryland.	
Characterization of reference sites within a regional context *Information not provided*		historical conditions
		least disturbed sites
		gradient response
		professional judgment
		other:
Stream stratification within regional reference conditions		ecoregions (or some aggregate)
		elevation
		stream type
		multivariate grouping
	✓	jurisdictional (i.e., statewide)
		other:
Additional information		reference sites linked to ALU
		reference sites/condition referenced in water quality standards
	✓	some reference sites represent acceptable human-induced conditions

Field and Lab Methods

Assemblages assessed	✓	benthos *(<100 samples/year; single observation, limited sampling)*
	✓	fish *(<100 samples/year; single observation, limited sampling)*
		periphyton
	✓	other: phytoplankton and zooplankton *(<100 samples/year; single observation, limited sampling)*

Benthos	
sampling gear	D-frame, kick net (1 meter); mesh size information not provided
habitat selection	riffle/run (cobble)
subsample size	100 count
taxonomy	family
Fish	
sampling gear	backpack electrofisher
habitat selection	pool/glide, riffle/run (cobble)
sample processing	length measurement, biomass – individual
subsample	none
taxonomy	species
Habitat assessments	hydrogeomorphology; performed with bioassessments
Quality assurance program elements	standard operating procedures, quality assurance plan, periodic meetings and training for biologists

Data Analysis and Interpretation

Data analysis tools and methods		summary tables, illustrative graphs
		parametric ANOVAs
		multivariate analysis
	✓	biological metrics
		disturbance gradients
		other:

Multimetric thresholds	
transforming metrics into unitless scores	*Information not provided*
defining impairment in a multimetric index	*Information not provided*
Multivariate thresholds	
defining impairment in a multivariate index	*Information not provided*

Evaluation of performance characteristics		repeat sampling
		precision
Information not provided		sensitivity
		bias
		accuracy

Biological data	
Storage	paper files only
Retrieval and analysis	data retrieved from paper files

FLORIDA

Contact Information

Russel Frydenborg, Environmental Administrator
Florida Department of Environmental Protection (FDEP)
2600 Blair Stone Road ■ Tallahassee, FL 32399-2400
Phone 850/921-9821 ■ Fax 850/922-4614
email: russel.frydenborg@dep.state.fl.us
FDEP Bioassessment homepage: http://www.dep.state.fl.us/water/bioassess/index.htm

Program Description

Biological sampling has been one component of the Florida Department of Environmental Protection's (FDEP) overall monitoring strategy since the early 1970s. The Bioassessment Program, in its current manifestation, has been in existence since 1992, in response to the need for tools that would detect and characterize the nature and extent of nonpoint source pollution (*sensu* the 319 program). The primary goal of FDEP's bioassessment activities are to determine the biological health, or degree of impairment, in the State's surface waters. The biological assessment results are heavily utilized by a number of FDEP programs for making informed environmental decisions:

- Total Maximum Daily Load (303(d)) program – determining the impairment status of waterbodies for potential inclusion on the 303(d) list
- The National Pollutant Discharge Elimination System (NPDES) program – determining effectiveness of discharge permit limits
- Nonpoint Source Program – targeting areas with nonpoint source problems and determining the effectiveness of Best Management Practices
- Rotating Basin Assessment program – overall assessment of all human activities in a watershed
- Mine Reclamation program – determining the success of mitigation efforts
- FDEP's Division of Waste Management – ensuring that clean up efforts are sufficient to protect aquatic life adjacent to waste clean up sites (e.g., RCRA).

Biological data are used in Florida's 305(b) report as one of the key pieces of Aquatic Life Use Support (ALUS) information for determining if a waterbody meets its designated use. Bioassessment data are also used for establishing the impairment status of a waterbody for 303(d) listing purposes.

After recalibration of bioassessment metrics and indices (currently underway), it is anticipated that Florida's water quality standards (Rule 62.302 Florida Administrative Code) will be revised accordingly. Although the primary target community for the bioassessment program is currently benthic macroinvertebrates, Florida is also working on potential assessment methods that use algal and vascular plant assemblages. While multimetric biological indices are currently complete for streams, rivers, and lakes, it is anticipated that ongoing index development for wetlands and estuaries will be finalized over the next several years.

The most important recent accomplishment of the Bioassessment Program has been the inclusion of the Stream Condition Index, the BioRecon, and Lake Condition Index as impairment indicator tools in Florida's Impaired Waters Rule (IWR), Rule 62-303, FAC. The IWR is a new administrative code that provides detailed specifications for how surface waters are determined to be impaired for Section 303(d) listing. Future challenges include incorporating the bioassessment tools into a Statewide probabilistic survey design, as well as continuing to meet the increasing demands for biological tools and data.

Documentation and Further Information

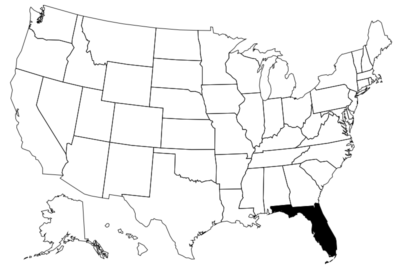
2000 Florida Water Quality Assessment 305(b) Report: http://www.dep.state.fl.us/water/305b/index.htm

Numerous technical reports are available online at http://www.dep.state.fl.us/labs/reports/index.htm and http://www.dep.state.fl.us/water/bioassess/pubs.htm

For an online collection of FDEP standard operating procedures, go to: http://www.dep.state.fl.us/labs/qa/sops.htm

Surface Water Quality Classifications: http://www.dep.state.fl.us/water/surfacewater/index.htm

FLORIDA



Contact Information

Russel Frydenborg, Environmental Administrator
Florida Department of Environmental Protection (FDEP)
2600 Blair Stone Road ■ Tallahassee, FL 32399-2400
Phone 850/921-9821 ■ Fax 850/922-4614
email: russel.frydenborg@dep.state.fl.us

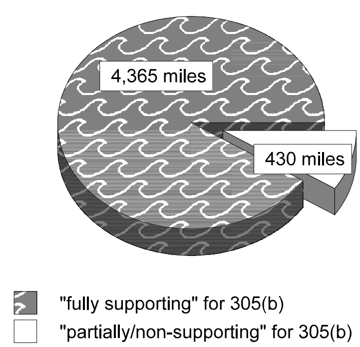
Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
	✓	monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
	✓	promulgated into state water quality standards as biocriteria
	✓	support of antidegradation
	✓	evaluation of discharge permit conditions
	✓	TMDL assessment and monitoring
	✓	other: biocriteria development
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(comprehensive use throughout jurisdiction)*
		fixed station (i.e., water quality monitoring stations)
		probabilistic by stream order/catchment area
		probabilistic by ecoregion, or statewide
	✓	rotating basin *(5-year rotation, comprehensive use throughout jurisdiction)*
		other:

Stream Miles

Total miles *(determined using waterbody identification- segment of stream, generally 5 mile increments)*	**51,858**
Total perennial miles	22,993
Total miles assessed for biology	**4,795**
fully supporting for 305(b)	4,365
partially/non-supporting for 305(b)	430
listed for 303(d)	430
number of sites sampled (over 2 years)	959
number of miles assessed per site	5

4,795 Miles Assessed for Biology



Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Single aquatic life use	
ALU designations in state water quality standards	One designation: propagation of a healthy, well balanced fish and wildlife community	
Narrative Biocriteria in WQS	Procedures used to support narrative biocriteria located in FDEP's Standard Operating Procedures	
Numeric Biocriteria in WQS	Numeric biocriteria located in Rule 62-302 Florida Administrative Code – "Shannon-Weaver diversity shall not be reduced more than 25% of background conditions" *	
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
	✓	cause and effect determinations
	✓	permitted discharges
	✓	monitoring (e.g., improvements after mitigation)
	✓	watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	TMDLs, restoration/mitigation studies, BMP effectiveness studies, discharge permit renewal	

*Florida has made substantial progress in developing new multimetric indices for streams (Stream Condition Index and BioRecon), lakes (Lake Condition Index), and wetlands for eventual inclusion in the Florida Administrative Code. When the new indices are adopted as water quality standards, the role of Shannon-Weaver diversity as a numeric standard will be re-evaluated.

Reference Site/Condition Development

Number of reference sites	**150 total**	
Reference site determinations		site-specific
		paired watersheds
	✓	regional (aggregate of sites)
	✓	professional judgment
		other:
Reference site criteria	least impaired by human activities in a region, optimal habitat, benign land use in watershed, uncontaminated water quality, undisturbed hydrology	
Characterization of reference sites within a regional context		historical conditions
	✓	least disturbed sites
	✓	gradient response *(for recalibration of existing indexes)*
		professional judgment
		other:
Stream stratification within regional reference conditions	✓	ecoregions (or some aggregate)
		elevation
		stream type
		multivariate grouping
		jurisdictional (i.e., statewide)
		other:
Additional information		reference sites linked to ALU
		reference sites/condition referenced in water quality standards
	✓	some reference sites represent acceptable human-induced conditions

Field and Lab Methods

Assemblages assessed	✓	benthos *(100-500 samples/year; single season, multiple sites - watershed level)*
		fish
	✓	periphyton *(100-500 samples/year; single season, multiple sites - not at watershed level)*
	✓	other: phytoplankton, macrophytes *(100-500 samples/year; single observation, limited sampling)*

Benthos	
sampling gear	d-frame, dipnet (500-600 micron mesh), multiplate (Hester-Dendys)
habitat selection	multihabitat (snags, roots, leaf packs, aquatic vegetation)
subsample size	100-count target
taxonomy	species level (where possible)
Periphyton	
sampling gear	**natural substrate**: brushing/scraping device (razor, toothbrush, etc.), collect by hand **artificial substrate**: periphytometer, microslides or other suitable substratum
habitat selection	multihabitat
sample processing	chlorophyll *a*/phaeophytin, taxonomic identification
taxonomy	all algae, species level (diatoms to variety level)
Habitat assessments	visual based; performed with bioassessments
Quality assurance program elements	standard operating procedures, quality assurance plan, periodic meetings and training for biologists, sorting and taxonomic proficiency checks, specimen archival, habitat assessment tests, sampling field audits, sampling variability studies, performance testing program for bioassessment

Data Analysis and Interpretation

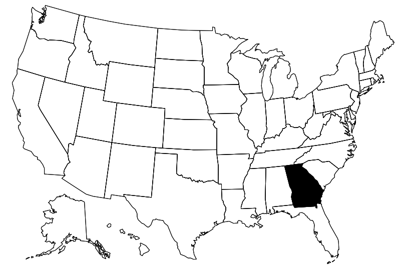
Data analysis tools and methods	✓	summary tables, illustrative graphs
		parametric ANOVAs
		multivariate analysis
	✓	biological metrics *(aggregate metrics into an index)*
	✓	disturbance gradients
		other:

Multimetric thresholds	
transforming metrics into unitless scores	25th percentile of reference population
defining impairment in a multimetric index	quadrasection of best score

Evaluation of performance characteristics	✓	repeat sampling *(same team, same reach; different teams in same reach)*
	✓	precision *(coefficient of variation)*
		sensitivity
		bias
	✓	accuracy *(species accumulation)*

Biological data	
Storage	custom Oracle-based program, “S-BIO”
Retrieval and analysis	custom Oracle-based program, “S-BIO”

GEORGIA



Contact Information

Kathy Methier, Ambient Monitoring Unit Manager
Georgia Department of Natural Resources (GA DNR)
4220 International Parkway, Suite 101 ■ Atlanta, GA 30354
Phone 404/675-6236 ■ Fax 404/675-6244
email: kathy_methier@dnr.state.ga.us
GA DNR Environmental Protection Division: http://www.dnr.state.ga.us/dnr/environ/

Program Description

The Georgia Department of Natural Resources (GA DNR) Environmental Protection Division (EPD) monitoring program integrates physical, chemical, and biological monitoring to provide information for water quality, use attainment assessments, and basin planning. EPD monitors the surface waters of the state to collect baseline and trend data, document existing conditions, study impacts of specific discharges, determine improvements resulting from upgraded water pollution control plants, support enforcement actions, establish wasteload allocations for new and existing facilities, verify water pollution control plant compliance, document water use impairment and reasons for problems causing less than full support of designated water uses, and develop TMDLs. Intensive surveys; lake, coastal, biological, fish tissue, toxic substance, and trend monitoring; and facility compliance sampling are the major monitoring tools used by EPD.

Long-term, trend, and ambient monitoring of streams at strategic locations throughout Georgia, was initiated by EPD during the late 1960s. This work was and continues to be accomplished to a large extent through cooperative agreements with federal, state, and local agencies who collect samples from groups of stations at specific, fixed locations throughout the year.

In 1995, EPD adopted and implemented significant changes to the strategy for trend monitoring in Georgia. The changes were implemented to support the River Basin Management Planning program. The number of fixed stations statewide was reduced in order to focus resources for sampling and analysis in a particular group of basins in any one year in accordance with the basin planning schedule. This approach provides the framework for identifying, assessing, and prioritizing water resource issues, developing implementation strategies, and providing opportunities for targeted, cooperative actions to reduce pollution, enhance aquatic habitat, and provide a dependable water supply.

The Watershed Planning and Monitoring Section of the EPD Water Protection Branch performs the following tasks:

- Conducts monitoring of Georgia streams, rivers, lakes and estuaries for use with wasteload allocations and to determine compliance with water quality standards;
- Develops River Basin Management Plans for river basins in Georgia;
- Conducts water quality modeling for wasteload allocations, water use classifications, and water quality standards in Georgia; and
- Collects samples of facility discharges for laboratory testing of samples.

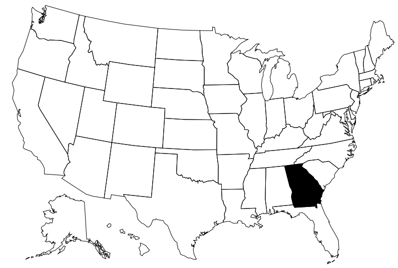
Currently, reference site selection and biocriteria development are being carried out under contract with Columbus State University. The project is in Phase III with projected completion in 2003. The final phase, Phase IV, is projected to be completed in 2004.

Documentation and Further Information

Georgia's 2000 305(b) Report, *Water Quality in Georgia, 1998-1999;* the *Final Georgia 2000 305(b)/303(d) List Documents*, including *Summary of Changes from the 2000 to 2002 305(b)/303(d) List*, can be found under Georgia's Environment, Water Quality in the Table of Contents at the following site:
http://www.dnr.state.ga.us/dnr/environ/

2000. DRAFT *Standard Operating Procedures for Freshwater Macroinvertebrate Biological Assessment*. Georgia Department of Natural Resources, Water Protection Branch, Atlanta, GA.

GEORGIA



Contact Information

Kathy Methier, Ambient Monitoring Unit Manager
Georgia Department of Natural Resources (GA DNR)
4220 International Parkway, Suite 101 ■ Atlanta, GA 30354
Phone 404/675-6236 ■ Fax 404/675-6244
email: kathy_methier@dnr.state.ga.us

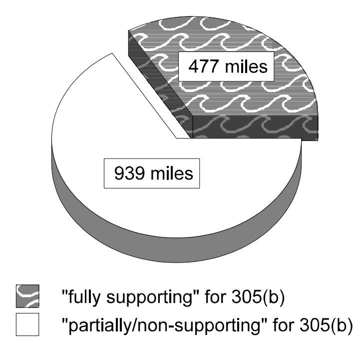
Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
	✓	monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
	✓	promulgated into state water quality standards as biocriteria
	✓	support of antidegradation
	✓	evaluation of discharge permit conditions
	✓	TMDL assessment and monitoring
		other:
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(specific river basins or watersheds)*
	✓	fixed station (i.e., water quality monitoring stations) *(specific river basins or watersheds, and comprehensive use throughout jurisdiction)*
		probabilistic by stream order/catchment area
		probabilistic by ecoregion, or statewide
	✓	rotating basin *(comprehensive use throughout jurisdiction)*
		other:

Stream Miles

Total miles *(determined using state based coverage)*	**70,150**
Total perennial miles	44,056
Total miles assessed for biology*	**1,416**
fully supporting for 305(b)	477
partially/non-supporting for 305(b)	939
listed for 303(d)	–
number of sites sampled *(in 2000)*	153
number of miles assessed per site	varies

1,416 Miles Assessed for Biology



*In 2000, 72 stations were sampled and a total of 477 miles were assessed as fully supporting for 305(b) (6.6 miles assessed/station); 75 stations were sampled and a total of 799 miles were assessed as partially supporting (10.7 miles assessed/station); 6 stations were sampled and 140 miles were assessed as not supporting (23.3 miles assessed/station). This results in a total of 153 stations and 1,416 stream miles assessed in 2000 (9.25 miles assessed/station). The stream miles listed above are not divided into those monitored for biology versus chemistry because 305(b) reporting requirements use both types of data. The sampling length per site varies and the length of stream represented by each sample is determined by the surrounding hydrography.

Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Fishery Based Uses	
ALU designations in state water quality standards	Three designations: Coastal fishing; fishing, propagation of fish, shellfish, game, and other aquatic life; primary and secondary trout waters	
Narrative Biocriteria in WQS	Procedures used to support narrative biocriteria are located in the Environmental Protection Division’s SOPs for macroinvertebrates and DNR/Wildlife Resources Division's IBI protocols for fish	
Numeric Biocriteria in WQS	none	
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
	✓	cause and effect determinations
	✓	permitted discharges
	✓	monitoring (e.g., improvements after mitigation)
	✓	watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	Fish IBI and macroinvertebrate assessments were conducted to evaluate approximately 80 previously 303(d)-listed sites in the last two years. While some sites were removed from the list others, found to be impaired due to (clean) sediment deposition, remained on the list.	

Reference Site/Condition Development

Number of reference sites	**Reference site selection is under development.**	
Reference site determinations		site-specific
		paired watersheds
	✓	regional (aggregate of sites)
		professional judgment
		other:
Reference site criteria	Columbus State University is using several criteria for selecting reference sites, including minimum overall habitat score, managed land, urban land, minimum forested riparian zone width, forested riparian zone in catchment, silviculture activity, and point source discharges. Reference sites would be defined as least-disturbed according to these criteria.	
Characterization of reference sites within a regional context		historical conditions
	✓	least disturbed sites
		gradient response
		professional judgment
		other:
Stream stratification within regional reference conditions	✓	ecoregions (or some aggregate)
		elevation
		stream type
		multivariate grouping
		jurisdictional (i.e., statewide)
		other:
Additional information		reference sites linked to ALU
		reference sites/condition referenced in water quality standards
	✓	some reference sites represent acceptable human-induced conditions

Field and Lab Methods

Assemblages assessed	✓	benthos *(100-500 samples/year; single season, multiple sites - watershed level)*
	✓	fish *(100-500 samples/year; single season, multiple sites - watershed level)*
		periphyton
		other:

Benthos	
sampling gear	collect by hand and D-frame; 500-600 micron mesh
habitat selection	multihabitat
subsample size	200 count
taxonomy	genus
Fish	
sampling gear	seine, backpack electrofisher, pram unit (tote barge); 3/16" and 1/4" mesh
habitat selection	Sample all habitats within a sample reach that is 35X the mean stream width. Habitat assessments are broken out between riffle/run and glide/pool based on the ecoregion in which the sample is located.
sample processing	biomass – batch, anomalies
subsample	none
taxonomy	species
Habitat assessments	visual based and zig-zag pebble count; performed with bioassessments
Quality assurance program elements	standard operating procedures, quality assurance plan, periodic meetings and training for biologists, sorting and taxonomic proficiency checks

Data Analysis and Interpretation

Data analysis tools and methods	✓	summary tables, illustrative graphs
		parametric ANOVAs
	UD	multivariate analysis
	✓	biological metrics *(aggregate metrics into an index)*
		disturbance gradients
		other:

Multimetric thresholds	
transforming metrics into unitless scores	under development
defining impairment in a multimetric index	under development
Multivariate thresholds	
defining impairment in a multivariate index	under development

Evaluation of performance characteristics		repeat sampling
		precision
Not currently evaluated		sensitivity
		bias
		accuracy

Biological data	
Storage	EDAS and Excel
Retrieval and analysis	EDAS

HAWAI`I

Contact Information

Katina Henderson, Water Quality Management Planner
Hawai`i State Department of Health (HIDOH)
919 Ala Moana Boulevard, Room 312 ■ Honolulu, HI 96814
Phone 808/587-4337 ■ Fax 808/587-4370
email: khenderson@eha.health.state.hi.us
HIDOH Environmental Planning Office homepage: http://www.hawaii.gov/health/eh/epo

Program Description

The primary objective of the Hawai`i State Department of Health (HIDOH) Bioassessment Program is to augment the commonly used physical and chemical water quality assessments performed (during ambient monitoring, use attainability studies, and other investigations) for classification, evaluation and regulation of water bodies. The program primarily utilizes the Hawai`i Stream Bioassessment Protocol (HSBP) 3.01 developed by Mike Kido and the Hawai`i Natural Resources Conservation Service (NRCS) Visual Assessment protocol for characterization of streams. HIDOH currently uses these protocols in conjunction with water quality data to establish TMDLs in the State of Hawai`i. In the future the HSBP and the Hawai`i NRCS protocol will be used in conjunction with physical and chemical water quality data to classify streams and determine exceedances of narrative criteria.

The HSBP includes both habitat and biotic metrics. The general approach of the HSBP is to compare measures of community characteristics and habitat of a study stream to a minimally impacted ecoregional reference condition. An Index of Biotic Integrity, currently focused on fish, composes the biotic portion of the protocol. Much of the basis for evaluation is the presence or absence of native taxa and the introduction of non-native species. Low abundance or low diversity of native fauna suggests diminished biological integrity. The habitat portion of the HSBP includes standard habitat metrics, including bank stability, embeddedness, canopy cover and presence of fine and coarse organic material. The State of Hawai`i will soon be working with USGS to census the macroinvertebrate community in Hawai`i and develop metrics for the Hawai`i Bioassessment Program, which will add a component to measure pollution tolerance. The macroinvertebrate community in Hawai`i is quite different from that of the mainland United States; therefore, the metric may be quite unlike that of any other state.

As a preliminary evaluation of sites and to compliment the HSBP habitat component, the Hawai`i NRCS Visual Assessment protocol is applied. This is a modified version of the national NRCS visual assessment protocol.

The State Water Quality Management Planner, along with a Stream Bioassessment Intern, primarily perform these assessments. Additionally, other scientists from HIDOH, scientists from other local, state and federal agencies, local university students and professors, and skilled community members volunteer their time to help perform these protocols. The time demand of each task is dependent upon the number of aquatic organisms in the stream, the size of the stream, and other local conditions. HIDOH currently sponsors training courses in the protocols to those with a scientific background on a limited basis.

Documentation and Further Information

excerpts from *Hawai`i 2000 305(b) Report*: http://www.hawaii.gov/health/eh/cwb/2000-305b/index.html

Proposed 2001 revisions to *Hawai`i Water Quality Standards, January 2002 Indicators of Environmental Quality Report:* http://www.hawaii.gov/health/eh/epo/wqrev.htm

Hawai`i Stream Bioassessment Protocol, Michael Kido, Version 3.01, January 2001: http://www.state.hi.us/doh/eh/epo/kawa.pdf

HAWAI`I

Contact Information

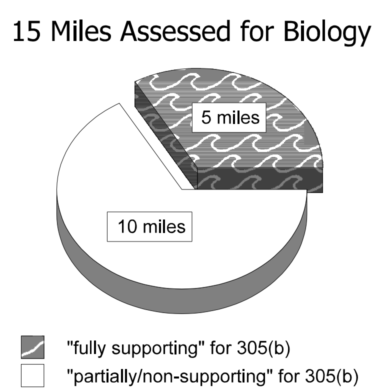
Katina Henderson, Water Quality Management Planner
Hawai`i State Department of Health (HIDOH)
919 Ala Moana Boulevard, Room 312 ■ Honolulu, HI 96814
Phone 808/587-4337 ■ Fax 808/587-4370
email: khenderson@eha.health.state.hi.us

Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
		monitoring the effectiveness of BMPs
		ALU determinations/ambient monitoring
	UD	promulgated into state water quality standards as biocriteria
		support of antidegradation
		evaluation of discharge permit conditions
	✓	TMDL assessment and monitoring
		other:
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(special projects only)*
		fixed station (i.e., water quality monitoring stations)
		probabilistic by stream order/catchment area
		probabilistic by ecoregion, or statewide
	✓	rotating basin *(specific river basins or watersheds)*
		other:

Stream Miles

Total miles *(determined using state based coverage)*	**249**
Total perennial miles	249
Total miles assessed for biology	**15**
fully supporting for 305(b)	5
partially/non-supporting for 305(b)	10
listed for 303(d)	10
number of sites sampled *(on an annual basis)*	17
number of miles assessed per site*	<1



*Less than 1 mile assessed per site was determined by dividing the 15 total miles assessed for biology by the 17 sites sampled, which equals roughly .88 miles.

Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Class System (A,B,C)	
ALU designations in state water quality standards	Two designations: 1) Protection of native breeding stock, and 2) Support and propagation of aquatic life	
Narrative Biocriteria in WQS	under development	
Numeric Biocriteria in WQS	under development – Hawai`i is currently proposing to add numeric biocriteria to WQS	
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
		cause and effect determinations
		permitted discharges
		monitoring (e.g., improvements after mitigation)
	✓	watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	none	

Reference Site/Condition Development

Number of reference sites	**3 total**	
Reference site determinations		site-specific
		paired watersheds
	✓	regional (aggregate of sites)
		professional judgment
		other:
Reference site criteria	Minimally impacted and most pristine. Always scores near 100% when using the Hawai`i Stream Bioassessment Protocol no matter when and where sampled.	
Characterization of reference sites within a regional context		historical conditions
	✓	least disturbed sites
		gradient response
		professional judgment
		other:
Stream stratification within regional reference conditions	✓	ecoregions (or some aggregate) *(the entire State of Hawai`i is one ecoregion)*
		elevation
		stream type
		multivariate grouping
		jurisdictional (i.e., statewide)
		other:
Additional information		reference sites linked to ALU
		reference sites/condition referenced in water quality standards
	✓	some reference sites represent acceptable human-induced conditions

Field and Lab Methods

Assemblages assessed	UD	benthos *(Hawai`i will soon be working with USGS to census the macroinvertebrate community in Hawai`i and develop metrics)*
	✓	fish *(<100 samples/year; single season, multiple sites - watershed level)*
		periphyton
		other:

Fish	
sampling gear	backback electrofisher and snorkel
habitat selection	multihabitat
sample processing	length measurement and biomass - individual
subsample	selected species
taxonomy	species
Habitat assessments	visual based, habitat availability, substrate embeddedness, Fine and Coarse Particulate Organic Matter (FPOM/CPOM) characterization, velocity-depth combinations, channel flow status, channel alteration, bank stability, riparian vegetative zone width, riparian understory coverage, and percent native riparian plant coverage; performed with bioassessments
Quality assurance program elements	standard operating procedures, periodic meetings and training for biologists, and taxonomic proficiency checks

Data Analysis and Interpretation

Data analysis tools and methods	✓	summary tables, illustrative graphs
		parametric ANOVAs
		multivariate analysis
	✓	biological metrics *(aggregate metrics into an index)*
		disturbance gradients
		other:

Multimetric thresholds	
transforming metrics into unitless scores	under development
defining impairment in a multimetric index	under development*

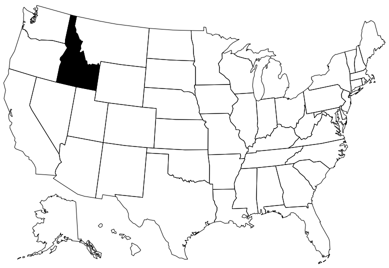
Evaluation of performance characteristics		repeat sampling
		precision
Not currently evaluated		sensitivity
		bias
		accuracy

Biological data	
Storage	Excel
Retrieval and analysis	Statistica

*The following are the *proposed* impairment thresholds:

	Class 1a (mainly undeveloped, "unimpaired")	Class 2a (mainly developed, “unimpaired”)
Habitat	greater than or equal to 75% of reference condition	between 50% and 75% of reference condition
Biotic integrity	greater than or equal to 70% of reference condition	between 30% and 70% of reference condition

IDAHO



Contact Information

Cynthia Grafe, Water Quality Assessment Program Coordinator
State of Idaho Department of Environmental Quality (IDEQ)
1410 North Hilton ■ Boise, ID 83706
Phone 208/373-0163 ■ Fax 208/373-0576
email: cgrafe@deq.state.id.us
IDEQ Water Quality homepage: http://www2.state.id.us/deq/water/water1.htm

Program Description

The Idaho surface water program uses biological information extensively to determine use support and impairment. In 1993, the Idaho Department of Environmental Quality (IDEQ) implemented a rapid bioassessment program aimed at integrating biological and chemical monitoring with physical habitat assessment as a way of characterizing water quality and stream integrity. This program, know as the Beneficial Use Reconnaissance Program (BURP), closely follows concepts and methods described in the *Rapid Bioassessment Protocols for Use in Streams and Rivers* (USEPA 1999). The main purpose of BURP is to provide consistency in monitoring, collecting data, and reporting. Specifically, biological along with physical, chemical, and landscape data are used to address the following objectives:

- Determine the degree of beneficial use support of the water body
- Determine the degree of biological integrity using biological information or other measures
- Compile descriptive information about the water body and data used in the assessment.

IDEQ has formal monitoring and assessment methods in place for large rivers and small streams. Methods for lakes and reservoirs are in development. For rivers and streams, there are a total of 8 multimetric indices for benthic macroinvertebrates, periphyton, fish, habitat, and physicochemical measures. Indices are integrated into attaining or non-attaining use support determinations. The integration uses a weight-of-evidence approach combined with individual minimum benchmarks for each assemblage and numeric criteria exceedances.

IDEQ has several plans to improve the current monitoring and assessment program. A draft statewide monitoring strategy will be introduced in July 2002. Future plans include incorporating a probabilistic monitoring design for screening purposes as well as adding methods for other water body types (e.g., wetlands, intermittent streams, springs, etc.). Implementation of these plans is dependent on agency priorities and available resources.

Documentation and Further Information

Idaho's 1998 303(d) List: http://www2.state.id.us/deq/water/1998_303d/303dlist.pdf

Grafe, C.S.et al. 2002. *Water body assessment guidance, 2nd edition*. Idaho Department of Environmental Quality. Boise, Idaho. 113 pp. http://www2.state.id.us/deq/water/surface_water/wbag/WBAG2001.htm

Grafe, C.S. (editor) April 2002. *Idaho small stream ecological assessment framework: an integrated approach*. Idaho Department of Environmental Quality. Boise, Idaho. 304 pp.
http://www2.state.id.us/deq/water/surface_water/wbag/WBAG_AssessmentFramework.htm

Grafe, C.S. (editor). April 2002. *Idaho river ecological assessment framework: an integrated approach*. Idaho Department of Environmental Quality. Boise, Idaho. 222 pp.
http://www2.state.id.us/deq/water/surface_water/wbag/WBAG_AssessmentFramework.htm

Beneficial Use Reconnaissance Program (BURP) 2001 Annual Work Plan for Wadeable (Small) Streams, 2001:
http://www2.state.id.us/deq/water/surface_water/2001_BURP_annual_work_plan_wadeable_streams.pdf

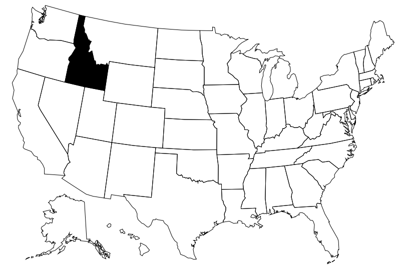
BURP Quality Assurance Plan for Field Data Sheets on Wadeable (Small) Streams, 2001:
http://www2.state.id.us/deq/water/surface_water/BURP_QualityAssurancePlan.pdf

1999 BURP Workplan for Wadeable Streams (Methods Manual):
http://www2.state.id.us/deq/water/surface_water/99_BURP_WORKPLAN.pdf

Streams: 1999 Post-Field Evaluation Summary Report (BURP), 2001:
http://www2.state.id.us/deq/water/surface_water/BURP_streams_Field_Report_99.pdf

Public Involvement and Response to Comment Summary:
http://www2.state.id.us/deq/water/surface_water/wbag/WBAG2001.htm

IDAHO



Contact Information

Cynthia Grafe, Water Quality Assessment Program Coordinator
State of Idaho Department of Environmental Quality (DEQ)
1410 North Hilton ■ Boise, ID 83706
Phone 208/373-0163 ■ Fax 208/373-0576
email: cgrafe@deq.state.id.us

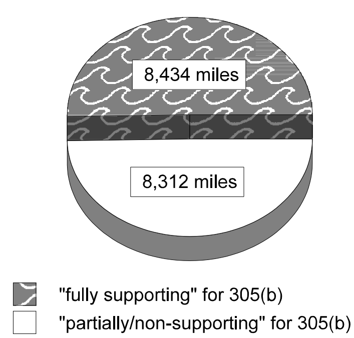
Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
	✓	monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
	✓	promulgated into state water quality standards as biocriteria
		support of antidegradation
		evaluation of discharge permit conditions
	✓	TMDL assessment and monitoring
		other:
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(special projects, specific river basins or watersheds, and comprehensive use throughout jurisdiction)*
	✓	fixed station (i.e., water quality monitoring stations) *(special projects only)*
		probabilistic by stream order/catchment area
		probabilistic by ecoregion, or statewide
		rotating basin
		other:

Stream Miles

Total miles *(determined using the National Hydrography Database)*	**96,200**
Total perennial miles	49,500
Total miles assessed for biology	**16,742**
fully supporting for 305(b)	8,434
partially/non-supporting for 305(b)	8,312
listed for 303(d)	8,312
number of sites sampled	4,500
number of miles assessed per site	~3.5

16,742 Miles Assessed for Biology



Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Warm Water vs. Cold Water	
ALU designations in state water quality standards	Sub-categories are cold water, seasonal cold water, warm water, modified (UAA required), and salmonid spawning.	
Narrative Biocriteria in WQS	IDEQ's "Waterbody Assessment Guidance" and supporting technical reports are used to interpret and implement WQS, including ALU assessment. Although the term "biocriteria" is not used, functional elements are included in the WQS and in implementing ALU designation and support status guidance. Please see: http://www2.state.id.us/adm/adminrules/rules/IDAPA58/58INDEX.HTM	
Numeric Biocriteria in WQS	none	
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
	✓	cause and effect determinations
	✓	permitted discharges
	✓	monitoring (e.g., improvements after mitigation)
	✓	watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	Used as restoration criteria in CERCLA cleanup monitoring effectiveness plans/consent decrees; bioassessment is required prior to removing 303(d) listed waters Most TMDLs have ALUS biomonitoring as part of implementation; one recent example is the North Fork of the Coeur d'Alene River.	

Reference Site/Condition Development

Number of reference sites	**200 total**	
Reference site determinations		site-specific
		paired watersheds
	✓	regional (aggregate of sites)
	✓	professional judgment
		other:
Reference site criteria	Reference site criteria based on nearby road condition, riparian vegetation complexity, channel morphology and complexity, habitat structure complexity, evidence of chemical stressors, substrate heterogeneity, and evidence of point and nonpoint sources. Also, land satellite images are reviewed for evidence of disturbance in the watershed (see IDAPA 58.01.02.003.85).	
Characterization of reference sites within a regional context		historical conditions
	✓	least disturbed sites
		gradient response
	✓	professional judgment
	✓	other: mostly least disturbed sites, but also minimally disturbed sites in some bioregions
Stream stratification within regional reference conditions		ecoregions (or some aggregate)
		elevation
		stream type
		multivariate grouping
		jurisdictional (i.e., statewide)
	✓	other: bioregions based on groupings of ecoregions. Some of the indices classify by elevation and stream type.
Additional information	✓	reference sites linked to ALU
		reference sites/condition referenced in water quality standards
	✓	some reference sites represent acceptable human-induced conditions

Field and Lab Methods

Assemblages assessed	✓	benthos *(100-500 samples/year; single season, multiple sites - broad coverage)*
	✓	fish *(100-500 samples/year; single season, multiple sites - broad coverage)*
	✓	periphyton *(100-500 samples/year; single season, multiple sites - broad coverage)*
		other:

Benthos	
sampling gear	Surber, Hess, Slack (0.5 meter, in rivers only); 500-600 micron mesh
habitat selection	richest habitat
subsample size	500 count
taxonomy	species
Fish	
sampling gear	backpack electrofisher
habitat selection	multihabitat
sample processing	length measurement, biomass - individual, biomass - batch and anomalies
subsample	none; full sample work-up
taxonomy	species (count and keep voucher specimens for species that are not identified in the field)
Periphyton	
sampling gear	**natural substrate**: brushing/scraping device (razor, toothbrush, etc.)
habitat selection	selected near macroinvertebrate sample
sample processing	taxonomic identification
taxonomy	species level
Habitat assessments	visual based, canopy closure (densiometer), Wolman pebble count, pool complexity (width, depth), stream width/depth, large woody debris; performed with bioassessments
Quality assurance program elements	standard operating procedures, quality assurance plan, periodic meetings and training for biologists, sorting and taxonomic proficiency checks, specimen archival

Data Analysis and Interpretation*

Data analysis tools and methods	✓	summary tables, illustrative graphs
	✓	parametric ANOVAs
	✓	multivariate analysis
	✓	biological metrics *(aggregate metrics into an index)*
	✓	disturbance gradients
		other:

Multimetric thresholds	
transforming metrics into unitless scores	Varies by index - a combination of 95th percentile of reference and cumulative distribution function used to scale metrics scores is most frequently used.
defining impairment in a multimetric index	25th percentile of reference population**

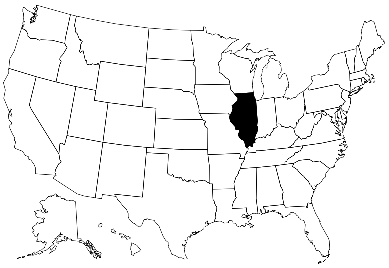
Evaluation of performance characteristics	✓	repeat sampling
	✓	precision *(variability study of reference conditions)*
	✓	sensitivity
	✓	bias
	✓	accuracy

Biological data	
Storage	MS Access, changing to Oracle/Visual Basic indexed to NHD
Retrieval and analysis	Custom interface (Biological Assessment Tool) developed to calculate metrics, indices, and physical and biological summary statistics. Systat is also used.

*Formal methods have been developed for non-wadeable rivers and wadeable streams. Lentic methods are under development. A total of eight multimetric indices for bugs, diatoms, fish, habitat, and physicochemical measures have been developed or adapted for rivers and streams. Indices are integrated into attaining or non-attaining use support determinations.

**Idaho uses a measure of CONDITION, which aggregates 3 different indices - Habitat, Benthos and Fish. Each index is compared to the median of reference condition and is given a score of 1, 2 or 3. All three scores are then combined (averaged). If > or = 2, then fully supporting; if <2, then not supporting.

ILLINOIS



Contact Information

Gregg Good, Manager - Surface Water Section
Illinois Environmental Protection Agency (IEPA)
1021 North Grand Avenue East ■ Springfield, Illinois 62794-9276
Phone 217/782-3362 ■ Fax 217/785-1225
email: gregg.good@epa.state.il.us
IEPA Bureau of Water homepage: http://www.epa.state.il.us/water/

Program Description

Illinois EPA (IEPA) conducts intensive river basin surveys on a five-year rotational basis in cooperation with the Illinois Department of Natural Resources (IDNR). These surveys are a major source of information for annual 305(b) assessments. Illinois has 33 major river basins within its borders. Stations sampled by IEPA and IDNR are selected on the basis of where intensive data are currently lacking or historical data need updating. Water chemistry and biological (fish and macroinvertebrate) data along with qualitative and quantitative instream habitat information, including stream discharge, are collected to characterize stream segments within the basin, identify water quality conditions, and evaluate aquatic life use impairment. Fish tissue contaminant and sediment chemistry sampling are also conducted to screen for the accumulation of toxic substances.

Illinois' "biological expectations" are based on a regional reference site approach that enables within-region comparisons between the aquatic community at any stream site and the reference expectation. The regional reference site approach is a key component of biocriteria. The approach ensures reasonably attainable biological goals that recognize and account for the unique combination of regional land form, land use, and physical habitat characteristics, which influence the distribution of fish, macroinvertebrates and other aquatic organisms. Illinois is currently developing this framework, which includes refinement of existing biological assessment tools and, where needed, development of new state-of-the-art monitoring approaches.

Illinois EPA is working with IDNR, USEPA, members of the agricultural, industrial, academic and regulated communities, as well as outside contractors, and other interested parties to develop biological criteria for streams and rivers. This approach to biocriteria will enable IEPA to better assess the ecological/environmental quality of Illinois rivers and streams and should allow the Agency to continue to update and refine the stream use designations contained in Illinois' water quality standards.

Documentation and Further Information

Illinois Water Quality Report 2002 (CWA Section 305(b) Report), July 2002, IEPA, Bureau of Water:
http://www.epa.state.il.us/water/water-quality/report-2002/305b-2002.pdf

2001 305(b) Summary Report (1999 data), Rivers and Streams:
http://www.epa.state.il.us/water/water-quality/report-2001/report-2001.pdf

Condition of Illinois Water Resources - menu of Illinois 305(b) Reports and Assessments, including maps and graphs: http://www.epa.state.il.us/water/water-quality/index.html

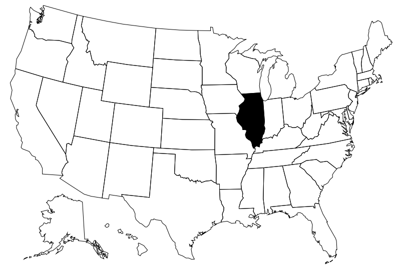
Illinois Targeted Watershed Approach: http://www.epa.state.il.us/water/targeted-watershed/index.html

IEPA Bureau of Water, Surface Water Quality Monitoring and Assessment Programs homepage:
http://www.epa.state.il.us/water/surface-water/index.html

IEPA Bureau of Water, River and Stream Monitoring Program homepage, with links to biocriteria development and other relevant information: http://www.epa.state.il.us/water/surface-water/river-stream-mon.html

Hite, R.L. and B.A. Bertrand. 1989. *Biological Stream Characterization (BSC): A Biological Assessment of Illinois Stream Quality*, Special Report No. 13 of the Illinois State Water Plan Task Force. Illinois Environmental Protection Agency.

ILLINOIS



Contact Information

Gregg Good, Manager - Surface Water Section
Illinois Environmental Protection Agency (IEPA)
1021 North Grand Avenue East ■ Springfield, Illinois 62794-9276
Phone 217/782-3362 ■ Fax 217/785-1225
email: gregg.good@epa.state.il.us

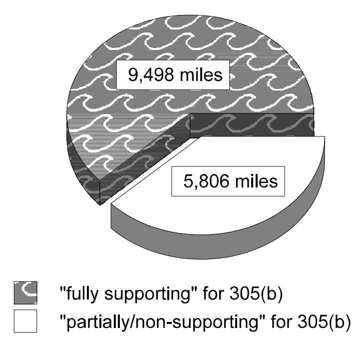
Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
		monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
	UD	promulgated into state water quality standards as biocriteria
	✓	support of antidegradation
	✓	evaluation of discharge permit conditions
	✓	TMDL assessment and monitoring
		other:
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(special projects and specific river basins or watersheds)*
	✓	fixed station (i.e., water quality monitoring stations) *(comprehensive use throughout jurisdiction)*
		probabilistic by stream order/catchment area
		probabilistic by ecoregion, or statewide
	✓	rotating basin *(comprehensive use throughout jurisdiction)*
		other:

Stream Miles

Total miles *(determined using RF3 and existing maps)*	**86,021**
Total perennial miles	30,246
Total miles assessed for biology	**15,304**
fully supporting for 305(b)	9,498
partially/non-supporting for 305(b)	5,806
listed for 303(d)*	–
number of sites sampled	115
number of miles assessed per site**	site specific

15,304 Miles Assessed for Biology



*Total miles listed for 303(d) is a subset of the miles partially/non-supporting for 305(b) and will be determined in the next update.

**10 miles for wadeable sites and 25 miles for non-wadeable sites with some site-specific detailing following the 1997 305(b) guidance.

Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Single Aquatic Life Use	
ALU designations in state water quality standards	Secondary contact and indigenous aquatic life use waters (IL Title 35, Subtitle C, Chapter I, Part 303.204)	
Narrative Biocriteria in WQS	under development - IEPA has written guidelines and thresholds for fish and invertebrate indices that are not part of the WQS, but are in the 305(b) guidelines (see flowchart). These numeric biological measures are used as decision criteria to determine attainment of ALU.	
Numeric Biocriteria in WQS	none	
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
	✓	cause and effect determinations
	✓	permitted discharges
	✓	monitoring (e.g., improvements after mitigation)
	✓	watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	Data have been used to make permitting and nonpoint source BMP decisions. Illinois DNR's Biological Stream Characterization (BSC) program is used to determine antidegradation tiers and to influence IDNR natural heritage area designations.	

Reference Site/Condition Development*

Number of reference sites	**120 total**	
Reference site determinations*	✓	site-specific
		paired watersheds
		regional (aggregate of sites)
		professional judgment
	✓	other: watershed measures of physical and chemical disturbance
Reference site criteria	Illinois EPA is in the process of formally defining reference criteria.*	
Characterization of reference sites within a regional context	✓	historical conditions
	✓	least disturbed sites
		gradient response
	✓	professional judgment
		other:
Stream stratification within regional reference conditions	✓	ecoregions (or some aggregate)
		elevation
	✓	stream type
	✓	multivariate grouping
	✓	jurisdictional (i.e., statewide)
		other:
Additional information		reference sites linked to ALU
		reference sites/condition referenced in water quality standards
	✓	some reference sites represent acceptable human-induced conditions

*IEPA currently does not use "reference conditions" for making use-support decisions. Reference conditions were not explicitly defined or used for the present stream IBIs. A not-yet completed reevaluation of Illinois IBIs used reference conditions to develop the new indices. IEPA uses a general concept of least impacted reference condition where there are no data available; no further quantitative development has been done.

Field and Lab Methods

Assemblages assessed	✓	benthos *(100-500 samples/year; single season, multiple sites – not at watershed level)*
	✓	fish *(100-500 samples/year; single season, multiple sites – not at watershed level)*
		periphyton
		other:

Benthos	
sampling gear	collect by hand, dipnet; 500-600 micron mesh
habitat selection	richest habitat, rifle/run (cobble), multihabitat and woody debris
subsample size	300 count and entire sample
taxonomy	combination - order, family, genus and species
Fish	
sampling gear	backpack and boat electrofishers, and seine; 1/4" and 3/8" mesh
habitat selection	pool/glide, riffle/run (cobble) and multihabitat
sample processing	length measurement, biomass - individual and batch
subsample	none
taxonomy	species
Habitat assessments	visual based and quantitative measurements; performed with bioassessments
Quality assurance program elements	standard operating procedures, quality assurance plan, periodic meetings and training for biologists, sorting and taxonomic proficiency checks

Data Analysis and Interpretation

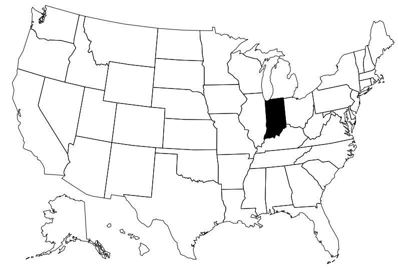
Data analysis tools and methods	✓	summary tables, illustrative graphs
	✓	parametric ANOVAs
	✓	multivariate analysis
	✓	biological metrics *(aggregate metrics into an index)*
	✓	disturbance gradients
	✓	other: nonparametric statistical tests

Multimetric thresholds	
transforming metrics into unitless scores	Metric values representing least-disturbed conditions statewide are stratified by region; within-region regression of each metric vs. environmental covariate, e.g., stream size and slope, defines benchmark for defining metric-scoring ranges.
defining impairment in a multimetric index	Thresholds are based on the possible index scoring range divided into discrete categories and are not driven by reference sites.

Evaluation of performance characteristics		repeat sampling
		precision
Not currently evaluated		sensitivity
		bias
		accuracy

Biological data	
Storage	IEPA database and spreadsheets
Retrieval and analysis	SAS, Systat, database, spreadsheet, statistical-analysis and statistical-graphics applications, including MS Access, FoxPro, Excel, QuattroPro, Minitab, and Sigma Plot

INDIANA



Contact Information

C. Lee Bridges, Chief - Biological Studies Section
Indiana Department of Environmental Management (IDEM)
P.O. Box 6015 ■ Indianapolis, IN 46206-6015
Phone 317/308-3183 ■ Fax 317/308-3219
email: lbridges@dem.state.in.us
IDEM Office of Water Quality homepage: http://www.IN.gov/idem/water/

Program Description

The Biological Studies Section (BSS) of IDEM's Office of Water Quality conducts studies of fish and macroinvertebrate communities, as well as stream habitats. These data are used to help develop biological criteria to which all other streams can be compared in order to identify impaired streams or watersheds. BSS also conducts fish tissue and sediment sampling to monitor sources of toxic and bioconcentrating substances too low to be detected in other environmental media. Fish tissue data serve as the basis for fish consumption advisories issued to protect the health of people who consume fish caught in Indiana waters. Fish tissue data are also useful for wildlife health risk assessments for fish-eating birds and mammals, and for providing the information needed to develop models for assessing changes in the quality of Indiana ecosystems.

The BSS is responsible for determining the biological integrity of aquatic communities of Indiana streams and lakes. This is accomplished through a variety of field and laboratory studies that involve several different forms of aquatic life. These data are used to determine compliance with the existing narrative biological criteria in Indiana's current water quality standards, to determine the use attainability, and to make correlations to physical and/or chemical impairments which may exist.

The BSS participates in the review of requests for site-specific water quality criteria for waters influenced by NPDES discharges. In the course of its various monitoring and assessment field activities, the staff finds point and nonpoint source-related problems, which are then referred to the appropriate IDEM programs. The Section also cooperates in the monitoring and assessment of the Ohio River in conjunction with the Ohio River Valley Water Sanitation Commission (ORSANCO), and other state and federal agencies.

Lake and reservoir assessments prior to 1989 were conducted by the State and have since been contracted to Indiana University, School of Public and Environmental Affairs. From 1990 through 1995, the State in conjunction with USEPA - Region 5, conducted a statewide ecoregion-based fish community study. Indiana has historically collected macroinvertebrate community samples at a network of fixed stations. In addition the State has been conducting macroinvertebrate community assessments at wadeable stream sites since 1990. Since 1996 the biological assessments for fish and invertebrate community assessments have been conducted using probabilistic sampling on a rotational watershed basis as per Indiana's *Surface Water Quality Monitoring Strategy*. In 2000 the State participated in a study to determine if fish and macroinvertebrate indices could be developed for lakes and reservoirs. Conclusions are still pending.

Documentation and Further Information

Indiana 2001 - 2005 Surface Water Quality Monitoring Strategy:
http://www.in.gov/idem/water/assessbr/016surfwaterqualmonstrat.pdf

Indiana 303(d) List of Impaired Waterbodies, information and links:
http://www.in.gov/idem/water/planbr/wqs/303d.html

Indiana Water Quality 305(b) Report, general information: http://www.IN.gov/idem/water/planbr/wqs/quality.html

Indiana Water Quality Standards: http://www.state.in.us/legislative/iac/title327.html

IDEM Office of Water Quality's Assessment Branch - Biological Studies Section homepage, with numerous links to relevant fact sheets and reports: http://www.in.gov/idem/water/assessbr/biostud/index.html

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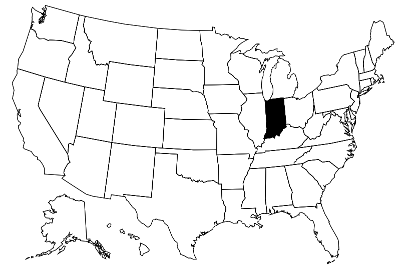


Contact Information

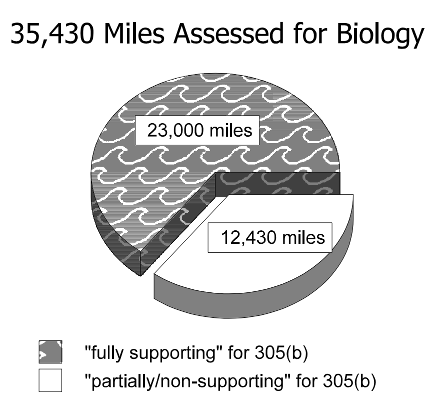
C. Lee Bridges, Chief - Biological Studies Section
Indiana Department of Environmental Management (IDEM)
P.O. Box 6015 ■ Indianapolis, IN 46206-6015
Phone 317/308-3183 ■ Fax 317/308-3219
email: lbridges@dem.state.in.us

Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
	✓	monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
	UD	promulgated into state water quality standards as biocriteria
	✓	support of antidegradation
	✓	evaluation of discharge permit conditions
	✓	TMDL assessment and monitoring
		other:
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(specific river basins or watersheds and comprehensive use throughout jurisdiction)*
	✓	fixed station (i.e., water quality monitoring stations) *(specific river basins or watersheds and comprehensive use throughout jurisdiction)*
	✓	probabilistic by stream order/catchment area *(specific river basins or watersheds and comprehensive use throughout jurisdiction)*
	✓	probabilistic by ecoregion, or statewide *(specific river basins or watersheds and comprehensive use throughout jurisdiction)*
	✓	rotating basin *(specific river basins or watersheds and comprehensive use throughout jurisdiction)*
		other:

Stream Miles

Total miles *(determined using RF3 and the National Hydrography Database)*	**35,673**
Total perennial miles	21,094
Total miles assessed for biology	**35,430**
fully supporting for 305(b)	23,000
partially/non-supporting for 305(b)	12,430
listed for 303(d)	unknown
number of sites sampled *(on an annual basis)*	< 200
number of miles assessed per site	site specific



Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Warm Water vs. Cold Water	
ALU designations in state water quality standards	Two designations: Well balanced warmwater aquatic community and Cold water put-and-take trout waters	
Narrative Biocriteria in WQS	under development - The narrative biocriteria in Indiana have only been proposed and are not formal. They are loosely defined by 327 IAC 2-1-3(a)(2), 327 IAC-2-1-9 (49); and for the Great Lakes waters 327 IAC 2-1.5-5(a)(2) and (3), and 327 IAC 2-1.5-2 (92). IDEM uses informal numeric procedures to support narrative biocriteria (see http://www.in.gov/IDEM/water/planbr/wqs/quality.html).	
Numeric Biocriteria in WQS	none	
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
	✓	cause and effect determinations
		permitted discharges
	✓	monitoring (e.g., improvements after mitigation)
	✓	watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	Biological assessment data are used for 305(b)/303(d) purposes and was used for the FY 2000 Unified Watershed Assessment (updated 2001), which was used for the Watershed Restoration Action Strategies.	

Reference Site/Condition Development*

Number of reference sites	**unknown**	
Reference site determinations		site-specific
		paired watersheds
	✓	regional (aggregate of sites)
	✓	professional judgment
		other:
Reference site criteria	Deviation from central tendencies on multimetric indices and the qualitative habitat evaluation index (QHEI) is also taken into consideration when evaluating impairment. Field chemistry is measured and probabilistic sites are sampled for broad chemical analysis.	
Characterization of reference sites within a regional context	✓	historical conditions**
	✓	least disturbed sites
	✓	gradient response
		professional judgment
	✓	other: IBI is calibrated on drainage area for headwater streams, wadeable rivers, large rivers and great rivers
Stream stratification within regional reference conditions	✓	ecoregions (or some aggregate)
		elevation
		stream type
	✓	multivariate grouping
		jurisdictional (i.e., statewide)
	✓	other: 8 digit USGS Hydrologic Unit Codes
Additional information	✓	reference sites linked to ALU *(in a statistical sense)*
		reference sites/condition referenced in water quality standards
	✓	some reference sites represent acceptable human-induced conditions *(it is understood that all sites have a human-induced condition)*

*IDEM uses a non-typical process for developing reference condition: reference condition is represented by a percentage of the total population of the sites sampled. The number of reference sites in Indiana is not available at this time.

**Reference condition is defined by a historical cross-section of sample sites representing the full gradient of ecological conditions as they existed during statewide or ecoregion specific investigation.

Field and Lab Methods

Assemblages assessed	✓	benthos *(<100 samples/year; single season, multiple sites - broad coverage)*
	✓	fish *(<100 samples/year; single season, multiple sites - broad coverage)*
	✓	periphyton *(<100 samples/year; solely through a pilot contract with USGS)*
	✓	other: phytoplankton and zooplankton *(<100 samples/year; single observation, limited sampling)*

Benthos	
sampling gear	multiplate, dipnet, and kick net (1 meter); 243-600 micron mesh
habitat selection	riffle/run (cobble) and artificial substrate in the absence of riffle/run
subsample size	100 count and proportional/volume
taxonomy	family
Fish	
sampling gear	backpack, boat, longline and pram unit (tote barge) electrofishers; and 1/8" mesh seine
habitat selection	multihabitat
sample processing	enumeration, length measurement, biomass - batch, and anomalies
subsample	none
taxonomy	species
Habitat assessments	visual based; performed with bioassessments
Quality assurance program elements	standard operating procedures, quality assurance plan, periodic meetings and training for biologists, sorting and taxonomic proficiency checks, specimen archival

Data Analysis and Interpretation

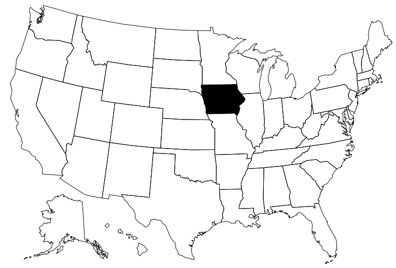
Data analysis tools and methods	✓	summary tables, illustrative graphs
	✓	parametric ANOVAs
	✓	multivariate analysis
	✓	biological metrics *(aggregate metrics into an index)*
	✓	disturbance gradients
		other:

Multimetric thresholds	
transforming metrics into unitless scores	cumulative distribution function
defining impairment in a multimetric index	cumulative distribution function and use various break points for impairments
Multivariate thresholds	
defining impairment in a multivariate index	significant departure from mean of reference population

Evaluation of performance characteristics	✓	repeat sampling *(watersheds are sampled on 5 yr rotational basis)*
	✓	precision *(Standard Error, 95% Confidence Interval and Relative Percent Difference)*
		sensitivity
		bias
	✓	accuracy *(10% field duplicates, 10% laboratory duplicates)*

Biological data	
Storage	Assessment Information Management System (AIMS), MS Access based utility, and some historical data still in paper files
Retrieval and analysis	Statistica and MINITAB for cluster analysis of large matrices

IOWA



Contact Information

Tom Wilton, Water Quality Specialist
Iowa Department of Natural Resources (IDNR)
502 East 9th Street ■ Des Moines, IA 50319-0034
Phone 515/281-8867 ■ Fax 515/281-8895
email: tom.wilton@dnr.state.ia.us
IDNR Water Quality Bureau: http://www.state.ia.us/dnr/organiza/epd/wtrq/wtrqbur.htm

Program Description

Since 1994, the Iowa Department of Natural Resources (IDNR) and the University Hygienic Laboratory (UHL) have conducted a biological assessment program for Iowa's wadeable streams and rivers. So far, biological sampling has been conducted at 289 stream locations throughout the state. Biological data are collected for a variety of purposes including: ambient monitoring, problem investigation, evaluation of point source and nonpoint source pollution control measures, and TMDL development. The IDNR uses bioassessment information to assess the status of stream aquatic life designated uses for the Section 305(b) report and the Section 303(d) list of impaired waters.

Benthic macroinvertebrates and fish serve as indicators of stream biological integrity. Standardized sampling procedures are used to collect species composition and proportional abundance data from which a suite of biological metrics is calculated. Individual metric values are aggregated to obtain scores for the Benthic Macroinvertebrate Index of Biotic Integrity (BMIBI) and the Fish Index of Biotic Integrity (FIBI). Biological impairment thresholds are based on the statistical distribution of biotic index scores obtained from stream reference site sampling. Currently, the IDNR has identified 96 reference sites that represent least disturbed stream conditions in Iowa's ten ecological regions.

Until 2002, a targeted approach was used to select sampling locations for Iowa's stream biological assessment program. From 1994 through 1998, the program emphasized candidate reference site and test (impacted) site sampling, which provided data for evaluating and calibrating biological data metrics. From 1999-2001, the emphasis shifted toward site-specific problem investigation and follow-up. Beginning in 2002, IDNR and UHL are initiating a probabilistic survey that will provide an unbiased, statistically powerful assessment of Iowa's perennial streams and rivers. The survey design calls for sampling 56 randomly-selected sites per year through 2005. During this period, IDNR and UHL also plan to resample the existing network of reference streams at a rate of 20-25 sites per year.

The IDNR is working toward incorporating narrative and numeric stream biocriteria in Iowa's water quality standards. The bioassessment framework that is currently used for 305(b) assessments can potentially serve as a foundation for biocriteria. The 2002-2005 probabilistic survey will provide useful data from non-wadeable streams and rivers for biocriteria development. Biocriteria development for Iowa's lakes, reservoirs, and wetlands has not been initiated.

Documentation and Further Information

Water Quality in Iowa During 1998 and 1999 (Iowa's 2000 Section 305(b) report): http://www.state.ia.us/dnr/organiza/epd/wtrq/305b00/index.htm

Final Approved Iowa 1998 303(d) List: http://www.state.ia.us/dnr/organiza/epd/wtresrce/files/303dlist.pdf

Iowa's STORET Database (ambient water quality program dataset): http://wqm.igsb.uiowa.edu/storet/

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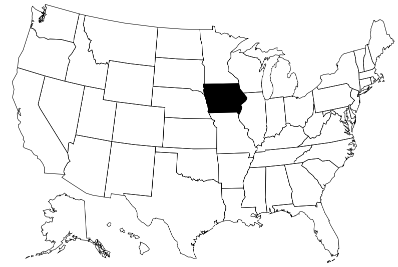


Contact Information

Tom Wilton, Water Quality Specialist
Iowa Department of Natural Resources (IDNR)
502 East 9th Street ■ Des Moines, IA 50319-0034
Phone 515/281-8867 ■ Fax 515/281-8895
email: tom.wilton@dnr.state.ia.us

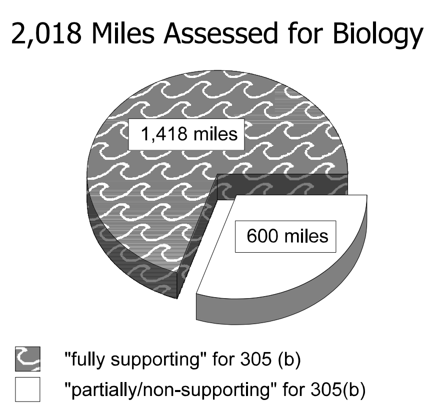
Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
	✓	monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
	UD	promulgated into state water quality standards as biocriteria
		support of antidegradation
		evaluation of discharge permit conditions
	✓	TMDL assessment and monitoring
		other:
Applicable monitoring designs*	✓	targeted (i.e., sites selected for specific purpose) *(special projects, specific river basins or watersheds, comprehensive use throughout jurisdiction)*
	✓	fixed station (i.e., water quality monitoring stations) *(specific river basins or watersheds)*
		probabilistic by stream order/catchment area
	✓	probabilistic by ecoregion, or statewide *(comprehensive use throughout jurisdiction)*
		rotating basin
		other:

*In 2002, IDNR will initiate a REMAP probabilistic survey of perennial streams and rivers.

Stream Miles

Total miles *(State based determination)*	**71,665**
Total perennial miles	26,630
Total miles assessed for biology*	**2,018**
fully supporting for 305(b)	1,418
partially/non-supporting for 305(b)	600
listed for 303(d)	n/a
number of sites sampled	149
number of miles assessed per site	0.1 - 0.22



*Stream miles reported are based on Iowa's 2000 305(b) assessment. A 303(d) list was not prepared in 2000.

Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Class System (A, B, C), Warm Water vs. Cold Water	
ALU designations in state water quality standards	Four designations: B(LR) - limited resource warmwater streams/rivers; B(WW) - significant resource warmwater streams/rivers; B(CW) - coldwater streams; B(LW) - lakes and wetlands	
Narrative Biocriteria in WQS	under development (Iowa's water quality standards include language associated with ALUs but it was not intended to be formal narrative biocriteria. IA is moving toward incorporating narrative biocriteria into the State's water quality standards.)	
Numeric Biocriteria in WQS	none (IA uses thresholds to report data in 305(b) report, but not formal numeric biocriteria.)	
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
	✓	cause and effect determinations
		permitted discharges
	✓	monitoring (e.g., improvements after mitigation)
	✓	watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	303(d) listing, to address point source impacts, and to support TMDL development	

Reference Site/Condition Development

Number of reference sites	**96 total**	
Reference site determinations		site-specific
		paired watersheds
	✓	regional (aggregate of sites)
	✓	professional judgment
		other:
Reference site criteria	Regionally representative and least disturbed by human activities, consider impact of livestock waste, wastewater, channel alterations, riparian land use, and quality of instream habitat	
Characterization of reference sites within a regional context		historical conditions
	✓	least disturbed sites
		gradient response
		professional judgment
		other:
Stream stratification within regional reference conditions	✓	ecoregions (or some aggregate)
		elevation
		stream type
		multivariate grouping
		jurisdictional (i.e., statewide)
		other:
Additional information		reference sites linked to ALU
		reference sites/condition referenced in water quality standards
	✓	some reference sites represent acceptable human-induced conditions

Field and Lab Methods

Assemblages assessed	✓	benthos *(100 - 500 samples per year; single season, multiple sites - broad coverage)*
	✓	fish *(<100 samples per year; single season, multiple sites - broad coverage)*
		periphyton
		other:

Benthos	
sampling gear	Surber, Hess, multiplate, collect by hand; 500 - 600 micron mesh
habitat selection	riffle/run (cobble), multihabitat, artificial substrate
subsample size	100 count, entire sample
taxonomy	combination - order, family, genus, species
Fish	
sampling gear	backpack electrofisher, pram unit (tote barge); 3/16" mesh
habitat selection	multihabitat
sample processing	anomalies, species abundance
subsample	none
taxonomy	species
Habitat assessments	visual based, quantitative measurements; performed with bioassessments
Quality assurance program elements	standard operating procedures, periodic meetings/training for biologists, taxonomic proficiency checks, specimen archival

Data Analysis and Interpretation

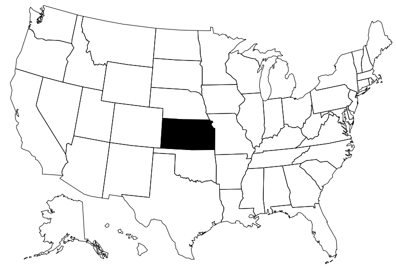
Data analysis tools and methods	✓	summary tables, illustrative graphs
	✓	parametric ANOVAs
	✓	multivariate analysis *(for data exploration only)*
	✓	biological metrics *(aggregate metrics into an index)*
	✓	disturbance gradients
		other:

Multimetric thresholds	
transforming metrics into unitless scores	linear interpolation between optimum (95%) reference population level and the minimum level
defining impairment in a multimetric index	25^{th} percentile of reference population

Evaluation of performance characteristics	✓	repeat sampling
	✓	precision
	✓	sensitivity
		bias
		accuracy

Biological data	
Storage	EDAS (benthic macroinvertebrate data) and MS Access (fish, physical habitat, and water chemistry data)
Retrieval and analysis	STATISTIX (Analytical Software) and Excel

KANSAS



Contact Information

Steve Cringan, Environmental Scientist III
Kansas Department of Health and Environment (KDHE)
1000 SW Jackson Street, Suite 430 ■ Topeka, KS 66612-1367
Phone 785/296-5571 ■ Fax 785/291-3266
email: scringan@kdhe.state.ks.us
KDHE Bureau of Environmental Filed Services homepage:
http://www.kdhe.state.ks.us/befs/index.html

Kristen Hase, Stream Monitoring Program Coordinator
Kansas Department of Wildlife and Parks (KDWP)
512 SE 25th Avenue ■ Pratt, KS 67124
Phone 620/672-0710 ■ Fax 620/672-2972
email: KristenM@wp.state.ks.us
website: http://www.kdwp.state.ks.us

Program Description

Kansas has maintained a stream biological monitoring program since 1972. Since 1980, the program has remained primarily unchanged. Program data are evaluated and incorporated in five year increments into the 305(b) report and 303(d) list. Data is used to determine aquatic life use support status in combination with chemical water quality data. Further details may be found in the program Quality Management Plan (see documentation below).

Contemporary Program Objectives
The stream biological monitoring program endeavors to provide scientifically defensible information on the quality of flowing waters in Kansas through the analysis of aquatic macroinvertebrate communities. This information is intended for use in:

(1) complying with the water quality monitoring and reporting requirements of 40 CFR 130.4 and sections 106(e)(1), 303(d) and 305(b) of the federal Clean Water Act;

(2) evaluating waterbody compliance with the Kansas surface water quality standards (K.A.R. 28-16-28b *et seq*.);

(3) identifying point and nonpoint sources of pollution contributing most significantly to water use impairments in streams;

(4) documenting spatial and temporal trends in surface water quality resulting from changes in land use patterns, resource management practices, pollutant loadings, and climatological conditions;

(5) developing scientifically defensible environmental standards, wastewater treatment plan permits, and waterbody/watershed pollution control plans; and

(6) evaluating the efficacy of pollution control efforts and waterbody remediation/restoration initiatives implemented by the department and other agencies and organizations.

The Kansas Department of Health and Environment's (KDHE) Bureau of Environmental Field Services is responsible for macroinvertebrate data collection and analysis. The Bureau also analyzes fish community data that are collected by the Kansas Department of Wildlife and Parks (KDWP). KDHE is currently working with the Central Plains Center for BioAssessment (CPCB) at the University of Kansas, to develop both a systematic approach to the identification of reference sites and a regionally standardized approach to habitat assessment.

Documentation and Further Information

Division of Environment Quality Management Plan Part III: Stream Biological Monitoring Program Quality Assurance Management Plan, December 2000: http://www.kdhe.state.ks.us/environment/qmp_2000/download/SBMP_QAMP.pdf

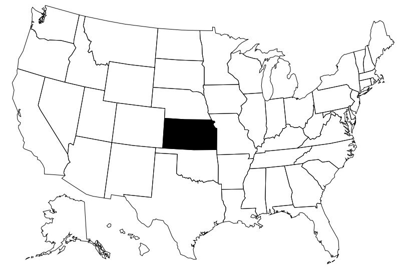
2002 Kansas Water Quality Assessment (305(b) report), April 2002:
http://www.kdhe.state.ks.us/befs/305b_2002/ks305b2002f.pdf

Guidance Document for Use Attainability Analyses, December 2001: http://www.kdhe.state.ks.us/befs/uaas/UAAGuidance.pdf

Draft 2002 303(d) Methodology and List: http://www.kdhe.state.ks.us/tmdl/303d.htm

Kansas State Water Quality Standards: http://www.kdhe.state.ks.us/water/index.html

KANSAS



Contact Information

Steve Cringan, Environmental Scientist III
Kansas Department of Health and Environment (KDHE)
1000 SW Jackson Street, Suite 430 ■ Topeka, KS 66612-1367
Phone 785/296-5571 ■ Fax 785/291-3266
email: scringan@kdhe.state.ks.us

Kristen Hase, Stream Monitoring Program Coordinator
Kansas Department of Wildlife and Parks (KDWP)
512 SE 25th Avenue ■ Pratt, KS 67124
Phone 620/672-0710 ■ Fax 620/672-2972
email: KristenM@wp.state.ks.us

Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
	✓	monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
	✓	promulgated into state water quality standards as biocriteria
		support of antidegradation
	✓	evaluation of discharge permit conditions
	✓	TMDL assessment and monitoring
	✓	other: trend analysis
Applicable monitoring designs*	✓	targeted (i.e., sites selected for specific purpose) *(comprehensive use throughout jurisdiction)*
	✓	fixed station (i.e., water quality monitoring stations) *(comprehensive use throughout jurisdiction)*
		probabilistic by stream order/catchment area
	✓	probabilistic by ecoregion, or statewide *(comprehensive use throughout jurisdiction)*
	✓	rotating basin *(comprehensive use throughout jurisdiction)*
	✓	other: rotational sites, statewide *(comprehensive use throughout jurisdiction)*

*KDWP uses a combination of probabilistic design, rotating basin, and fixed sites; KDHE relies primarily on a targeted design, including fixed and rotational sites statewide.

Stream Miles

Total miles *(determined using RF3)*	**134,338**
Total perennial miles	23,731
Total miles assessed for biology*	**23,731**
fully supporting for 305(b)	n/a
partially/non-supporting for 305(b)	n/a
listed for 303(d)	n/a
number of sites sampled	178 targeted over 22 years (KDHE); several hundred probabalistic (KDWP)
number of miles assessed per site	site specific

*Because KDWP uses a probabilistic sampling design, it can be said that all 23,731 perennial stream miles in Kansas are being assessed for biology. KDHE is working with KDWP to incorporate the latter agency's findings into Kansas' 305(b) reports and 303(d) lists. Kansas' 2002 305(b) report is based on four years of ambient stream chemistry data (1998-2001) and only acute aquatic life use support application.

Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Class System (A,B,C)	
ALU designations in state water quality standards	Three designations: special aquatic life use, expected aquatic life use, restricted aquatic life use	
Narrative Biocriteria in WQS	Procedures used to support narrative biocriteria are located in the most recent 305(b) reports	
Numeric Biocriteria in WQS	none (Numeric biocriteria have not been adopted into the state standards, but are nevertheless used for diagnostic purposes and in 305(b) assessments.)	
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
	✓	cause and effect determinations
	✓	permitted discharges
	✓	monitoring (e.g., improvements after mitigation)
		watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	Various point source upgrades and TMDL-related applications	

Reference Site/Condition Development

Number of reference sites	**44 total**	
Reference site determinations*		site-specific
		paired watersheds
		regional (aggregate of sites)
	✓	professional judgment
		other:
Reference site criteria	To date, sites have been selected on the basis of land cover and land use, known hydrological properties and channel characteristics, general absence of confined animal feeding operations, point sources and urban areas, and favorable water quality attributes (low levels of total suspended solids, biochemical oxygen demand, fecal coliform bacteria, total phosphorus, inorganic nitrogen, herbicides, and other contaminants). Rare taxa and historically occurring key species are mainly used for validation purposes. Reference sites, by definition, should also be minimally impacted by anthropogenic phenomena and approach the presettlement condition in terms of hydrology, water quality, available biological habitat, surrounding landscape and watershed attributes, and historically documented plant and animal communities.	
Characterization of reference sites within a regional context	✓	historical conditions
	✓	least disturbed sites
		gradient response
		professional judgment
		other:
Stream stratification within regional reference conditions	✓	ecoregions (or some aggregate)
		elevation
		stream type
		multivariate grouping
		jurisdictional (i.e., statewide)
	✓	other: stream size
Additional information		reference sites linked to ALU
		reference sites/condition referenced in water quality standards
	✓	some reference sites represent acceptable human-induced conditions

*Currently working with the Central Plains Center for BioAssessment (CPCB) at the University of Kansas to develop a more systematic approach to the identification of reference sites.

Field and Lab Methods

Assemblages assessed	✓	benthos *(100 - 500 samples/year; single season, multiple sites - broad coverage; multiple seasons, select sites)*
	✓	fish *(<100 samples/year; single season, multiple sites - broad coverage by KDWP only)*
	✓	periphyton *(100 - 500 samples/year; multiple seasons, multiple sites - broad coverage for watershed level)**
	✓	other: phytoplankton

Benthos	
sampling gear	collect by hand, D-frame; 500 - 600 micron mesh
habitat selection	richest habitat, riffle/run, multihabitat, woody debris, random sampling by KDWP only
subsample size	entire sample, 100 count minimum
taxonomy	genus/species where practical
Fish	
sampling gear	seine, backpack electrofisher, pram unit (tote barge); 1/8" and 3/16" mesh
habitat selection	multihabitat
sample processing	length measurement, biomass – batch
subsample	batch (generally do not subsample)
taxonomy	species
Periphyton*	
sampling gear	**natural substrate**: suction device, bar clamp sample; **artificial substrate**: periphytometer
habitat selection	wadeable area within stream segment that is designated based on other sampled biota
sample processing	chlorophyll *a/* phaeophytin, taxonomic identification (limited use)
taxonomy	diatoms only
Habitat assessments	visual based (KDHE), quantitative measurements (KDWP); performed with bioassessments
Quality assurance program elements	standard operating procedures, quality assurance plan, periodic meetings/training for biologists, sorting and taxonomic proficiency checks, specimen archival, replicate sampling, field audits, and staff certification program

*Periphyton sampling is a new venture for the Kansas Biological Survey and the Central Plains Center for BioAssessment. Whole stream respiration as well as net and gross production via the DO diel cycle method are also determined. Software has been built to support these calculations using large continuous data sets of several weeks to months.

Data Analysis and Interpretation

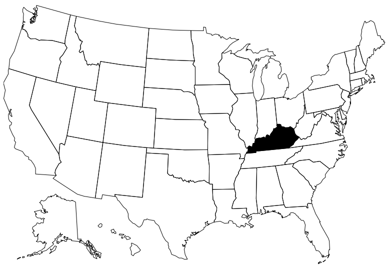
Data analysis tools and methods	✓	summary tables, illustrative graphs
		parametric ANOVAs
		multivariate analysis
	✓	biological metrics *(return single metrics)*
		disturbance gradients
	✓	other: regressions, correlations, trends, and other statistical applications

Multimetric thresholds	
transforming metrics into unitless scores	cumulative distribution function
defining impairment in a multimetric index	Kansas returns single metrics but is exploring various indices.

Evaluation of performance characteristics	✓	repeat sampling
	✓	precision
Refer to Quality Management Plan for SOPs and further information.	✓	sensitivity
	✓	bias
	✓	accuracy

Biological data	
Storage	Lotus Notes, Excel
Retrieval and analysis	Minitab, spreadsheet graphics, ArcView, ArcGIS, GARP (pending)

KENTUCKY



Contact Information

Terry P. Anderson, Manager - Water Quality Branch
Kentucky Division of Water
14 Reilly Road ■ Frankfort, KY 40601
Phone 502/564-3410 ■ Fax 502-564-0111
email: terryp.anderson@mail.state.ky.us
KY Division of Water homepage: http://water.nr.state.ky.us/dow/dwhome.htm

Program Description

A 100 point scale multi-metric index is under development in order to give equal weight to the three assemblages collected (fish, macroinvertebrates and algae). KY Division of Water is also working in conjunction with USEPA/Cincinnati to develop boatable water collection methods for the larger rivers as a first phase of biocriteria and assessment methods for larger rivers. There is a long term goal of establishing response relationships between biological indicators and nutrients in wadeable and boatable waters in order to investigate the feasibility of establishing nutrient criteria in these waters.

The Division of Water has shifted to a watershed approach in assessing stream miles. At this time about two fifths of the stream miles assessed have been entered in the data base, and data from another two fifths are being inputted. The first round of watershed sampling (the last fifth) will be completed in summer 2002. Somewhere between 30,000 to 40,000 actual miles will have been assessed by the time this project is completed.

Probabilistic sampling is also being conducted in all major watersheds. When this is completed, KY Division of Water will be able to estimate the number of stream miles meeting and not meeting designated uses. KY Division of Water was able to carry out this expansion thanks to valuable partnerships with Universities and the Kentucky Department of Fish and Wildlife Resources. These data are used to assess use support for Kentucky's 305(b) Report and for listing streams on the 303(d) list. Biological data can override chemical data if they are contradictory. There is a strong belief that the biological data collected and the collection methods used paint a truer picture of use attainment than chemical data.

Another important application of increased biological knowledge of waters in Kentucky has been the development of biological endpoints for successful stream restoration projects undertaken as a result of environmental damage incidents.

Documentation and Further Information

2000 Kentucky Report to Congress on Water Quality, 305(b) report:
http://water.nr.state.ky.us/wq/305b/2000/2000_305b.htm

1998 303(d) List of Waters for Kentucky, June 1998: http://water.nr.state.ky.us/303d/

1998-1999 Monitoring Strategy: Kentucky River Basin Management Unit, March 2000:
http://www.uky.edu/WaterResources/Watershed/KRB_AR/PDF_Files/Monitoring%20Report.PDF

For a list and links to more references and documents, conduct a search on the *Kentucky Natural Resources and Environmental Protection Cabinet (NREPC)* publication site:
http://www.kyenvironment.org/nrepc/publications/publications.asp

Kentucky Watershed Management Framework

Other documents include Reference Reach Reports on Algae, Fish and Macroinvertebrates; Division of Water SOP manuals; Consultant reports; USFWS surveys; Kentucky State Nature Preserve Commission surveys; Kentucky Department of Fish and Wildlife Resources surveys; Federal Register notices on Federal T&E listings.

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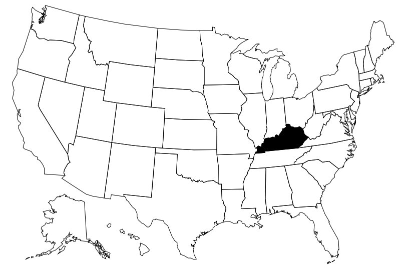


Contact Information

Terry P. Anderson, Manager - Water Quality Branch
Kentucky Division of Water
14 Reilly Road ■ Frankfort, KY 40601
Phone 502/564-3410 ■ Fax 502-564-0111
email: terryp.anderson@mail.state.ky.us

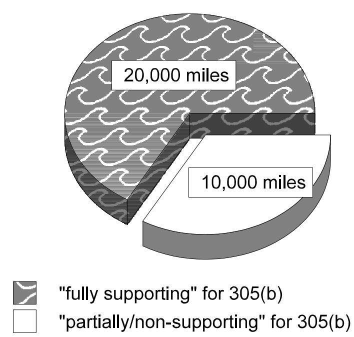
Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
	✓	monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
	✓	promulgated into state water quality standards as biocriteria
	✓	support of antidegradation
	✓	evaluation of discharge permit conditions
	✓	TMDL assessment and monitoring
		other:
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(special projects only, specific river basins or watersheds, and comprehensive use throughout jurisdiction)*
	✓	fixed station (i.e., water quality monitoring stations) *(comprehensive use throughout jurisdiction)*
		probabilistic by stream order/catchment area
	✓	probabilistic by ecoregion, or statewide *(specific river basins or watersheds)*
	✓	rotating basin *(specific river basins or watersheds)*
		other:

Stream Miles

Total miles *(determined using the National Hydrography Database)*	**89,431**
Total perennial miles	34,334
Total miles assessed for biology*	**~30,000**
fully supporting for 305(b)	~20,000
partially/non-supporting for 305(b)	~10,000
listed for 303(d)	7,500
number of sites sampled	1,750
number of miles assessed per site	–

30,000 Miles Assessed for Biology



*Kentucky has shifted to a basin approach in assessing stream miles. At this time about 2/5ths of the stream miles assessed have been entered in the database, which translates to 10,200 actual miles assessed. There is also data from another 2/5ths that is presently being inputted into the database. The first round of watershed sampling (the last 1/5th) will be completed this summer. 30,000 to 40,000 actual miles will have been assessed upon completion. Probabilistic sampling is also being conducted in all major watersheds. The number of stream miles meeting and not meeting designated uses can be estimated when this is completed.

Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Warm water vs. Cold water
ALU designations in state water quality standards	Two designations - Warm water and Cold water
Narrative Biocriteria in WQS	Numeric procedures used to support narrative biocriteria referenced in KAR 5:030, and in Division publications and SOP manuals.
Numeric Biocriteria in WQS	none

Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
	✓	cause and effect determinations
	✓	permitted discharges
	✓	monitoring (e.g., improvements after mitigation)
	✓	watershed based management

Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	Bioassessments have been used to delist streams from the 303(d) list.

Reference Site/Condition Development

Number of reference sites	**140 total**	
Reference site determinations		site-specific
		paired watersheds
	✓	regional (aggregate of sites)
		professional judgment
		other:
Reference site criteria	Minimally impacted from point and nonpoint pollution, natural habitat with high forest density relative to other land uses. Other criteria listed in KY's reference reach report on fish communities. Also depends on ecoregion: habitat score - conductivity (region specific) - nutrients (in some cases).*	
Characterization of reference sites within a regional context		historical conditions
	✓	least disturbed sites
		gradient response
		professional judgment
	✓	other: minimally impacted*
Stream stratification within regional reference conditions	✓	ecoregions (or some aggregate)
		elevation
		stream type
	✓	multivariate grouping
		jurisdictional (i.e., statewide)
		other:
Additional information		reference sites linked to ALU
	✓	reference sites/condition referenced in water quality standards *(found in 401 KAR 5:030 Section 1(1)(b)4)*
	✓	some reference sites represent acceptable human-induced conditions

*KY tries to use minimally impacted reference sites whenever possible, but least disturbed sites are used to set targeted conditions when there are no minimally impacted sites in a subecoregion.

Field and Lab Methods

Assemblages assessed	✓	benthos *(<100 samples/year; single season, multiple sites - broad coverage)*
	✓	fish *(<100 samples/year; single season, multiple sites - broad coverage)*
	✓	periphyton *(<100 samples/year; single season, multiple sites - broad coverage)*
		other:

Benthos	
sampling gear	D-frame, dipnet, kick net (1 meter), collect by hand; >800 micron mesh
habitat selection	multihabitat
subsample size	entire sample
taxonomy	combination - family, genus, species
Fish	
sampling gear	seine, backback electrofisher, boat electrofisher, pram unit (tote barge), gill nets, trammel nets; 3/16" mesh
habitat selection	multihabitat
sample processing	none
subsample	none
taxonomy	species
Periphyton	
sampling gear	**natural substrate**: suction device, brushing/scraping device (razor, toothbrush, etc.), collect by hand; **artificial substrate**: periphytometer (in non-wadeable waters)
habitat selection	multihabitat
sample processing	taxonomic identification
taxonomy	species
Habitat assessments	visual based; performed with bioassessments
Quality assurance program elements	standard operating procedures, quality assurance plan, periodic meetings and training for biologists, sorting and taxonomic proficiency checks, specimen archival

Data Analysis and Interpretation

Data analysis tools and methods		summary tables, illustrative graphs
		parametric ANOVAs
	✓	multivariate analysis
	✓	biological metrics *(aggregate metrics into an index)*
		disturbance gradients
		other:

Multimetric thresholds	
transforming metrics into unitless scores	95th percentile of all sites-standard based on a 100 unit scale
defining impairment in a multimetric index	25th percentile of reference population (100 point scale multi-metric index is under development)

Evaluation of performance characteristics	✓	repeat sampling *(annual variability)*
	✓	precision *(repeatability)*
	✓	sensitivity *(Box-Whisker distributions)*
		bias
	✓	accuracy *(% test sites - nonreference, impaired - validation)*

Biological data	
Storage	EDAS
Retrieval and analysis	SAS, Systat, EDAS, Excel, MVSP (Multi-Variate Statistical Package), Statigraphics

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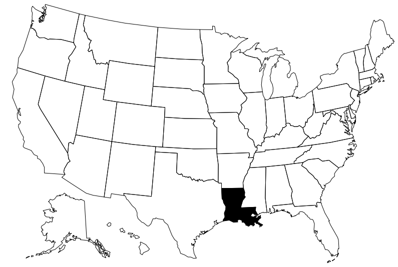

Contact Information

Dugan Sabins, Senior Environmental Scientist - Office of Environmental Assessment
Jennifer Lindquist, Environmental Scientist III
Keith Sepulvado, Environmental Scientist III
Louisiana Department of Environmental Quality (LDEQ)
P.O. Box 82178 ■ Baton Rouge, LA 70884-2178
Phone 225/765-0246 ■ Fax 225/765-0617
email: dugan_s@deq.state.la.us
LDEQ Planning homepage: http://www.deq.state.la.us/planning/

Program Description

In Louisiana, bioassessments have been used principally to characterize and delineate reference streams. Bioassessments have also been used for assessing the biological conditions of waterbodies being evaluated for site-specific standards development and use attainability analysis. Bacterial monitoring is conducted for swimming use assessment, Periodic toxicity testing is also conducted. In a very special case, biocriteria were developed for specific wetlands to receive treated disinfected wastewater for wetland restoration.

Further development of bioassessment procedures is dependent on the legal responsibilities and outcome of a consent decree on the Louisiana TMDL program. Any additional development will have to be compatible with TMDL deadlines and deliverables. Since Louisiana does not have biocriteria, there is not a great need for LDEQ to conduct large scale bioassessments to determine criteria attainment. When the concept of biocriteria is adequately thought out and developed for use in state permitting and TMDL programs, then LDEQ will have a larger, more inclusive, bioassessment program. The use and revision of chemical/physical criteria, standards, and assessment procedures are considered the present priority.

The Louisiana Department of Wildlife and Fisheries (LDWF) monitors fishery resources on large rivers and in coastal waters of the state for management purposes and for establishing commercial and recreational regulations on harvest. However, these assessments are not conducted to determine compliance with the Clean Water Act. Environmental agencies are increasing collaboration and coordination with LDWF and are hoping to begin combining monitoring efforts and sharing biological data at a future date.

Documentation and Further Information

State of Louisiana Water Quality Management Plan Water Quality Inventory Section 305(b) 2000:
http://www.deq.state.la.us/planning/305b/2000/index.htm

Dewalt, R. E. 1997. *Fish and macroinvertebrate taxonomic richness, habitat quality, and in-situ water chemistry of ecoregion reference streams in the Western Gulf Coastal Plains and Terrace Upland Ecoregions of Southern Louisiana*. Prepared for the Louisiana Department of Environmental Quality. Baton Rouge, LA. 72 pages.

Dewalt R. E. 1995. *Biological communities of reference streams in the South Central Plains and Upper Mississippi Alluvial Plains ecoregions of Louisiana*. Prepared for the Louisiana Department of Environmental Quality. Baton Rouge, LA. 85 pages.

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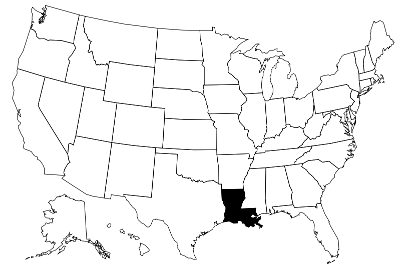


Contact Information

Dugan Sabins, Senior Environmental Scientist - Office of Environmental Assessment
Jennifer Lindquist, Environmental Scientist III
Keith Sepulvado, Environmental Scientist III
Louisiana Department of Environmental Quality (LDEQ)
P.O. Box 82178 ■ Baton Rouge, LA 70884-2178
Phone 225/765-0246 ■ Fax 225/765-0617
email: dugan_s@deq.state.la.us

Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
		nonpoint source assessments
		monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
	✓	promulgated into state water quality standards as biocriteria
		support of antidegradation
		evaluation of discharge permit conditions
		TMDL assessment and monitoring
	✓	other: ecoregion reference stream delineation, public education, bacteria assessment for swimming use, occasional toxicity testing, wetlands criteria
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(special projects and specific river basins or watersheds)*
		fixed station (i.e., water quality monitoring stations)
		probabilistic by stream order/catchment area
		probabilistic by ecoregion, or statewide
		rotating basin
		other:

Stream Miles

Total miles *(State based estimation)*	**66,294**
Total perennial miles	–
Total miles assessed for biology*	**–**
fully supporting for 305(b)	n/a
partially/non-supporting for 305(b)	n/a
listed for 303(d)	n/a
number of sites sampled	–
number of miles assessed per site	–

*Bioassessments are not used for 305(b)/303(d) reporting purposes or biocriteria development. Louisiana's 2000 305(b) report listed 7,228 total river and stream miles assessed using chemical/physical criteria for fish and wildlife propagation and limited aquatic life/wildlife designated uses: 1,118 miles fully supporting and 6,110 miles partially/non-supporting for 305(b).

Aquatic Life Use (ALU) Designations and Decision-Making*

ALU designation basis	Class System (A,B,C)	
ALU designations in state water quality standards	Two designations: 1) Fish and wildlife propagation, 2) Limited aquatic/wildlife (a subcategory of fish and wildlife propagation)	
Narrative Biocriteria in WQS	A qualitative and/or narrative scale of condition that supports narrative biocriteria decisions is found in Louisiana's water quality standards, LAC 33:IX.1111.C and 1113.B.12	
Numeric Biocriteria in WQS	none	
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
		cause and effect determinations
		permitted discharges
		monitoring (e.g., improvements after mitigation)
		watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	Bioassessments have been used to delineate reference streams, which in turn have been used in management decisions for setting DO criteria across ecoregions.	

*Aquatic life use is assessed using chemical/physical numerical and general criteria. Louisiana does have general (narrative) criteria for biological and aquatic community integrity.

Reference Site/Condition Development

Number of reference sites	**16 total**	
Reference site determinations	✓	site-specific
		paired watersheds
		regional (aggregate of sites)
	✓	professional judgment
		other:
Reference site criteria	Least impacted wadeable streams, determined using best professional judgment ("common sense criteria")	
Characterization of reference sites within a regional context	✓	historical conditions *(when information is available)*
	✓	least disturbed sites
		gradient response
		professional judgment
	✓	other: wadeable streams
Stream stratification within regional reference conditions	✓	ecoregions (or some aggregate)
		elevation
		stream type
		multivariate grouping
		jurisdictional (i.e., statewide)
		other:
Additional information	✓	reference sites linked to ALU
	✓	reference sites/condition referenced in water quality standards *(found in LAC 33 33:IX.1113.B.12)*
	✓	some reference sites represent acceptable human-induced conditions

Field and Lab Methods

Assemblages assessed	✓	benthos *(<100 samples/year; multiple seasons, multiple sites - broad coverage for watershed level)*
	✓	fish *(<100 samples/year; multiple seasons, multiple sites - broad coverage for watershed level)*
		periphyton
		other:

Benthos	
sampling gear	collect by hand, dipnet, kick net (1 meter); 500-600 micron mesh
habitat selection	multihabitat, woody debris, richest habitat
subsample size	300 count
taxonomy	family and species
Fish	
sampling gear	backpack and boat electrofishers, Rotenone, seine; 1/8" and 1/4" mesh
habitat selection	multihabitat
sample processing	length measurement and anomalies
subsample	none
taxonomy	species
Habitat assessments	visual based; performed with bioassessments (habitat reference conditions found in WQS, LAC 33:IX.1113.B.12.)
Quality assurance program elements	standard operating procedures and quality assurance plan

Data Analysis and Interpretation

Data analysis tools and methods	✓	summary tables, illustrative graphs
		parametric ANOVAs
	✓	multivariate analysis
	✓	biological metrics *(aggregate metrics into an index)*
		disturbance gradients
	✓	other: nonparametric analysis

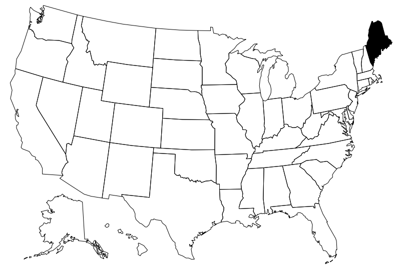
Multimetric thresholds	
transforming metrics into unitless scores	cumulative distribution function, North Carolina Biotic Index (NCBI), EPT, fish richness metrics (USEPA 1989)
defining impairment in a multimetric index	cumulative distribution function, NCBI, EPT, fish richness metrics (USEPA 1989)*

Evaluation of performance characteristics		repeat sampling
		precision
Not currently evaluated		sensitivity
		bias
		accuracy

Biological data	
Storage	spreadsheets and paper files
Retrieval and analysis	SAS and Excel

*LDEQ has used biological indices and matrices for evaluating wadeable streams in several ecoregions and for determining appropriate reference sites. These indices and matrices have not been adopted into the water quality standards and are not used to assess impairment for 305(b) or regulatory purposes.

MAINE



Contact Information

Susan P. Davies, Program Manager, Biologist III
Maine Department of Environmental Protection (MDEP)
SHS 17 ■ Augusta, ME 04333
Phone 207/287-7778 ■ Fax 207/287-7191
email: susan.p.davies@state.me.us
MDEP Biomonitoring Program website: http://www.state.me.us/dep/blwq/biohompg.htm
For General Information, contact: BioME@state.me.us

Program Description

Biological monitoring is a primary method used by the State of Maine to assess water quality. The Biological Monitoring Program is one of five Sections within the Division of Environmental Assessment. All field, analytical and statistical methods, including the resultant numeric biocriteria have been designed, developed and tested by the MDEP Biomonitoring Program staff and a consulting biostatistician (Dr. Francis Drummond, University of Maine, Orono, Maine). Water quality standards in current use in Maine, including tiered aquatic life uses and statutory definitions of biological terms, were drafted by the Biomonitoring Program and other staff of the Division of Environmental Assessment.

The State of Maine began the process of biological criteria development by incorporating explicit narrative standards for aquatic life uses in the state water quality classification law. Each of three classes, ranging from “natural” (Class A) to minimum state standards (Class C), contains specific language that defines the allowable biological response, taking into consideration other designated uses, and expectations of community response to human activities allowed in that class. The benthic macroinvertebrate community is assessed to determine attainment of standards.

Maine’s numeric biological criteria rely on a three stage decision process. The first stage is a linear discriminant model, utilizing nine metrics to assign an initial classification probability for an unknown site. The second stage linear discriminant model uses 17 additional metrics and indicator taxa, along with probabilities derived in the first stage model, to compute final probabilities of group membership. The output is expressed as a probability of group membership for each of the four water quality classes. The highest class attained, with at least 60% probability, is used as the final model outcome. The third stage uses expert biologist’s judgement to make a final decision about attainment, based on the outcome of the linear discriminant analysis, with adjustments for any known sampling errors, unexplained community structure anomalies or atypical conditions surrounding the sampling event.

The regulatory authority for the Department's numeric biological criteria is derived from the tiered aquatic life use designations that are explicitly defined in the water quality standards law (MRSA Title 38 Article 4-A § 464-465). The Department has draft rules in support of the numeric biocriteria protocol and is expected to go to rule-making as soon as a needed electronic database upgrade is completed. The Biological Monitoring Program provides water quality information for a wide array of programs and initiatives including:

- evaluation of water quality classification attainment and 303(d) listing;
- evaluation of impacts downstream of discharges;
- general, long-term ambient monitoring and trend assessment;
- evaluation of the effects of management activities
- evaluation of the effects of nonpoint source impacts;
- evaluation of impacts from diffuse toxic contamination through the Surface Water Ambient Toxics Program (MDEP 1993)
- evaluation of the impacts of hydropower activities in fulfillment of requirements for the Clean Water Act SEC. 401 water quality certification process.

In addition, the Program is refining methods and criteria to better assess aquatic biological impacts of poor land use practices on stream and wetland systems.

MDEP is funded to do a pilot project using the EPA Stressor Identification protocol applied to an intensively surveyed 303(d) listed urban watershed. To facilitate the development of TMDLs, findings from the SI procedure will be used to better target the assessment approach for a set of five other similarly impacted urban streams.

Documentation and Further Information

State of Maine 305(b) Report, Summer 2000

Biomonitoring Retrospective: Fifteen Year Summary for Maine Rivers and Streams, December 1999: http://www.state.me.us/dep/blwq/docmonitoring/biological/biorep2000.htm

S.P. Davies & L. Tsomides, (1997) "*Methods for Biological Sampling and Analysis of Maine's Inland Waters*", MDEP, revised June 1997: http://www.state.me.us/dep/blwq/docmonitoring/finlmeth.pdf

Relevant biomonitoring materials can be accessed online: http://www.state.me.us/dep/blwq/

MAINE

Contact Information

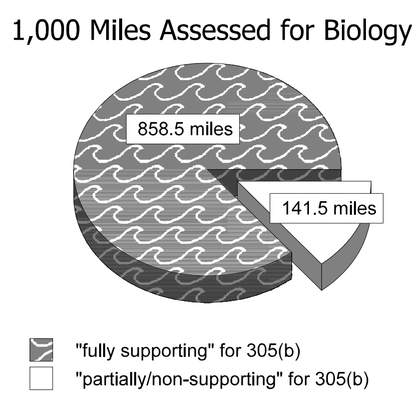
Susan P. Davies, Program Manager, Biologist III
Maine Department of Environmental Protection (MDEP)
SHS 17 ■ Augusta, ME 04333
Phone 207/287-7778 ■ Fax 207/287-7191
email: susan.p.davies@state.me.us
For General Information, contact: BioME@state.me.us

Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
	✓	monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
	✓	promulgated into state water quality standards as biocriteria
	✓	support of antidegradation
	✓	evaluation of discharge permit conditions
	✓	TMDL assessment and monitoring
	✓	other: hydropower dam licensing, uncontrolled hazardous waste site monitoring
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(special projects only)*
	✓	fixed station (i.e., water quality monitoring stations) *(specific river basins or watersheds)*
		probabilistic by stream order/catchment area
		probabilistic by ecoregion, or statewide
	✓	rotating basin *(5 yr rotation, specific river basins or watersheds)*
	✓	other: hydropower dam licensing, uncontrolled hazardous waste site monitoring

Stream Miles

Total miles *(determined using state based local GIS coverage)*	**31,672**
Total perennial miles	23,879
Total miles assessed for biology	**1,000***
fully supporting for 305(b)	858.5
partially/non-supporting for 305(b)	141.5
listed for 303(d)	141.5
number of sites sampled *(on an annual basis)*	40
number of miles assessed per site	~5



*These miles are based on the last five years of monitoring. Stream and river miles are combined, with streams accounting for roughly 80% of the total miles assessed. For program-wide estimation purposes, miles are estimated assuming that each monitored station assesses about 5 miles of river or stream, though this number does vary. The last few years, up to 55 sites have been sampled, but 40 is the average number.

Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis		Class system (AA, A, B, C)
ALU designations in state water quality standards*		Four designations based on a gradient of biological condition: AA- "as naturally occurs", natural flow regime; A- "as naturally occurs", hydro allowed; B- "no detrimental change"; C- "maintain structure and function, support for salmonids"
Narrative Biocriteria in WQS		Procedures used to support narrative biocriteria located in MDEP WQS.
Numeric Biocriteria in WQS		under development – Draft numeric biocriteria rule in internal agency review, due for promulgation in 2002. (A probabilistic model - linear discriminant analysis - designed using expert judgment and statistical analysis is currently used to determine attainment of conditions described in aquatic life standards. Numeric biocriteria have been used to implement agency policy since 1990.)
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
	✓	cause and effect determinations
	✓	permitted discharges
	✓	monitoring (e.g., improvements after mitigation)
	✓	watershed based management *(pertains to "small" watersheds)*
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU		Many examples of this have been documented in case studies provided in "Biomonitoring Retrospective: Fifteen year summary for Maine rivers and streams" available in .pdf on website: http://www.state.me.us/dep/blwq/docmonitoring/biological/biorep2000.htm

*Tiered aquatic life uses in Maine Water Quality standards are consistent with the condition gradient describing other applicable WQ standards (dissolved oxygen, bacteria, toxics) for each class.

Reference Site/Condition Development

Number of reference sites		**370 total**
Reference site determinations		site-specific
		paired watersheds
	✓	regional (aggregate of sites)
	✓	professional judgment
		other:
Reference site criteria		Minimally disturbed reference site standards are defined by the following criteria – Based on ArcView GIS coverages; by percent of watershed upstream of the sampled station: >90% forested; <5% active logging; <1% cropland, residential or urban.
Characterization of reference sites within a regional context		historical conditions
	✓	least disturbed sites
	✓	gradient response
	✓	professional judgment
	✓	other: minimally disturbed**
Stream stratification within regional reference conditions		ecoregions (or some aggregate)
		elevation
		stream type
	✓	multivariate grouping *(4 multivariate groups)*
		jurisdictional (i.e., statewide)
		other:
Additional information	✓	reference sites linked to ALU
	✓	reference sites/condition referenced in water quality standards *(State of Maine. 1985. Maine Laws Ch. 698 §15 - in part. An Act to Amend the Classification System for Maine Waters)*
	✓	some reference sites represent acceptable human-induced conditions

**Minimally disturbed characterization is one component of established reference conditions; they are also divided into different classes and groups with different biological attributes. Maine has a range of streams, from pristine to severely degraded.

Field and Lab Methods

Assemblages assessed	✓	benthos *(100-500 samples/year; single season, multiple sites - watershed level and broad coverage)*
		fish
	✓	periphyton *(<100 samples/year; single season, multiple sites - broad coverage)*
		other:

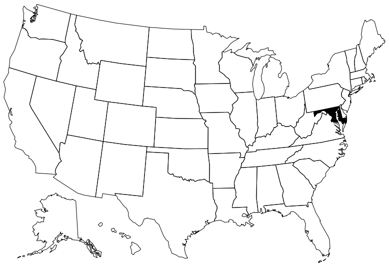
Benthos	
sampling gear	rock baskets (500-600 micron mesh)
habitat selection	riffle/run (cobble), artificial substrate
subsample size	entire sample *(if >500 organisms, subsamples are taken proportionately at 25% of sample, then adjusted back to whole sample counts)*
taxonomy	genus, species *(identified to lowest possible level; adjusted to genus in database)*
Periphyton	
sampling gear	**natural substrate**: brushing/scraping device (razor, toothbrush, etc.) **artificial substrate**: periphytometer
habitat selection	open canopy in riffle/run
sample processing	chlorophyll *a*/ phaeophytin; biomass; taxonomic identification
taxonomy	all algae; genus level; species level
Habitat assessments	visual based; performed with bioassessments
Quality assurance program elements	standard operating procedures, quality assurance plan, periodic meetings, training for biologists, sorting proficiency checks, taxonomic proficiency checks, specimen archive

Data Analysis and Interpretation

Data analysis tools and methods	✓	summary tables, illustrative graphs
		parametric ANOVAs
	✓	multivariate analysis
	✓	biological metrics *(multiple computed metrics are used as input variables in probabilistic model)*
	✓	disturbance gradients
		other:
Multivariate thresholds		
defining impairment in a multivariate index		Probabilistic model using *a priori* sites defined by expert judgement
Evaluation of performance characteristics	✓	repeat sampling *(long-term annual monitoring sites)*
	✓	precision *(percent accuracy compared to a priori class)*
		sensitivity
	✓	bias *(in relation to stream size, latitude/longitude, velocity, eco-region)*
	✓	accuracy *(percent accuracy compared to a priori class; a priori reference sites compared to land use - selected reference sites)*

Biological data	
Storage	STORET; Oracle/Visual Basic relational database (with linkage to ARCINFO spatial database with point coverage for all monitoring stations)
Retrieval and analysis	Core linear discriminant models statistical routines are run and reported from within the Oracle database; spatial analysis in ArcView and ARCINFO; routine queries run in MS Access, Systat or Excel

MARYLAND



Contact Information

Paul Kazyak, Monitoring and Non-Tidal Assessment Division Director
Maryland Department of Natural Resources (MD DNR)
Tawes State Office Bldg., C-2 ■ Annapolis, MD 21401
Phone 410/260-8607 ■ Fax 410/260-8620
email: pkazyak@dnr.state.md.us
MD DNR Maryland Streams homepage: http://www.dnr.state.md.us/streams/index.html

Richard Eskin, PhD, Deputy Director - Technical and Regulatory Services Administration
Maryland Department of the Environment (MDE)
1800 Washington Blvd. ■ Baltimore, MD 21230
Phone 410/537-3000 ■ Fax 410/631-3998
email: reskin@mde.state.md.us
website: http://www.mde.state.md.us/

Program Description

The Maryland Biological Stream Survey (MBSS) is a program of the Maryland Department of Natural Resources (MD DNR) and is intended to provide statistically unbiased estimates of the condition of first through third-order (wadeable) non-tidal streams and rivers of Maryland on a local (e.g., drainage basin or county) as well as a statewide scale. The survey is based on a probabilistic stream sampling approach where random selections are made from all streams in the state that can physically be sampled. The approach supports statistically valid population estimation of variables of interest (e.g., largemouth bass densities, miles of streams with degraded physical habitat, miles of streams with poor Index of Biotic Integrity scores, etc.). When repeated, the Survey will also provide a basis for assessing future changes in ecological condition of flowing waters of the state. At present, plans are to repeat the Survey at regular intervals and expand the approach to larger streams and tidal creeks.

Benthic macroinvertebrates and water quality samples are collected during the spring index period from March through early May, while fish, herpetofauna, *in situ* stream chemistry, and physical habitat sampling are conducted during the low flow period in the summer, from June through September.

Data collected from each sample site are used to develop statewide and basin-specific estimates of totals, means (or averages), proportions, and percentiles for the parameters of interest. The amount of variability (or margin of error) associated with any estimate of a total, mean, proportion, or percentile is determined by calculating a standard error, a statistic that measures the reliability of an estimate. A standard error also provides a statistical basis for deciding if the observed changes in any parameter of interest over time or space are significantly different or simply due to chance alone.

Documentation and Further Information

2000 Maryland Section 305(b) Water Quality Report, with *Appendix E, Assessment Methodology*:
http://dnrweb.dnr.state.md.us/download/bays/MD2000_305b.pdf

DRAFT 2002 Integrated 303(d) List: http://www.mde.state.md.us/tmdl/2002_303dlist/index.html

From the Mountains to the Sea: The State of Maryland's Freshwater Streams, December 1999:
http://www.dnr.state.md.us/streams/pubs/md-streams.pdf

Maryland Biological Stream Survey (MBSS) Sampling Manual, February 2000:
http://www.dnr.state.md.us/streams/pubs/2000samp_manual.pdf

MBSS Laboratory Methods for Benthic Macroinvertebrate Processing and Taxonomy, November 2000:
http://www.dnr.state.md.us/streams/pubs/ea00-6_lab_man.pdf

Refinement and Validation of a Fish Index of Biotic Integrity (IBI) for Maryland Streams, October 2000:
http://www.dnr.state.md.us/streams/pubs/ea00-2_fibi.pdf

Development of a Benthic Index of Biological Integrity for Maryland Streams, December 1998:
http://www.dnr.state.md.us/streams/pubs/1998_Benthic%20IBI.pdf

For more documents and publications, go to: http://www.dnr.state.md.us/streams/mbss/mbss_pubs.html or
http://www.dnr.state.md.us/streams/pubs/pub_list.html

MARYLAND

Contact Information

Paul Kazyak, Monitoring and Non-Tidal Assessment Division Director
Maryland Department of Natural Resources (MD DNR)
Tawes State Office Bldg., C-2 ■ Annapolis, MD 21401
Phone 410/260-8607 ■ Fax 410/260-8620
email: pkazyak@dnr.state.md.us

Richard Eskin, PhD, Deputy Director - Technical and Regulatory Services Administration
Maryland Department of the Environment (MDE)
1800 Washington Blvd. ■ Baltimore, MD 21230
Phone 410/537-3000 ■ Fax 410/631-3998
email: reskin@mde.state.md.us

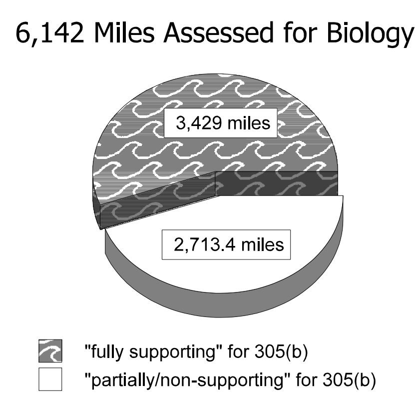
Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
	✓	monitoring the effectiveness of BMPs *(LIMITED)*
	✓	ALU determinations/ambient monitoring *(LIMITED)*
	UD	promulgated into state water quality standards as biocriteria *(through MDE)*
	✓	support of antidegradation
	✓	evaluation of discharge permit conditions *(LIMITED)*
	✓	TMDL assessment and monitoring *(MDE using MBSS data)*
	✓	other: target restoration costs and locations; areas for preservation; track trends in stream conditions; identify relationships between stressors and biota; predict future conditions based on land use changes
Applicable monitoring designs*	✓	targeted *(small portion - special projects and specific river basins or watersheds)*
	✓	fixed station (i.e., water quality monitoring stations) *(sentinel site network, best of the best streams in the state, comprehensive use throughout jurisdiction)*
	✓	probabilistic by stream order/catchment area *(comprehensive use throughout jurisdiction)*
	✓	probabilistic by ecoregion, or statewide *(comprehensive use throughout jurisdiction)*
	✓	rotating basin *(comprehensive use throughout jurisdiction)*
		other:

*The largest portion of sampling effort is for probabilistic sampling with watershed as primary strata.

Stream Miles

Total miles *(determined using National Hydrography Database)*	**17,000**
Total perennial miles	12,343
Total miles assessed for biology**	**6,142**
fully supporting for 305(b)	3,429.0
partially/non-supporting for 305(b)	2,713.4
listed for 303(d)**	178 actual listings
number of sites sampled *(from 1995-1997)*	1,000
number of miles assessed per site	–



**The miles listed above were extracted from Maryland's 2000 305(b) Report, which stated, "The assessment of non-tidal rivers and streams is based on monitoring data, including ambient water quality monitoring programs and other water quality data collected by [various agencies and programs]." The above miles are categorized as "monitored" in the 2000 305(b). However, the MBSS method only applies to *wadeable* nontidal streams, thus some portion of the total assessed stream and river miles listed above were not assessed using this method. The 178 sites listed for 303(d) were pulled from the DRAFT 2002 303(d) Report. These miles do not include streams larger than 4th order or with tidal flow.

Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Single Aquatic Life Use, Fishery Based Uses, Warm Water vs. Cold Water	
ALU designations in state water quality standards	Seven uses: I: support of fish & aquatic life and recreation; I-P: adds drinking water supply to Use I; II: shellfish harvesting; III: natural trout; III-P: adds drinking water supply; IV: recreational trout (put and take); IV-P: adds drinking water.	
Narrative Biocriteria in WQS	Narrative regulations and formal/informal numeric procedures specifically addressing biocriteria applications are under development.	
Numeric Biocriteria in WQS	none - documented quantitative method applied	
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
	✓	cause and effect determinations
	✓	permitted discharges *(RARELY)*
	✓	monitoring (e.g., improvements after mitigation)
	✓	watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	Threatened and Endangered species listings are being revised based on MBSS fish population data; cost estimates for habitat restoration in MD streams are being finalized in support of Chesapeake Bay 2000 Agreement action items; MBSS data integral to developing restoration priority ranking for MD watersheds; also used by The Nature Conservancy to develop highest priority watersheds for land acquisition and other preservation activities	

Reference Site/Condition Development

Number of reference sites	**152 total**	
Reference site determinations		site-specific
		paired watersheds
		regional (aggregate of sites)
		professional judgment
	✓	other: use combination of *a priori* physical and chemical criteria applied to randomly selected sites - these represent the best remaining sites in Maryland
Reference site criteria	Must meet *a priori* chemical and physical criteria (criteria found in MBSS IBI documents for fish and benthos)	
Characterization of reference sites within a regional context		historical conditions
	✓	least disturbed sites
		gradient response
		professional judgment
		other:
Stream stratification within regional reference conditions	✓	ecoregions (or some aggregate)
		elevation
		stream type
		multivariate grouping
		jurisdictional (i.e., statewide)
	✓	other: reference sites stratified by stream order
Additional information		reference sites linked to ALU
		reference sites/condition referenced in water quality standards
	✓	some reference sites represent acceptable human-induced conditions

Field and Lab Methods

Assemblages assessed	✓	benthos *(100-500 samples/year; single season, multiple sites - watershed level)*
	✓	fish *(100-500 samples/year; single season, multiple sites - watershed level)*
		periphyton
	✓	other: macrophytes and amphibians/reptiles (*presence/absence only) (100-500 samples/year; single season, multiple sites - watershed level*)
Benthos		
sampling gear		D-frame; 500-600 micron mesh
habitat selection		multihabitat, focus on most productive habitat - riffles
subsample size		100 count
taxonomy		genus (family level taxonomy for volunteer Stream Waders Program)
Fish		
sampling gear		backpack electrofisher, barge shocker sometimes used on larger streams, herpetile search also conducted by hand; 1/4" mesh
habitat selection		whatever is in the 75 meter segment
sample processing		length measurement and biomass – batch (gamefish only); anomalies (unusual types or prevalence noted)
subsample		none
taxonomy		species
Habitat assessments		visual based, quantitative measurements, buffer width and vegetation size category, linear and areal extent of eroded banks; performed with bioassessments
Quality assurance program elements		standard operating procedures; quality assurance plan; periodic meetings/ training for biologists; sorting and taxonomic proficiency checks; specimen archival; double entry of data; range checks; peer review of reports; certification program for bioassessment

Data Analysis and Interpretation

Data analysis tools and methods	✓	summary tables, illustrative graphs
	✓	parametric ANOVAs
	✓	multivariate analysis
	✓	biological metrics *(aggregate metrics into an index)*
	✓	disturbance gradients
	✓	other: various, depending on needs
Multimetric thresholds*		
transforming metrics into unitless scores		50^{th} percentile of reference population
defining impairment in a multimetric index		10^{th} percentile used as threshold between metric scores of 3 and 1; confidence intervals used to evaluate sample results for attainment decisions
Multivariate thresholds		
defining impairment in a multivariate index		For development of IBI; not current analysis
Evaluation of performance characteristics	✓	repeat sampling *(see IBI documents plus interim biocriteria document produced by MDE)*
	✓	precision *(replicate sample/same team, same reach)*
	✓	sensitivity *(classification efficiency)*
		bias
	✓	accuracy *(classification efficiency)*
	✓	other: re-sort in laboratory
Biological data		
Storage		MS Access, SAS primarily, but also use spreadsheets for some applications (data dictionaries are produced for external users - see MBSS publications page)
Retrieval and analysis		SAS, Excel, Quattro pro, ARC View

*Fish and Benthic IBIs are also combined into a "Combined Biological Index."

MASSACHUSETTS

Contact Information

Arthur S. Johnson, Environmental Monitoring Coordinator
Massachusetts Department of Environmental Protection (MADEP)
627 Main Street ■ Worcester, MA 01608
Phone 508/767-2873 ■ Fax 508/791-4131
email: arthur.johnson@state.ma.us
website: http://www.state.ma.us/dep/

Program Description

Biological monitoring techniques are an important component of the watershed-based surface water quality monitoring and assessment program administered by the Massachusetts Department of Environmental Protection (MADEP). The goals of this program are to assess whether the surface waters of Massachusetts are of sufficient quality and quantity to support their multiple uses, and to report those findings in watershed assessment reports, the 305(b) Summary of Water Quality Report and the 303(d) List of Impaired Waters. Monitoring is also used to identify causes and sources of water use impairments as the first step toward developing water quality and quantity management strategies.

MADEP biologists assess the condition of resident macroinvertebrate, fish and algal communities in streams to provide a direct measure of the ecological response to the cumulative effects of pollutant loadings and habitat degradation. These bioassessments, coupled with water quality data and other relevant information, form the basis for determining the aquatic life use-support status, as defined in the *Massachusetts Surface Water Quality Standards*.

Rapid bioassessment protocols (RBPs), based on those developed by the USEPA, are used to monitor the integrity of the benthic macroinvertebrate community. A targeted sampling design is employed whereby sites are selected for upstream/downstream comparisons, comparisons against a regional or surrogate reference, or for long-term trend monitoring. Based on scoring of several metrics, four categories of impairment are discerned by the RBP analysis (non-impaired, slightly impaired, moderately impaired, and severely impaired). Approximately 50-75 sites are assessed each year in accordance with a rotating watershed monitoring scheme.

The analysis of the structure of the finfish community as a measure of biological integrity is another component of the water quality monitoring program. MADEP utilizes a standardized method based on RBP V (USEPA 1989) to improve data comparability among wadeable sampling sites. The fish collection procedures involve sampling habitats in relative proportion to their local availability. A representative 100-meter stream reach is selected to include the primary physical habitat characteristics of the stream (i.e., riffle, run, and pool habitats). Electrofishing is the preferred method for obtaining a representative sample of the fish community at each sampling site. Fish (except young-of-the-year) collected within the study reach are identified to species, counted, and examined for external anomalies, (i.e., deformities, eroded fins, lesions, and tumors). Aquatic life use-support status is derived from a knowledge of the environmental requirements (e.g., water temperature and clarity, dissolved oxygen content) and relative tolerance to water pollution of the species collected.

Algae represent a third community that may be assessed. The analysis of the attached algae or periphyton community in shallow streams, or the phytoplankton in deeper rivers and lakes employs an indicator species approach whereby inferences on water quality conditions are drawn from an understanding of the environmental preferences and tolerances of the species present. Because the algal community typically exhibits dramatic temporal shifts in species composition throughout a single growing season, results from a single sampling event are generally not indicative of historical conditions. For this reason the information gained from the algal community assessment is more useful as a supplement to the assessments of other communities that serve to integrate conditions over a longer time period.

In addition to the community analyses described above, MADEP also collects some fish to be assayed for the presence of toxic contaminants in their tissues. The goal of this monitoring element is primarily to provide data for the assessment of the risk to human consumers associated with the consumption of freshwater finfish. In the past fish collection efforts were generally restricted to waterbodies where wastewater discharge data or previous water quality studies indicated potential toxic contamination problems. More recently, concerns about mercury contamination from both local and far-field sources have led to a broader survey of waterbodies throughout Massachusetts. In both cases, nonetheless, the analyses have been restricted to edible fish fillets.

Documentation and Further Information

Commonwealth of Massachusetts Summary of Water Quality 2000

Massachusetts Surface Water Quality Standards, May 1997: http://www.state.ma.us/dep/bwp/iww/files/314004.pdf

For a list of online resources, go to: http://www.state.ma.us/dep/brp/wm/wmpubs.htm#other

Jessup, B.K., J. Gerritsen, M.T. Barbour, and R. Haynes. 2001. *Analysis and Interpretation of Pilot Study Data as an Initial Step in the Development of Biological Criteria for Streams and Small Rivers in Massachusetts*. Prepared by Tetra Tech, Inc., for Massachusetts Department of Environmental Protection, Worcester, MA.

MASSACHUSETTS

Contact Information

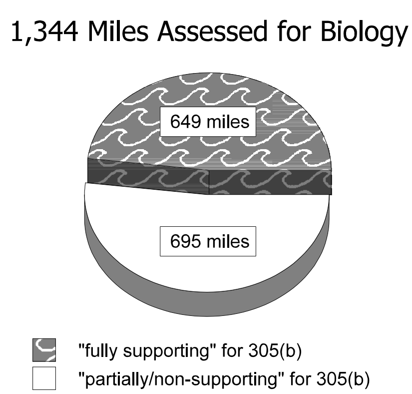
Arthur S. Johnson, Environmental Monitoring Coordinator
Massachusetts Department of Environmental Protection (MADEP)
627 Main Street ■ Worcester, MA 01608
Phone 508/767-2873 ■ Fax 508/791-4131
email: arthur.johnson@state.ma.us

Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
		monitoring the effectiveness of BMPs
	✓	ALU determinations, ambient monitoring
		promulgated into state water quality standards as biocriteria
		support of antidegradation
	✓	evaluation of discharge permit conditions
		TMDL assessment and monitoring
	✓	other: development of numeric biocriteria
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(specific river basins or watersheds)*
		fixed station (i.e., water quality monitoring stations)
		probabilistic by stream order/catchment area
		probabilistic by ecoregion, or statewide
	✓	rotating basin *(specific river basins or watersheds)*
		other:

Stream Miles

Total miles *(determined using a state based program)*	**8,229**
Total perennial miles	7,133
Total miles assessed for biology	**1,344**
fully supporting for 305(b)	649
partially/non-supporting for 305(b)	695
listed for 303(d)	695
number of sites sampled *(on an annual basis)**	~100
number of miles assessed per site*	site specific



*The number of sites sampled varies annually, as does the number of miles assessed per site.

Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Warm water vs. Cold water	
ALU designations in state water quality standards	Three designations: 1. General Aquatic Life Support 2. Cold Water/Warm Water Fishery 3. Shellfish Harvesting	
Narrative Biocriteria in WQS	none - General aquatic life statement found in WQS; informal process in place to translate RBP metrics to level of use support.	
Numeric Biocriteria in WQS	none	
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
		cause and effect determinations
	✓	permitted discharges
		monitoring (e.g., improvements after mitigation)
	✓	watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	Information discussed in water quality assessment reports along with recommendations for management, restoration and further monitoring.	

Reference Site/Condition Development

Number of reference sites	**5 - 10 total** *(on an annual basis)**	
Reference site determinations	✓	site-specific
	✓	paired watersheds
	✓	regional (aggregate of sites)
	✓	professional judgment
		other:
Reference site criteria	Least impacted by known point discharges; least impacted by riparian zone land uses; habitat qualities comparable to test sites. For regional reference sites MADEP attempts to locate the least-disturbed sites by conducting extensive reconnaissance throughout the watershed and selecting sites that do not appear to have point or nonpoint sources of pollution upstream from them. Reference sites that represent the various sub-ecoregions that exist in Massachusetts are gradually being identified. This process is not yet complete, however.	
Characterization of reference sites within a regional context		historical conditions
	✓	least disturbed sites
		gradient response
		professional judgment
		other:
Stream stratification within regional reference conditions	✓	ecoregions (or some aggregate)
		elevation
		stream type
		multivariate grouping
		jurisdictional (i.e., statewide)
	✓	other: MADEP is working on identifying reference sites to represent various sub-ecoregions
Additional information		reference sites linked to ALU
		reference sites/condition referenced in water quality standards
	✓	some reference sites represent acceptable human-induced conditions

*MADEP does not have a fixed set of reference stations situated throughout the state. Rather, during the rotating basin schedule MADEP reconnaissances new reference sites depending upon where the sampling will take place. Therefore the number of reference sites may vary from year to year.

Field and Lab Methods

Assemblages assessed	✓	benthos *(<100 samples/year; single season, multiple sites - watershed level)*
	✓	fish *(<100 samples/year; single season, multiple sites - watershed level)*
	✓	periphyton *(<100 samples/year; single season, multiple sites - some at watershed level)*
	✓	other: macrophytes *(<100 samples/year; single season, multiple sites - not at watershed level)*

Benthos	
sampling gear	multi-plate, rock baskets, collect by hand, single-pole kick-net (45 cm, rectangular, 500-600 micron mesh)
habitat selection	riffle/run (cobble)
subsample size	100 count
taxonomy	combination--genus, species
Fish	
sampling gear	backpack electrofisher, boat electrofisher, seine; 1/8", 3/16" and 1/4" mesh
habitat selection	multihabitat
sample processing	length measurement, biomass - individual, anomalies
subsample	all species, 25 individuals of each
taxonomy	sub-species
Periphyton	
sampling gear	**natural substrate**: suction device, brushing/scraping device (razor, toothbrush, etc.), collect by hand; **artificial substrate**: microslides or other suitable substratum
habitat selection	richest habitat, riffle/run (cobble), multihabitat, artificial substrate
sample processing	chlorophyll *a*/ phaeophytin, biomass, taxonomic identification
taxonomy	genus level for soft-bodied algae when possible; diatoms are not cleared
Habitat assessments	visual based; performed with bioassessments
Quality assurance program elements	standard operating procedures; quality assurance plan; periodic meetings, training for biologists; limited taxonomic proficiency checks; specimen archival

Data Analysis and Interpretation

Data analysis tools and methods	✓	summary tables, illustrative graphs
		parametric ANOVAs
		multivariate analysis
	✓	biological metrics *(aggregate metrics into an index)*
		disturbance gradients
		other:

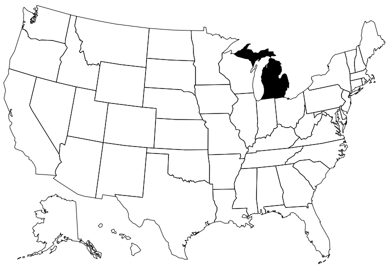
Multimetric thresholds*	
transforming metrics into unitless scores	Follow 1989 EPA RBP guidelines (Figure 6.3-4)
defining impairment in a multimetric index	Follow 1989 EPA RBP guidelines: anything <83% of reference is impaired/impacted

Evaluation of performance characteristics		repeat sampling
	✓	precision *(duplicate sampling)*
		sensitivity
		bias
		accuracy

Biological data	
Storage	MS Access 2000
Retrieval and analysis	MS Access 2000 - benthos database customized from EDAS

*Everything is determined relative to the reference sites; however some parts of this have been refined, including the similarity index thresholds, and MADEP hopes to use biocriteria data to further modify thresholds. MADEP has also evaluated a model community at order level as a substitute for similarity indices (see Novak & Bode, 1992).

MICHIGAN



Contact Information

William Creal, Environmental Manager
Michigan Department of Environmental Quality (MDEQ)
P.O. Box 30273 ■ Lansing, MI 48909
Phone 517/335-4181 ■ Fax 517/241-8133
email: crealw@michigan.gov
MDEQ Water homepage: http://www.michigan.gov/deq/1,1607,7-135-3313---,00.html

Program Description

In 1997, the Michigan Department of Environmental Quality (MDEQ) completed a report entitled, *A Strategic Environmental Quality Monitoring Program for Michigan's Surface Waters* (Strategy). This Strategy describes the monitoring activities necessary for a comprehensive assessment of water quality in Michigan's surface waters. One component of the Strategy is expanded and improved monitoring of biological integrity and physical habitat.

This program element includes all monitoring conducted for fish and benthic invertebrate community structure, nuisance aquatic plants, algae, and slimes, and assessment of physical habitat. The MDEQ's goal in conducting watershed surveys is to assess 80 percent of the stream and river miles in Michigan over a five-year period.

Enhanced biological integrity and physical habitat monitoring is consistent with existing MDEQ programs and activities. MDEQ uses the existing five-year basin units defined by the NPDES permitting program, which includes 45 watershed units based on drainage to the four Great Lakes. Monitoring activities in each watershed include not only biological integrity, but also fish and wildlife contaminant studies, water chemistry, and sediment chemistry. Integrating the enhanced biological monitoring with the other activities, within the framework of the five-year permitting cycle, will ensure that the monitoring is closely linked with other MDEQ programs and contributes to resource management decisions. Specific objectives of biological integrity and physical habitat monitoring are to:

1. Determine whether waters of the state are attaining standards for aquatic life.
2. Assess the biological integrity of the waters of the state.
3. Determine the extent to which sedimentation in surface waters is impacting indigenous aquatic life.
4. Determine whether the biological integrity of surface waters is changing with time.
5. Assess the effectiveness of BMPs and other restoration efforts in protecting and/or restoring biological integrity and physical habitat.
6. Evaluate the overall effectiveness of MDEQ programs in protecting the biological integrity of surface waters.
7. Identify waters that are high quality, as well as those that are not meeting standards.
8. Identify the waters of the state that are impacted by nuisance aquatic plants, algae, and bacterial slimes.

Rapid, qualitative biological assessments of wadeable streams and rivers are conducted using the Great Lakes and Environmental Assessment Section Procedure 51, which compares fish and benthic invertebrate communities at a site to the communities that are expected at an un-impacted, or reference, site. This is a key tool used by MDEQ to determine whether waterbodies are attaining Michigan WQS. Because Procedure 51 is meant to be a qualitative, rapid assessment tool, the MDEQ established a contract with the Great Lakes Environmental Center to develop a statistically valid sample design and procedure for detection of trends using benthic macroinvertebrates. This project is scheduled for completion in January 2003.

All biological community data are entered into MDEQ's MS Access database. Biological and habitat data collected as part of the five-year watershed surveys are summarized in watershed reports. The list of these reports is stored in a database that will be accessible to the public via the MDEQ Surface Water Quality Division's website.

Documentation and Further Information

Michigan Water Quality Report (Year 2000 305(b) Report):
http://www.michigan.gov/deq/1,1607,7-135-3313_3686_3728-12711--,00.html

CWA Section 303(d) List: Michigan Submittal for Year 2002:
http://www.deq.state.mi.us/documents/deq-swq-gleas-303_d_Rpt2002b.pdf

Michigan's WQS, revised April 1999: http://www.deq.state.mi.us/documents/deq-swq-gleas-305b2002Appl.doc

MDEQ Biosurveys website:
http://www.michigan.gov/deq/0,1607,7-135-3313_3686_3728-32369--,00.html

MICHIGAN

Contact Information

William Creal, Environmental Manager
Michigan Department of Environmental Quality (MDEQ)
P.O. Box 30273 ■ Lansing, MI 48909
Phone 517/335-4181 ■ Fax 517/241-8133
email: crealw@michigan.gov

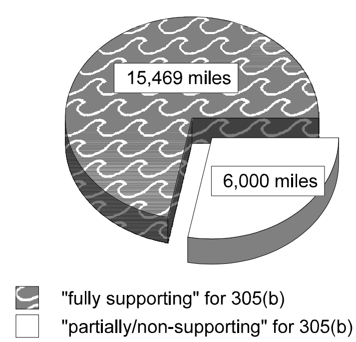
Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
	✓	monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
		promulgated into state water quality standards as biocriteria
	✓	support of antidegradation
	✓	evaluation of discharge permit conditions
	✓	TMDL assessment and monitoring
		other:
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(special projects only)*
		fixed station (i.e., water quality monitoring stations)
		probabilistic by stream order/catchment area
		probabilistic by ecoregion, or statewide
	✓	rotating basin *(specific river basins or watersheds and comprehensive use throughout jurisdiction)*
		other:

Stream Miles

Total miles *(determined using RF3)*	**49,141**
Total perennial miles	27,873
Total miles assessed for biology	**21,469**
fully supporting for 305(b)	15,469
partially/non-supporting for 305(b)	6,000
listed for 303(d)	2,600
number of sites sampled	3,500
number of miles assessed per site	–

21,469 Miles Assessed for Biology



Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Warm Water vs. Cold Water	
ALU designations in state water quality standards	Three designations: coldwater fisheries, warmwater fisheries, and other indigenous aquatic life and wildlife (per Rule 100 of Michigan's WQS). Coldwater fishery includes any of the following: trout, salmon, whitefish, cisco. Warmwater fishery includes fish species that thrive in relatively warmwater, including any of the following: bass, pike, walleye, panfish.	
Narrative Biocriteria in WQS	none*	
Numeric Biocriteria in WQS	none	
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
	✓	cause and effect determinations
	✓	permitted discharges
	✓	monitoring (e.g., improvements after mitigation)
	✓	watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	TMDL listing and delisting decisions	

*Michigan does not have narrative biocriteria, per se. However, MI does have tiered ALU designations and numeric procedures (the Gleas Procedure #51) to implement WQS, evaluate nonpoint source impacts, and assess designated uses. According to MDEQ's *Qualitative and Biological Biological Survey Protocols for Wadeable Streams and Rivers* (Procedure #51), "The development of these biological and habitat survey protocols was a result of the increasing demand for a more vigorous and standardized evaluation of nonpoint source impacts. The nature and diversity of the causes of nonpoint pollution created a need for greater refinement and sophistication of the Surface Water Quality Division's standard biological survey procedures in order to assess the degree and causes of these biological impacts."

Reference Site/Condition Development

Number of reference sites	**200 total**	
Reference site determinations	✓	site-specific
		paired watersheds
		regional (aggregate of sites)
		professional judgment
		other:
Reference site criteria	excellent biota present	
Characterization of reference sites within a regional context		historical conditions
		least disturbed sites
Not applicable		gradient response
		professional judgment
		other:
Stream stratification within regional reference conditions	✓	ecoregions (or some aggregate)
		elevation
		stream type
		multivariate grouping
		jurisdictional (i.e., statewide)
		other:
Additional information		reference sites linked to ALU
		reference sites/condition referenced in water quality standards
	✓	some reference sites represent acceptable human-induced conditions

Field and Lab Methods

Assemblages assessed	✓	benthos *(>500 samples/year; single season, multiple sites - watershed level)*
	✓	fish *(<100 samples/year; single season, multiple sites - watershed level)*
		periphyton
		other:

Benthos	
sampling gear	D-frame and dipnet; 800-900 micron mesh
habitat selection	multihabitat
subsample size	100 count
taxonomy	combination - family, genus
Fish	
sampling gear	backpack electrofisher and pram unit (tote barge)
habitat selection	multihabitat
sample processing	length measurement and anomalies
subsample	none
taxonomy	species
Habitat assessments	visual based; performed with bioassessments
Quality assurance program elements	standard operating procedures, quality assurance plan, periodic meetings and training for biologists, specimen archival

Data Analysis and Interpretation

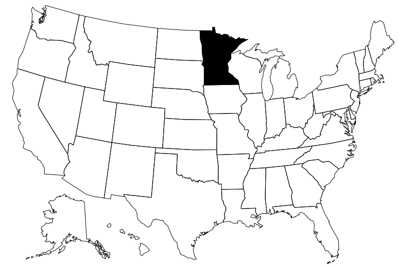
Data analysis tools and methods	✓	summary tables, illustrative graphs
		parametric ANOVAs
		multivariate analysis
	✓	biological metrics *(aggregate metrics into an index)*
		disturbance gradients
		other:

Multimetric thresholds	
transforming metrics into unitless scores	Two standard deviations from excellent condition
defining impairment in a multimetric index	Two standard deviations from excellent condition

Evaluation of performance characteristics	✓	repeat sampling
	✓	precision *(repeat sampling by teams during round robins over the years)*
		sensitivity
		bias
		accuracy

Biological data	
Storage	MS Access database, spreadsheets
Retrieval and analysis	SAS, Systat and Statistica

MINNESOTA



Contact Information

Scott Niemela, Research Scientist
Minnesota Pollution Control Agency (MPCA)
520 Lafayette Road ■ St. Paul, MN 55155
Phone 651/296-8878 ■ Fax 651/297-8324
email: scott.niemela@pca.state.mn.us
MPCA Water homepage: http://www.pca.state.mn.us/water/index.html

Program Description

The Minnesota Pollution Control Agency (MPCA) Biological Assessment Unit, located in the Environmental Standards and Analysis Section, performs many functions integral to water quality decision-making. Among these, the Unit:

- Develops biological measures of ecological integrity for streams and wetlands.
- Collects and analyzes biological monitoring data.
- Builds a biological monitoring system that includes streams in the 10 major river basins.
- Lays the groundwork for the development of biological indicators for lakes and large rivers.
- Determines biological impairments of rivers and streams for use in TMDL studies
- Coordinates creation of TMDL listing.

Documentation and Further Information

2000 Minnesota Water Quality: Surface Water Section, Years 1998 - 1999 305(b) Report:
http://www.pca.state.mn.us/publications/reports/305bfinalreport-2000.pdf

Stream Assessment Methods for Use Support: http://www.pca.state.mn.us/water/basins/method98.pdf

MPCA Water Quality Criteria - Aquatic Life Use Support in Rivers and Streams:
http://www.pca.state.mn.us/water/basins/rivkey98.pdf

Minnesota Lake Water Quality Assessment Data: 2000: http://www.pca.state.mn.us/water/pubs/lwqar.pdf

MPCA Environmental Outcomes Division website: http://www.pca.state.mn.us/about/eod.html

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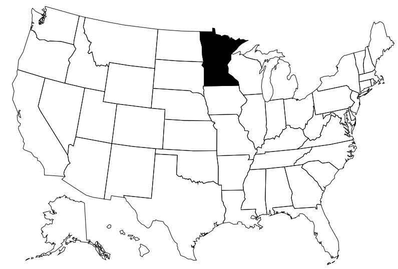


Contact Information

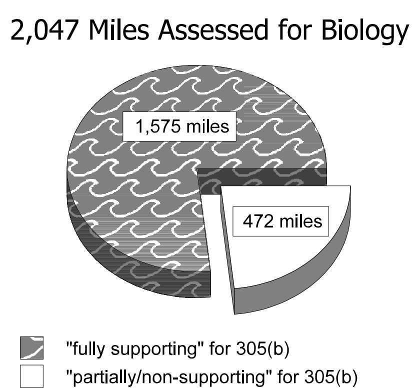
Scott Niemela, Research Scientist
Minnesota Pollution Control Agency (MPCA)
520 Lafayette Road ■ St. Paul, MN 55155
Phone 651/296-8878 ■ Fax 651/297-8324
email: scott.niemela@pca.state.mn.us

Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
		monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
	✓	promulgated into state water quality standards as biocriteria
		support of antidegradation
	✓	evaluation of discharge permit conditions
	✓	TMDL assessment and monitoring
		other:
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(in specific river basins or watersheds for biocriteria development, problem investigation, and effectiveness monitoring)*
		fixed station (i.e., water quality monitoring stations)
		probabilistic by stream order/catchment area
		probabilistic by ecoregion, or statewide
	✓	rotating basin *(in specific river basins or watersheds for condition monitoring and biocriteria development)*
	✓	other: probabilistic by major basin

Stream Miles

Total miles *(determined using National Hydrography Database)*	**91,944**
Total perennial miles	32,985
Total miles assessed for biology*	2,047
fully supporting for 305(b)	1,575
partially/non-supporting for 305(b)	472
listed for 303(d)	785
number of sites sampled *(on an annual basis)*	100
number of miles assessed per site	depends on segment length



*The discrepancy between 305(b) and 303(d) miles is due to a change in methods related to the threshold level of impairment. The numbers for 303(d) reflect the information from the latest proposed 303(d) list using the new threshold levels. The 305(b) miles will reflect the old threshold levels until the next 305(b) assessments occur.

Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Class System (1,2,3), Fishery Based Uses and Warm Water vs. Cold Water	
ALU designations in state water quality standards	Aquatic life and recreation, Class 2. 4 subclasses: 2A, cold water (salmonid) fishery; 2B cool & warm water fishery; 2C, "indigenous" fishery; 2D, wetlands	
Narrative Biocriteria in WQS	Numeric procedures to implement narrative biocriteria are in separate Guidance documents, not part of the water quality standards.	
Numeric Biocriteria in WQS	none	
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
		cause and effect determinations
	✓	permitted discharges
	✓	monitoring (e.g., improvements after mitigation)
	✓	watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	Bioassessment information is being used in the TMDL process and to support decisions regarding permitted discharges.	

Reference Site/Condition Development

Number of reference sites	**35 total**	
Reference site determinations*		site-specific
		paired watersheds
	✓	regional (aggregate of sites)
	✓	professional judgment
		other:
Reference site criteria	Reference sites are defined as minimally disturbed reaches/areas within a specific geographic region, within a given aquatic classification framework. The criteria used to define reference sites are based on biology, landuse, and habitat and are adjusted by region (basin, ecoregion, etc).	
Characterization of reference sites within a regional context		historical conditions
	✓	least disturbed sites
		gradient response
		professional judgment
	✓	other:**
Stream stratification within regional reference conditions	✓	ecoregions (or some aggregate)
		elevation
	✓	stream type
		multivariate grouping
		jurisdictional (i.e., statewide)
	✓	other: At this time MPCA is using major river basin as a framework. This could change once a statewide database is developed.
Additional information		reference sites linked to ALU
		reference sites/condition referenced in water quality standards
	✓	some reference sites represent acceptable human-induced conditions

*Candidate reference sites are initially selected using GIS coverages including landuse, point source, ditching, and feedlot. After the biological sampling has occurred, reference sites are chosen using the biological, habitat, and GIS based information.

**There are regions within Minnesota where *minimally impacted* reference sites will eventually be identified. MPCA has not had the opportunity to develop biological criteria for these areas yet, but is planning to do so within the next five to ten years.

Field and Lab Methods

Assemblages assessed	✓	benthos *(100-500 samples/year; single season, multiple sites - watershed level)*
	✓	fish *(100-500 samples/year; single season, multiple sites - watershed level)*
		periphyton
	✓	other: macrophytes *(<100 samples/year; single season multiple sites – not at watershed level)*

Benthos	
sampling gear	D-frame; 500-600 micron mesh
habitat selection	multihabitat
subsample size	300 count
taxonomy	genus
Fish	
sampling gear	backpack and boat electrofishers, and pram unit (tote barge)
habitat selection	multihabitat
sample processing	length measurement, biomass - batch and anomalies
subsample	none
taxonomy	species
Habitat assessments	quantitative measurements; performed with bioassessments
Quality assurance program elements	standard operating procedures, periodic meetings and training for biologists, sorting and taxonomic proficiency checks, specimen archival

Data Analysis and Interpretation

Data analysis tools and methods	✓	summary tables, illustrative graphs
		parametric ANOVAs
		multivariate analysis
	✓	biological metrics *(aggregate metrics into an index)*
	✓	disturbance gradients
		other:

Multimetric thresholds	
transforming metrics into unitless scores	95th percentile of all sites
defining impairment in a multimetric index	The percentile of the reference population will vary by major basin because of wide variability between basins regarding the level of human disturbance.

Evaluation of performance characteristics	✓	repeat sampling *(10% of all sites are repeated during a season)*
	✓	precision (*A multiyear study, currently 5 years long, is being conducted to evaluate the precision of IBI scores over a long term period. This work is taking place at reference sites and degraded sites - ten sites total.)*
	✓	sensitivity *(sensitivity has been examined by evaluating IBI scores against gradients of disturbance)*
		bias
	✓	accuracy *(accuracy has been informally examined by comparison of IBI scores to expected results from a landuse/habitat rating score)*

Biological data	
Storage	database (details not provided)
Retrieval and analysis	Systat

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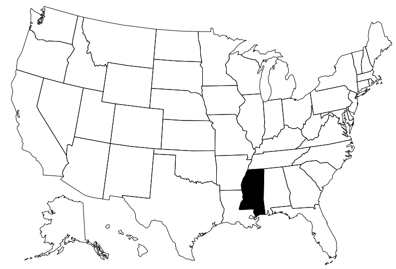

Contact Information

Randy Reed, Chief, Water Quality Assessment Branch
Mississippi Department of Environmental Quality (MDEQ)
P.O. Box 10385 ■ Jackson, MS 39289-0385
Phone 601/961-5158 ■ Fax 601/961-5357
email: randy_reed@deq.state.ms.us
MDEQ homepage:
http://www.deq.state.ms.us

Program Description

The Mississippi Department of Environmental Quality (MDEQ) has a Surface Water Monitoring Program (SWMP), which:

- Meets the requirements of Section 106 of CWA,
- Monitors, assesses and reports overall status and trends of surface water quality state-wide,
- Identifies impaired waterbodies and determines causes and sources of impairment,
- Determines effectiveness and supports monitoring and assessment activities of other Surface Water Division (SWD) Programs,
- Addresses surface water quality issues and economic development interests of public concern, and
- Determines better ways of monitoring and assessing surface waters.

Biological data collection, assessment and reporting are an integral component of MDEQ's SWMP and have been for many years. In addition, biological data are a primary assessment component of MDEQ's 305(b) and 303(d) reporting processes. Specifically, macroinvertebrate assessment results are used in the process of determining aquatic life use support and for identifying impaired waterbodies. Macroinvertebrate data are also used to complement other environmental data throughout the TMDL process, including stressor identification and TMDL implementation monitoring. A probabilistic survey design is planned for incorporation into MDEQ's ongoing ambient monitoring network in the future. This approach is intended to produce a more accurate, scientifically defensible and comprehensive assessment of biological condition throughout the state. This will result in collection of biological data at a combination of fixed and random stations each year in conjunction with MS DEQ's Basin Management Approach.

In 2001, MDEQ redesigned its biological monitoring and assessment program to include more rigorous training; field sampling; laboratory sorting, subsampling, and taxonomy; analytical methods; and documentation. It included a comprehensive QA Project Plan with detailed standard operating procedures (SOPs), revision of data entry and database management procedures, and documentation of data quality characteristics throughout the entire assessment process. Approximately 450 wadeable stream sites were sampled statewide with the exception of the MS River Alluvial Plain during a winter index period for benthic macroinvertebrates, physical habitat quality, substrate particle size distribution, and selected field and analytical chemistry. Using GIS, the drainage area for the each site was delineated and land use characterized. For five bioregions, reference conditions were developed based on the concept of "best attainable" conditions, and a multimetric index of biological integrity calibrated, the Mississippi Benthic Index of Stream Quality (M-BISQ).

Documentation and Further Information

State of Mississippi Water Quality Assessment 2002 Section 305(b) Report, Big Black River Basin Supplement: http://www.deq.state.ms.us Click: OPC then Surface Water then 305(b)

State of Mississippi 2002 List of Waterbodies, 303(d) Report: http://www.deq.state.ms.us Click: TMDLs

State of Mississippi Water Quality Criteria for Intrastate, Interstate and Coastal Waters, October 2002: http://www.deq.state.ms.us Click: MDEQ Regulations then By Type then Water then WPC-1

Quality Assurance Project Plan for 303(d) List Assessment and Calibration of the Index of Biological Integrity for Wadeable Streams in Mississippi.

Development and Application of the Mississippi Benthic Index of Stream Quality (M-BISQ).

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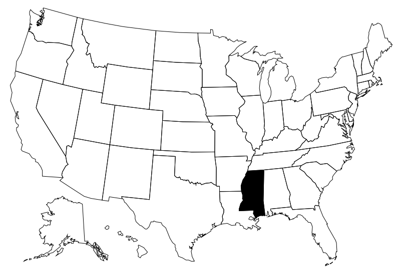


Contact Information

Randy Reed, Chief, Water Quality Assessment Branch
Mississippi Department of Environmental Quality (MDEQ)
P.O. Box 10385 ■ Jackson, MS 39289-0385
Phone 601/961-5158 ■ Fax 601/961-5357
email: randy_reed@deq.state.ms.us

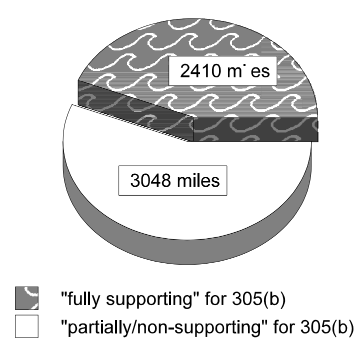
Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
	✓	monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
		promulgated into state water quality standards as biocriteria
	✓	support of antidegradation
	✓	evaluation of discharge permit conditions
	✓	TMDL assessment and monitoring
		other:
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(comprehensive use throughout jurisdiction)*
	✓	fixed station (i.e., water quality monitoring stations) *(comprehensive use throughout jurisdiction)*
		probabilistic by stream order/catchment area
		probabilistic by ecoregion, or statewide
	✓	rotating basin *(comprehensive use throughout jurisdiction)*
		other:

Stream Miles

Total miles *(determined using RF3)*	**84,003**
Total perennial miles	26,454
Total miles assessed for biology	**5,458**
fully attaining ALUS for 305(b)	2,410
not fully attaining ALUS for 305(b)	3,048
listed for 303(d)	3,048
number of sites sampled	455
number of miles assessed per site	~12

5,458 Miles Assessed for Biology



*MDEQ implemented a new biological assessment program (started in fall, 2001). Miles assessed for biology and 305(b)/303(d) numbers reflect this change and vary significantly from previous assessments.

NOTE: All information contained in this summary refers to procedures adopted under the *new* bioassessment program.

Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Single Aquatic Life Use	
ALU designations in state water quality standards	One designation: Fish and Wildlife (biological data are only assessed for fish and wildlife classification)	
Narrative Biocriteria in WQS	Presently, there are no written informal/formal numeric procedures to support narrative biocriteria decisions. Available procedures support a general aquatic life standard.	
Numeric Biocriteria in WQS	none	
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
	✓	cause and effect determinations
	✓	permitted discharges
	✓	monitoring (e.g., improvements after mitigation)
	✓	watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	none	

Reference Site/Condition Development

Number of reference sites	**83 total**	
Reference site determinations		site-specific
		paired watersheds
	✓	regional (aggregate of sites)
		professional judgment
		other:
Reference site criteria	Surrounding landuse, physical habitat, substrate particle size, water chemistry, biology, and historical information.	
Characterization of reference sites within a regional context		historical conditions
	✓	least disturbed sites
		gradient response
		professional judgment
		other:
Stream stratification within regional reference conditions		ecoregions (or some aggregate)
		elevation
		stream type
		multivariate grouping
		jurisdictional (i.e., statewide)
	✓	other: bioregion
Additional information	✓	reference sites linked to ALU
		reference sites/condition referenced in water quality standards
	✓	some reference sites represent acceptable human-induced conditions

Field and Lab Methods

Assemblages assessed	✓	benthos *(100-500 samples/year; single season, multiple sites - broad coverage)*
		fish
		periphyton
		other:

Benthos	
sampling gear	D-frame net (800 x 900 micron mesh) for wadeable streams
habitat selection	multihabitat
subsample size	200 count
taxonomy	genus
Habitat assessments	visual based habitat assessment and modified Wolman Pebble Count; performed with bioassessments
Quality assurance program elements	standard operating procedures, quality assurance plan, periodic meetings and training for biologists, field and laboratory performance audits, sorting and taxonomic proficiency checks, specimen archival

Data Analysis and Interpretation

Data analysis tools and methods	✓	summary tables, illustrative graphs
		parametric ANOVAs
	✓	multivariate analysis*
	✓	biological metrics *(aggregate metrics into an index)*
	✓	disturbance gradients
		other:

Multimetric thresholds	
transforming metrics into unitless scores	95th percentile of all sites
defining impairment in a multimetric index	25th percentile of reference condition

Evaluation of performance characteristics**	✓	repeat sampling *(different team, same reach; same team, adjacent reach)*
	✓	precision *(repeat & duplicate field samples, repeat sorting, taxonomic & data checks)*
	✓	sensitivity *(disturbance gradient for reference & degraded streams)*
	✓	bias *(repeat, duplicate samples)*
	✓	accuracy (discrimination efficiency)

Biological data	
Storage	EDAS
Retrieval and analysis	Systat, Statistica and EDAS

***** Multivariate analysis is being used to *develop* the new index, but the subsequent analysis of biological data will be multimetric.
**Additional evaluation procedures of performance characteristics include: field (biological, habitat and chemistry repeats), lab (pickate rechecks, QC checks), taxonomy (two taxonomists and a third party for precision; reference collection), data entry QC, and metric calculation QC checks.

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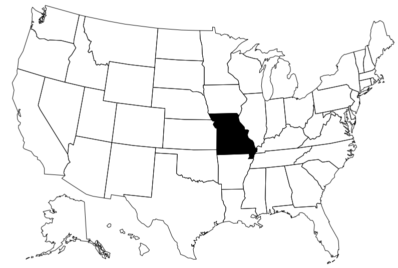

Contact Information

Randy Sarver, Aquatic Bioassessment Unit Supervisor
Missouri Department of Natural Resources (MDNR)
P.O. Box 176 ■ Jefferson City, MO 65102
Phone 573/526-3365 ■ Fax 573/526-3350
email: nrsarvr@mail.dnr.state.mo.us
website: http://www.dnr.state.mo.us/water.htm

Steve Fischer, Fisheries Research Biologist
Missouri Department of Conservation (MDC)
1110 South College Avenue ■ Columbia, MO 65201
Phone 573/882-9880 x3271 ■ Fax 573/882-4517
email: fischsa@mail.conservation.state.mo.us
website: http://www.conservation.state.mo.us/

Program Description

The overall aquatic biological assessment program for Missouri streams and wadeable rivers is a multi-agency collaborative effort between the Missouri Department of Conservation (MDC), the Missouri Department of Natural Resources (MDNR), The University of Missouri-Columbia, and the USEPA. The overall program involves a Resource Assessment and Monitoring Program, biological criteria development, monitoring of targeted sites to determine compliance with the designated use of aquatic life protection in the standards, monitoring for 303(d) purposes, and the development of a stream classification system framework.

The Resource Assessment and Monitoring Program is committed to sampling 120 sites per year beginning in 2002. These sites are a combination of targeted reference sites and randomly selected sites. The MDC is responsible for fish sampling, physical habitat assessment, and water quality contaminant sampling (to be analyzed by the USEPA). The MDNR is responsible for sampling macroinvertebrates at 30% of the sites. For the remainder of the sites, samples are collected by MDC and analyzed by the University of Missouri-Columbia. The Resource Assessment and Monitoring Program operates on a five year cycle with statewide random sites collected for one year and random sites in priority watersheds collected for four years. Data will be used to report on the status of Missouri's streams and wadeable rivers.

The MDNR initiated biological criteria development for wadeable, perennial streams in 1992. Numeric biocriteria for one trophic level (macroinvertebrate communities) were completed in February 2002. This effort also involved the cooperation of the University of Missouri-Columbia, School of Natural Resources and the Missouri Resource Assessment Partnership. Future biological criteria efforts will add an additional trophic level (fish communities) to wadeable, perennial streams and will initiate a low level effort to develop numeric criteria for other size ranges of streams and rivers. The numeric criteria and associated components have been used to evaluate compliance with the designated use of aquatic life protection as well as in the assessment of biological communities for 303(d) purposes.

The Missouri Resource Assessment Partnership is an interagency partnership that provides expertise in geographic information systems, remote sensing, and natural resource management. Since 1997, the Missouri Resource Assessment Partnership has been in the process of developing a hierarchical classification framework for Missouri's stream resources. This framework is expected to provide the foundation for biological study designs in the Resource Assessment and Monitoring Program, biological criteria, and targeted studies concerning the designated use of aquatic life protection and 303(d) purposes.

Documentation and Further Information

Methodology for the 2002 303(d) list, 1998 303(d) list, and Missouri's Water Quality Standards and criteria are all available on the MDNR Water Pollution Control Program homepage: http://www.dnr.state.mo.us/deq/wpcp/homewpcp.htm

Fischer, S.A. 2002. *Resource Assessment and Monitoring Program: Standard Operating Procedures - fish sampling*. Missouri Department of Conservation, Columbia, MO.

Sarver, R., S. Harlan, C. Rabeni, and S. Sowa. 2001. *Draft Report - Biological Criteria for Wadeable/Perennial Streams of Missouri*. Prepared by Missouri Department of Natural Resources, Air and Land Protection Division, Environmental Services Program.

Also available through MDNR: *Semi-quantitative Macroinvertebrate Stream Bioassessment Project Procedure* (2001); *Stream Habitat Assessment Project Procedure* (2000); Macroinvertebrate Levels of Taxonomy SOP/FSS/209 (1998); *Biological Criteria for Streams of Missouri* - A Final Report to the MO Department of Natural Resources, University of Missouri, Cooperative Fish and Wildlife Unit; *Quality Control Procedures for Data Processing* (2001) MDNR/WQMS/214.

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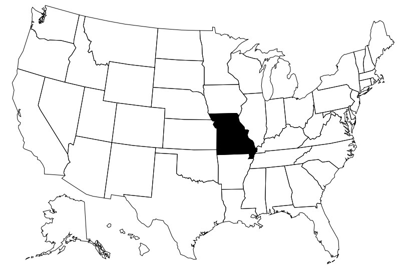


Contact Information

Randy Sarver, Aquatic Bioassessment Unit Supervisor
Missouri Department of Natural Resources (MDNR)
P.O. Box 176 ■ Jefferson City, MO 65102
Phone 573/526-3365 ■ Fax 573/526-3350
email: nrsarvr@mail.dnr.state.mo.us

Steve Fischer, Fisheries Research Biologist
Missouri Department of Conservation (MDC)
1110 South College Avenue ■ Columbia, MO 65201
Phone 573/882-9880 x3271 ■ Fax 573/882-4517
email: fischsa@mail.conservation.state.mo.us

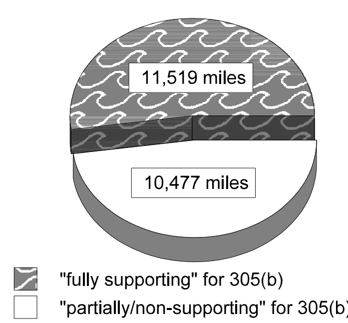
Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
	✓	monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
	✓	promulgated into state water quality standards as biocriteria
		support of antidegradation
	✓	evaluation of discharge permit conditions *(MDNR only)*
	✓	TMDL assessment and monitoring
		other:
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(comprehensive use throughout jurisdiction by MDNR)*
		fixed station (i.e., water quality monitoring stations)
	✓	probabilistic by stream order/catchment area *(comprehensive use throughout jurisdiction and in specific river basins or watersheds by MDC)*
	✓	probabilistic by ecoregion, or statewide *(comprehensive use throughout jurisdiction and in specific river basins or watersheds by MDC)*
	✓	rotating basin *(used in specific rivers basins or watersheds by MDNR)*
	✓	other: reference site monitoring

Stream Miles

Total miles *(estimated using National Hydrography Database)*	**52,194**
Total perennial miles	22,194
Total miles assessed for biology*	**21,996**
fully supporting for 305(b)	11,519
partially/non-supporting for 305(b)	10,477
listed for 303(d)	n/a
number of sites sampled *(on an annual basis)*	200
number of miles assessed per site	site specific *(MDC)* 0.25 *(MDNR)*

21,996 Miles Assessed for Biology



*Miles assessed for aquatic life as reported in Missouri's draft 2002 305(b) Water Quality Report are based on biological, chemical, physical and toxicological data. The status and number of stream miles assessed exclusively for biology is not readily available.

Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Warm Water vs. Cold Water	
ALU designations in state water quality standards	Four designations: General Warm Water Aquatic Life, Limited Warm Water Aquatic Life, Cool Water Fisheries, and Cold Water Fisheries	
Narrative Biocriteria in WQS	Procedures used to support narrative biocriteria located in SOPs and draft biocriteria document for wadeable/perennial streams housed at MDNR/Air and Land Protection Division, Environmental Services Program	
Numeric Biocriteria in WQS	under development (Numeric biocriteria for macroinvertebrate communities in wadeable, perennial streams will be completed sometime in 2002. These criteria are intended for inclusion in the water quality standards during the next triennial WQS review.)	
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
	✓	cause and effect determinations
	✓	permitted discharges
		monitoring (e.g., improvements after mitigation)
		watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	none	

Reference Site/Condition Development

Number of reference sites	**62 total**	
Reference site determinations	✓	site-specific *(MDC)*
		paired watersheds
	✓	regional (aggregate of sites)
	✓	professional judgment *(MDC)*
	✓	other: Missouri Ecologic Drainage Units/VST layer *(MDC)*
Reference site criteria	Representative of ecoregion and stream size, and in natural condition with respect to habitat, water quality, biological integrity and diversity, watershed land use and riparian conditions Disturbed habitat = <75% comparable to reference *(MDNR)* MDC uses R-EMAP terminology: perennial flow, relatively high heterogeneity of substrate materials, natural channel morphology, natural hydrograph, natural water color	
Characterization of reference sites within a regional context		historical conditions
	✓	least disturbed sites
		gradient response
		professional judgment
	✓	other: minimally disturbed in the Ozarks
Stream stratification within regional reference conditions	✓	ecoregions (or some aggregate)
		elevation
	✓	stream type *(MDNR)*
		multivariate grouping
		jurisdictional (i.e., statewide)
	✓	other: MDC is attempting to put reference sites into each of Missouri's 17 Ecologic Drainage Units.
Additional information	✓	reference sites linked to ALU
	✓	reference sites/condition referenced in water quality standards *(Sarver et al. 2001)*
	✓	some reference sites represent acceptable human-induced conditions

Field and Lab Methods

Assemblages assessed	✓	benthos *(100 - 500 samples per year; single season, multiple sites - broad coverage by MDC; multiple seasons, multiple sites - broad coverage for watershed level by MDNR)*
	✓	fish *(100 - 500 samples per year; single season, multiple sites - broad coverage by MDC only)*
		periphyton
		other:

Benthos	
sampling gear	kick net, 500 micron mesh nitex bag
habitat selection	multihabitat
subsample size	900 for glide/pool streams, 1200 for riffle/pool streams
taxonomy	genus, species
Fish	
sampling gear	backpack electrofisher, pram unit (tote barge), and seines; 3/16" mesh for 12' net and 1/4" mesh for 30' net
habitat selection	multihabitat
sample processing	biomass - batch
subsample	batch
taxonomy	species
Habitat assessments	visual based, quantitative measurements *(MDC)*, stream width and discharge *(MDNR)*; performed with bioassessments
Quality assurance program elements	standard operating procedures, quality assurance plan, periodic meetings and training for biologists, sorting and taxonomic proficiency checks, specimen archival, MDNR data entry QC, certification program for bioassessment within MDC

Data Analysis and Interpretation

Data analysis tools and methods	✓	summary tables, illustrative graphs
	✓	parametric ANOVAs
	✓	multivariate analysis
	✓	biological metrics *(aggregate metrics into index)*
		disturbance gradients
		other:

Multimetric thresholds	
transforming metrics into unitless scores	25th percentile of reference population *(MDNR)*; some based on log 10 mean wetted width, mean proportion of reference sites, or specific percentiles *(MDC)*
defining impairment in a multimetric index	cumulative score equivalent to 81% of reference condition *(MDNR)*
Multivariate thresholds	
defining impairment in a multivariate index	significant departure from mean of reference population *(MDC)*, threshold not used by MDNR for criteria but as supporting information only

Evaluation of performance characteristics	✓	repeat sampling *(multiple seasons and years by MDNR, annual revisits by MDC)*
	✓	precision *(10% duplicates within reach by MDNR)*
	✓	sensitivity *(evaluated in MDNR pilot project)*
	✓	bias *(MDNR eliminated redundant metrics during pilot project, multiple techniques used by MDC)*
		accuracy

Biological data	
Storage	STORET *(MDC)*, MS Access
Retrieval and analysis	SAS *(MDC)*, Programming in Visual Basics for MS Access and Sigmastat *(MDNR)*

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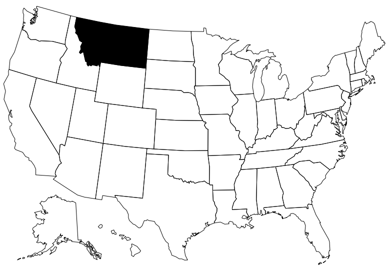

Contact Information

Rosie Sada de Suplee, Aquatic Microbiologist
Montana Department of Environmental Quality (DEQ)
1520 East 6th Avenue ■ Helena, MT 59620
Phone 406/444-6764 ■ Fax 406/444-6836
email: rsada@state.mt.us
DEQ Water Quality Monitoring and Assessment homepage:
http://www.deq.state.mt.us/wqinfo/MDM/WQMonitoring_Assessment.asp

Randy Apfelbeck, Water Quality Specialist
Montana Department of Environmental Quality (DEQ)
2209 Phoenix Avenue ■ Helena, MT 59601
Phone 406/444-2709 ■ Fax 406/444-5275
email: rapfelbeck@state.mt.us
DEQ Water Quality Information homepage: http://www.deq.state.mt.us/wqinfo/Index.asp

Program Description

The Montana Department of Environmental Quality (DEQ) strongly encourages the use of biological data for making ALUS determinations (more than 90% of MT's 303(d) assessments include biological data). It is very difficult to acquire sufficient credible data in Montana without having biological data; thus the incorporation of bioassessment in DEQ's monitoring program is very important.

DEQ is in the second year of collecting macroinvertebrate and periphyton data from fixed station sites that are located on major streams throughout Montana. The primary objective is to determine status and trends. In 2002, the Department initiated an effort to develop vegetation assessment tools for assessing the biological conditions of riparian areas and wetlands and is also looking at amphibians. In the past, wetland macroinvertebrate and diatom communities have been assessed.

DEQ collaborates with a number of agencies and organizations. The Montana Bureau of Land Management has helped fund DEQ's statewide biological monitoring efforts. USGS is collecting chemistry data at most fixed station sites. The Department is also working closely with the wetlands program, universities and the Montana Natural Heritage Program to assess riparian zones. For 303(d) purposes DEQ has collaborated with conservation districts, the Natural Resource Conservation Service, USFS, and USEPA, among others.

In 2000 DEQ developed a new listing methodology that strongly encourages the use of biological data to assess waters for 303(d) purposes. The Department was required to use this methodology for all waters that were previously listed as impaired, but were unfortunately not required to use the new listing methodology for streams that were previously listed as fully supporting ALU. Montana DEQ is also currently forming workgroups to begin the process of developing a state-wide water quality database that can be accessed by federal and state agencies in Montana.

Some challenges include achieving access to private lands and assessing prairie streams that are located in eastern Montana. In the future DEQ intends to develop and implement a random study design to assess the biological condition of smaller order streams.

Documentation and Further Information

Year 2001 305(b) Report Database and Year 2000 303(d) List Database:
http://nris.state.mt.us/scripts/esrimap.dll?name=TMDL&Cmd=INST

DRAFT 2002 Montana 303(d) List: http://nris.state.mt.us/scripts/esrimap.dll?name=TMDL2002&Cmd=INST

Montana's *Water Quality Standards and Classifications*: http://www.deq.state.mt.us/wqinfo/Standards/Index.asp

Water Quality Monitoring Standard Operating Procedures: http://www.deq.state.mt.us/ppa/mdm/SOP/sop.asp

Montana Natural Heritage Program homepage: http://nhp.nris.state.mt.us/

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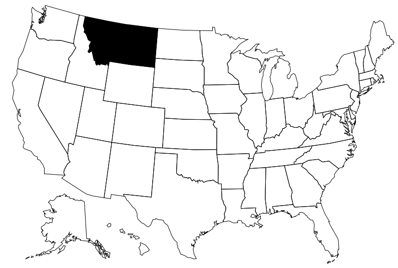


Contact Information

Rosie Sada de Suplee, Aquatic Microbiologist
Montana Department of Environmental Quality (DEQ)
1520 East 6th Avenue ■ Helena, MT 59620
Phone 406/444-6764 ■ Fax 406/444-6836
email: rsada@state.mt.us

Randy Apfelbeck, Water Quality Specialist
Montana Department of Environmental Quality (DEQ)
2209 Phoenix Avenue ■ Helena, MT 59601
Phone 406/444-2709 ■ Fax 406/444-5275
email: rapfelbeck@state.mt.us

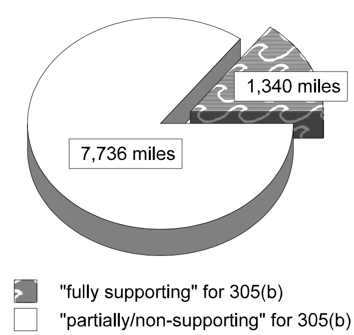
Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
	✓	monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
	UD	promulgated into state water quality standards as biocriteria
		support of antidegradation
		evaluation of discharge permit conditions
	✓	TMDL assessment and monitoring
		other:
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(special projects only)*
	✓	fixed station (i.e., water quality monitoring stations) *(comprehensive throughout jurisdiction)*
	✓	probabilistic by stream order/catchment area *(special projects only)*
	✓	probabilistic by ecoregion, or statewide *(special projects only)*
		rotating basin
		other:

Stream Miles

Total miles *(determined using RF3)*	**176,750**
Total perennial miles	53,221
Total miles assessed for biology*	**9,076**
fully supporting for 305(b)**	1,340
partially/non-supporting for 305(b)**	7,736
listed for 303(d)	7,736
number of sites sampled *(USGS sites)*	~40
number of miles assessed per site	–

9,076 Miles Assessed for Biology



*MT DEQ collects biological data as part of a joint project with USGS to assess 38 sites that are located near the mouth of major streams and rivers. Aside from this, Montana does not have a state biological monitoring program but it is currently under development.

**71% of the waters that were assessed as fully supporting ALU used biological data; 94% of the waters where ALUS was determined to be impaired used biological data.

Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Class System (A,B,C), Warm Water vs. Cold Water	
ALU designations in state water quality standards	Although there are 9 classifications (A, B, C and subdivided), Class A-Closed is suitable for growth and propagation of fishes and associated aquatic life (among other uses) and Classes A-1, B-1, B-2, B-3, C-1 AND C-2 must have water quality suitable for growth and propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers (among other uses).	
Narrative Biocriteria in WQS	under development (Brief biocriteria language without formal numeric translation mechanism located in WQS. Informal numeric procedures located in guidance document for 303(d) listing purposes complying with WQS.)	
Numeric Biocriteria in WQS	none	
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
	✓	cause and effect determinations
		permitted discharges
	✓	monitoring (e.g., improvements after mitigation)
	✓	watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	TMDL targets	

Reference Site/Condition Development

Number of reference sites	**~50 total (potential reference sites)***	
Reference site determinations	✓	site-specific
		paired watersheds
	✓	regional (aggregate of sites)
	✓	professional judgment
		other:
Reference site criteria	specific criteria under development; currently using best professional judgment to determine "least impaired" considering geomorphology, habitat, landuse, biology, and chemistry	
Characterization of reference sites within a regional context	✓	historical conditions
	✓	least disturbed sites
		gradient response
	✓	professional judgment
	✓	other: some sites are minimally disturbed**
Stream stratification within regional reference conditions	✓	ecoregions (or some aggregate)
	✓	elevation
	✓	stream type
		multivariate grouping
		jurisdictional (i.e., statewide)
		other:
Additional information	✓	reference sites linked to ALU
		reference sites/condition referenced in water quality standards
	✓	some reference sites represent acceptable human-induced conditions

*In 2001, Montana DEQ began the process of locating reference sites using GIS and sampled ~30 potential reference sites using EMAP methods. A similar effort was made in 1990 when ~38 sites were sampled. In total, Montana has assessed ~50 potential reference sites.

**Montana's regional reference sites are characterized as least disturbed. These sites are used to describe the best potential for a stream given the historical land use. However, many least disturbed reference sites are actually *minimally* disturbed, especially those sites that are located in the Rocky Mountain Ecoregion. In this case the best potential for a stream is near natural condition. These streams are often located in roadless areas, wilderness areas or National Parks.

Field and Lab Methods

Assemblages assessed	✓	benthos *(100 - 500 samples per year; single season, multiple sites - broad coverage)*
	✓	fish *(<100 samples per year; single season, multiple sites - broad coverage)*
	✓	periphyton *(100 - 500 samples per year; single season, multiple sites - broad coverage)*
	✓	other: macrophytes *(<100 samples per year; single season, multiple sites - watershed level)*

Benthos	
sampling gear	Hess, D-frame, kick net (1m); 500 - 600 and >800 micron mesh sizes
habitat selection	richest habitat, riffle/run (cobble), multihabitat, woody debris
subsample size	300-500 count
taxonomy	combination - lowest feasible
Fish	
sampling gear	backpack and boat electrofishers, seine; 1/4" mesh
habitat selection	multihabitat
sample processing	length measurement, anomalies
subsample	none
taxonomy	species
Periphyton	
sampling gear	**natural substrate**: suction device, brushing/scraping device
habitat selection	riffle/run (cobble), multihabitat
sample processing	chlorophyll *a* / phaeophytin, biomass, taxonomic identification
taxonomy	diatoms (mainly species level), all algae (genus and species)
Habitat assessments	visual based, quantitative measurements, hydrogeomorphology, pebble counts; performed with and independent of bioassessments
Quality assurance program elements	standard operating procedures, quality assurance plan, periodic meetings and training for biologists, sorting and taxonomic proficiency checks, specimen archival

Data Analysis and Interpretation

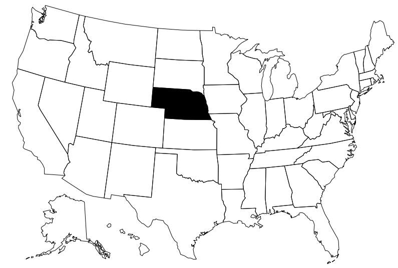
Data analysis tools and methods	✓	summary tables, illustrative graphs
	✓	parametric ANOVAs
	✓	multivariate analysis
	✓	biological metrics *(aggregate metrics into an index and return single metrics)*
	✓	disturbance gradients
		other:

Multimetric thresholds	
transforming metrics into unitless scores	cumulative distribution function
defining impairment in a multimetric index	75% of reference condition
Multivariate thresholds	
defining impairment in a multivariate index	significant departure from mean of reference population

Evaluation of performance characteristics	✓	repeat sampling *(duplicates)*
	✓	precision *(splits with USGS and EMAP for bioassessments)*
		sensitivity
	✓	bias *(comparison of different methods)*
		accuracy

Biological data	
Storage	developing use of MS Access and Excel
Retrieval and analysis	Systat, Statmost

NEBRASKA



Contact Information

Ken Bazata, Program Specialist - Surface Water Section
Nebraska Department of Environmental Quality (NDEQ)
1200 "N" Street, Suite 400 ■ Lincoln, NE 68509-8922
Phone 402/471-2192■ Fax 402/471-2909
email: ken.bazata@ndeq.state.ne.us
website: www.ndeq.state.ne.us

Program Description

Nebraska's biological monitoring program was started in 1985 with semi-quantitative methods for collecting fish and macroinvertebrates. The original purpose was to determine naturally occurring biological delineations within the state and to classify streams based on biological characteristics. In 1997, collection methods were changed to the REMAP methodology because the Nebraska Department of Environmental Quality (NDEQ) felt that more quantitative approaches were needed to summarize the data.

NDEQ's program for adapting the metrics to the standards and fine tuning the metrics has been slowed by data management and computer programming problems. NDEQ has a small staff and time constraints have affected this program. NDEQ is experiencing problems with the reference site concept. Since many of the streams have a "sameness" throughout a large area of the state, Nebraska lacks solid reference sites for the ecoregions and stream classes. Except for a few places, it seems most streams are heavily affected by agricultural use. NDEQ has a lot of data, but is having trouble analyzing it.

Due to concerns about the accuracy of the existing biological indices, NDEQ has chosen to reassess past biological data and redefine its indices. Five streams are currently listed on Nebraska's 303(d) list due to biodiversity impacts. Only about 20% of Nebraska's total stream miles are currently assessed for biology in the 305(b) report. These streams are known to be fully supporting (17%) or not supporting (3%).

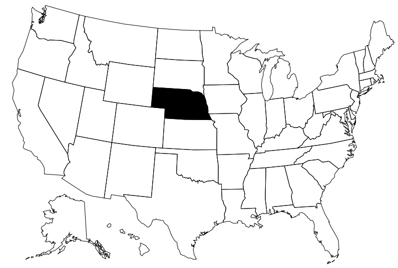
Nebraska agrees with the reference site concept but needs to determine if appropriate reference sites exist in Nebraska. NDEQ is currently evaluating macroinvertebrate and fish data to locate both excellent and severely impaired sites in order to determine the appropriate habitat conditions that correspond to both extremes. Reference site criteria have not yet been finalized.

Documentation and Further Information

Nebraska DRAFT 2000 305(b) report

DRAFT 2002 303(d) report, 2001, *Comprehensive Study of Water Quality Monitoring*, and Title 117 - Nebraska's Surface Water Quality Standards are available online at http://www.ndeq.state.ne.us

NEBRASKA



Contact Information

Ken Bazata, Program Specialist - Surface Water Section
Nebraska Department of Environmental Quality (NDEQ)
1200 “N” Street, Suite 400 ■ Lincoln, NE 68509-8922
Phone 402/471-2192 ■ Fax 402/471-2909
email: ken.bazata@ndeq.state.ne.us

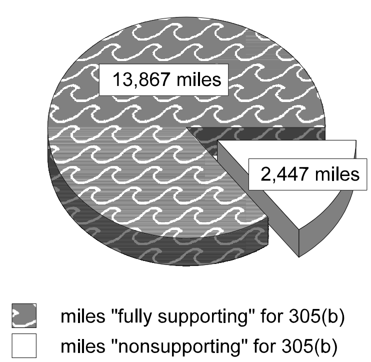
Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
	✓	monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
	✓	promulgated into state water quality standards as biocriteria
		support of antidegradation
		evaluation of discharge permit conditions
		TMDL assessment and monitoring
		other:
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) (*specific river basins or watersheds*)
	✓	fixed station (i.e., water quality monitoring stations) (*comprehensive use throughout jurisdiction*)
		probabilistic by stream order/catchment area
	✓	probabilistic by ecoregion, or statewide (*comprehensive use throughout jurisdiction*)
	✓	rotating basin (*comprehensive use throughout jurisdiction*)
		other:

Stream Miles

Total miles *(determined using RF3)*	**81,573**
Total perennial miles	16,090
Total miles assessed for biology*	**16,314**
fully supporting for 305(b)	13,867
non-supporting for 305(b)	2,447
listed for 303(d)	0
number of sites sampled *(on an annual basis)*	40
number of miles assessed per site	site specific

16,314 Miles Assessed for Biology



*The 16,314 stream miles assessed for biology are the streams known to be only very high fully supporting (13,867) and very low non-supporting (2,447).

Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Class system (A, B, C), Fishery Based Uses, Warm Water vs. Cold Water
ALU designations in state water quality standards	Four designations: Warmwater A, Warmwater B, Coldwater A, Coldwater B
Narrative Biocriteria in WQS	Procedures used to support narrative biocriteria located in various reports, e.g., biological classification, 305(b), bioassessment procedures
Numeric Biocriteria in WQS	none
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓ assessment of aquatic resources ✓ cause and effect determinations ☐ permitted discharges ☐ monitoring (e.g., improvements after mitigation) ☐ watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	none

Reference Site/Condition Development*

Number of reference sites	**38 total**
Reference site determinations	✓ site-specific ☐ paired watersheds ✓ regional (aggregate of sites) ✓ professional judgment ☐ other:
Reference Site Criteria	No waste water treatment plants, other point sources, or concentrated animal feeding operations (CAFOs); good instream habitat, riparian habitat, land use and cover, physical and chemical parameters, biological metrics, and faunal assemblages; no altered hydrologic regimes; representativeness. At a minumum, sites need to be in the top 10 to 20 percent of all sites sampled in the ecoregion, with little disturbance and no spills or discharges within sites area.
Characterization of reference sites within a regional context	☐ historical conditions ✓ least disturbed sites ☐ gradient response ☐ professional judgment ✓ other: regionally representative, reasonably attainable
Stream stratification within regional reference conditions	✓ ecoregions (or some aggregate) *(there are three ecoregions and six strata with roughly five reference sites in each)* ☐ elevation ✓ stream type ☐ multivariate grouping ☐ jurisdictional (i.e., statewide) ☐ other:
Additional information	✓ reference sites linked to ALU ☐ reference sites/condition referenced in water quality standards ✓ some reference sites represent acceptable human-induced conditions

*Reference site criteria have not been finalized. These responses are based on NDEQ's current efforts to evaluate reference sites and condition.

Field and Lab Methods

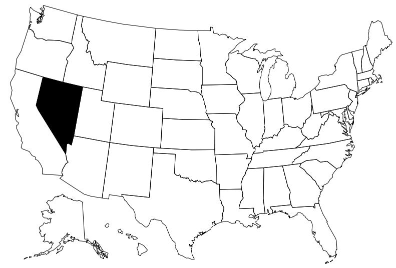
Assemblages assessed	✓	benthos *(<100 samples/year, single season, multiple sites - broad coverage)*
	✓	fish *(<100 samples/year, single season, multiple sites - broad coverage)*
		periphyton
		other:
Benthos		
sampling gear		surber, multiplate, collect by hand, D-frame, dipnet; 200 - 400 micron mesh
habitat selection		multihabitat, artificial substrate, woody debris
subsample size		300 count, entire sample
taxonomy		genus, species
Fish		
sampling gear		backpack electrofisher, boat electrofisher, pram unit (tote barge), seine; 1/4" mesh
habitat selection		pool/glide, riffle/run (cobble), multihabitat
sample processing		length measurement (gamefish only), anomalies
subsample		batch
taxonomy		species
Habitat assessments		visual based, quantitative measurements; performed with bioassessments
Quality assurance program elements		standard operating procedures, quality assurance plan, taxonomic proficiency checks and specimen archival

Data Analysis and Interpretation*

Data analysis tools and methods	✓	summary tables, illustrative graphs
	✓	parametric ANOVAs
		multivariate analysis
	✓	biological metrics *(aggregate metrics into an index)*
		disturbance gradients
		other:
Multimetric thresholds		
transforming metrics into unitless scores		95th percentile of reference population, dependent upon approach
defining impairment in a multimetric index		25th percentile of reference population
Evaluation of performance characteristics	✓	repeat sampling *(revisit sites)*
		precision
		sensitivity
		bias
		accuracy
Biological data		
Storage		STORET, Excel and MS Access spreadsheets
Retrieval and analysis		SAS, Minitab

*NDEQ is testing different indices for validity and, as mentioned earlier, is still exploring reference criteria. Responses are based on NDEQ's current evaluation efforts, which include several changes in the way past biological data were evaluated. Data analysis procedures may change before metrics, indices, and reference sites are finalized.

NEVADA



Contact Information

Karen Vargas, Bioassessment Coordinator/Environmental Scientist II
Nevada Division of Environmental Protection (NDEP)
123 West Nye Lane, Suite 138 ■ Carson City, NV 89706-0851
Phone 775/687-9444 ■ Fax 775/687-5856
email: kvargas@ndep.state.nv.us
NDEP Bureau of Water Quality Planning homepage: http://ndep.state.nv.us/bwqp/

Program Description

Nevada began its Bioassessment Program in the year 2000 and has continued to collect biological information on an annual basis. Although the program is in its infancy, the State plans to continue collecting biological data for ambient monitoring and to assist in defining reference conditions and sites. There are seven primary water basins in Nevada and the State has collected biological data annually on four of these basins covering approximately 600 river miles. It is expected the State will continue to collect at these river basins, in addition to new basins and several lakes, until a valid biological baseline has been established over the next four to five years. After such time, the State is expected to switch to an alternating site or basin ambient bioassessment monitoring program.

The program primarily consists of macroinvertebrate collection, physical habitat evaluations, and physical measurements of slope, velocity, flow, dissolved oxygen, specific conductivity, pH, temperature, substrate composition, canopy cover, and width and depth of the sampling area. Periphyton, plankton, and/or chlorophyll sampling is conducted when necessary to assist in defining problem areas. Water chemistry data is collected at sites where the water chemistry is currently unknown. The data will eventually be used in 305(b) and 303(d) reports in addition to basin assessments of stream health. Some NPDES dischargers in the State are voluntarily collecting macroinvertebrates to assess impact to the aquatic environment.

Reference site criteria are currently being defined based on available information. The State expects to use chemical data, habitat assessments, physical measurements, professional knowledge and degrees of human impact to define the conditions and sites. Where reference sites are unavailable, the State expects to use modeling and/or least disturbed sites to evaluate conditions. It is anticipated to take several years for reference sites to be selected.

An independent biological laboratory conducts identification of macroinvertebrates. QA/QC of macroinvertebrate identification consists of approximately 15% of the samples being analyzed by two distinct biological laboratories. Data collected will be stored annually in the Ecological Data Application System (EDAS). Analysis and evaluation of the bioassessment data will be developed as the program progresses and based on the most accurate methods. Reference sites, where appropriate, will be used as a baseline for analysis.

Nevada recently hosted its first bioassessment conference in the State. The conference resulted in the formation of a State Bioassessment Committee consisting of agencies, tribes, and industry. The primary goal of the committee is to evaluate and coordinate protocols, methodologies and sampling in the State. Nevada also participates in the National Aquatic Life Use (ALUS) work group based out of USEPA Headquarters in Washington, D.C. The State is also planning to host an Arid West Aquatic Life Use Workgroup in conjunction with other arid states, tribal entities and USEPA in the next year.

Documentation and Further Information

Nevada's 305(b) report, September 2000: http://ndep.state.nv.us/bwqp/305b1998.pdf

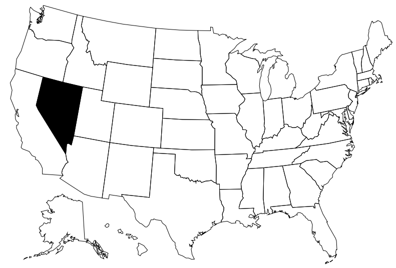
DRAFT Nevada's 2002 303(d) Impaired Waters List, June 2002: http://ndep.state.nv.us/bwqp/303list.pdf

Nevada's 1998 303(d) List, April 1998: http://ndep.state.nv.us/bwqp/nv303d98.pdf

Draft Continuing Planning Process, December 2001: http://ndep.state.nv.us/bwqp/cppdraft.pdf

Water Quality Standards, narrative and numeric: http://ndep.state.nv.us/bwqp/stdsw.htm

NEVADA



Contact Information

Karen Vargas, Bioassessment Coordinator/Environmental Scientist II
Nevada Division of Environmental Protection (NDEP)
123 West Nye Lane, Suite 138 ■ Carson City, NV 89706-0851
Phone 775/687-9444 ■ Fax 775/687-5856
email: kvargas@ndep.state.nv.us

Programmatic Elements

Uses of bioassessment within overall water quality program*	✓	problem identification (screening)
	✓	nonpoint source assessments
	✓	monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
		promulgated into state water quality standards as biocriteria
	✓	support of antidegradation
	✓	evaluation of discharge permit conditions
	✓	TMDL assessment and monitoring
	✓	other:
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(special projects, specific river basins or watersheds, and comprehensive use throughout jurisdiction)*
	✓	fixed station *(i.e., water quality monitoring stations) (special projects, specific river basins or watersheds, and comprehensive use throughout jurisdiction)*
		probabilistic by stream order/catchment area
		probabilistic by ecoregion, or statewide
	✓	rotating basin *(specific river basins or watersheds and comprehensive use throughout jurisdiction)*
		other:

*Bioassessment information will eventually be used in 303(d) and 305(b) reports.

Stream Miles

Total miles *(determined using River Reaches and calculated using GIS coverages.)*	**143,578**
Total perennial miles	14,988
Total miles assessed for biology**	**602**
fully supporting for 305(b)	0
partially/non-supporting for 305(b)	0
listed for 303(d)	0
number of sites sampled	50-60
number of miles assessed per site	–

**602 miles were assessed per year for 2000 and 2001 by the state (NDEP) and 97 miles were also assessed by others (Dischargers). The state estimates 900 river miles to be assessed in 2002. Since mileage is estimated and Nevada's 2001 data set has not been analyzed, the State has not used biology for 305(b)/303(d); therefore "0" is reported. However, it will be used in the future.

Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Class System (A,B,C), Fishery Based Uses and Warm Water vs. Cold Water	
ALU designations in state water quality standards	Propagation of aquatic life and the levels of warm water and cold water fisheries.	
Narrative Biocriteria in WQS	under development	
Numeric Biocriteria in WQS	none	
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
	✓	cause and effect determinations
		permitted discharges
	✓	monitoring (e.g., improvements after mitigation)
	✓	watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	Truckee River Restoration projects include the lahontan cutthroat trout.	

Reference Site/Condition Development*

Number of reference sites	**0 total**	
Reference site determinations	✓	site-specific
	✓	paired watersheds
	✓	regional (aggregate of sites)
	✓	professional judgment
		other:
Reference site criteria	This is under development. NDEP expects to use chemical, habitat, physical measurements and least human impact. Where reference sites are unavailable modeling and/or metrics will be used to evaluate conditions.	
Characterization of reference sites within a regional context	✓	historical conditions
	✓	least disturbed sites
		gradient response
	✓	professional judgment
		other:
Stream stratification within regional reference conditions	✓	ecoregions (or some aggregate)
	✓	elevation
	✓	stream type
	✓	multivariate grouping
		jurisdictional (i.e., statewide)
		other:
Additional information		reference sites linked to ALU
		reference sites/condition referenced in water quality standards
	✓	some reference sites represent acceptable human-induced conditions *(for fishery based uses)*

*Nevada is in the process of developing reference sites. This section has been completed based on the criteria that will be considered during development.

Field and Lab Methods

Assemblages assessed	✓	benthos *(<100 samples/year, single season, multiple sites - broad coverage)*
		fish
	UD	periphyton *(<100 samples/year, single season, multiple sites - watershed level)*
		other:

Benthos	
sampling gear	kick net (1 m); 500-600 micron mesh
habitat selection	riffle/run (cobble) *(when unavailable, use vegetation and sediment)*
subsample size	500 count
taxonomy	combination--family, genus, species
Periphyton	
sampling gear	**natural substrate**: brushing/scraping device (razor, toothbrush, etc.) Periphyton will be routinely collected and analyzed by a professional lab beginning in 2002. Chlorophyll analysis is performed at some stations.
habitat selection	n/a
sample processing	chlorophyll *a*/ phaeophytin and taxonomic identification
taxonomy	genus level for soft-bodied algae when possible; diatoms are not cleared
Habitat assessments	quantitative measurements (some sites) and visual based; performed with bioassessments; riffle slope, flow, average width and depth of flow, riffle velocity, canopy cover, some vegetation (grass, scrubs, trees) coverage along riparian zone, reach length, conductivity, temperature and dissolved oxygen
Quality assurance program elements	Quality assurance program elements are currently being developed (i.e., standard operating procedures, quality assurance plan, taxonomic proficiency checks, specimen archival).

Data Analysis and Interpretation*

Data analysis tools and methods	✓	summary tables, illustrative graphs
		parametric ANOVAs
	✓	multivariate analysis
	UD	biological metrics *(NDEP has not yet developed metrics but analysis tools and methods will be developed based on the most accurate method)*
	✓	disturbance gradients
		other:
Evaluation of performance characteristics	✓	repeat sampling *(ideally, 5 years worth of data will be collected at each site to determine the variability)*
		precision
		sensitivity
		bias
		accuracy

Biological data	
Storage	EDAS (being developed)
Retrieval and analysis	EDAS (being developed)

*Analysis tools and methods will be developed more fully in the future.

NEW HAMPSHIRE

Contact Information

David Neils, Biomonitoring Program Coordinator
New Hampshire Department of Environmental Services (NHDES)
6 Hazen Drive ■ Concord, NH 03302-0095
Phone 603/271-8865 ■ Fax 603/271-7894
email: dneils@des.state.nh.us
NHDES Watershed Management Bureau, *Biomonitoring Program*:
http://www.des.state.nh.us/wmb/biomonitoring/

Program Description

The New Hampshire Department of Environmental Services (NHDES) has been gathering biological data in wadeable streams and rivers since 1995. The primary goal of this effort is the development of numeric biological criteria in support of the current narrative standard. Biological communities assessed for this purpose are fish and macroinvertebrates. Since the program's inception, the protocols for collecting data have remained fairly consistent. The fish are collected with a backpack electro-shocker for 150 meters, with efforts to include all habitats typical of the stream type. Macroinvertebrate sampling is done by rock baskets deployed for 8 weeks and retrieved in the fall. A visual habitat assessment is also conducted at each station using USEPA's Rapid Bioassessment Protocols for high or low gradient streams, whichever is appropriate.

Since the program's beginnings, over 200 stations have been assessed. These stations are captured in an ArcView coverage that includes watershed delineations specific to the biological sampling station. Efforts are currently underway to determine the degree of human activity in each of the watersheds by evaluating parameters such as land use, population, hazardous waste sites and road density. This type of scoring will help to determine reference quality/least impacted sites.

The Biomonitoring Program is also investigating the need to classify the wadeable streams in New Hampshire. The state is small but very diverse, with low coastal systems and high mountainous regions. It is not yet clear whether it will be necessary to establish unique biological criteria for different regions of the state.

In the past, biomonitoring information has been used for 305(b) reporting and also for 303(d) listing. The Watershed Management Bureau, which is responsible for producing these reports, is currently evaluating the assessment and listing methodologies, using USEPA's CALM guidance. In 2002-2003 the Biomonitoring Program will be testing a probabilistic sampling design for site selection. This type of sampling will allow for greater confidence in statements of statewide water quality, and continue to provide useful data for biocriteria development.

Information about New Hampshire's Biomonitoring Program, including sampling protocols, can be found at http://www.des.state.nh.us/wmb/biomonitoring/.

Documentation and Further Information

State of New Hampshire 2000 Section 305(b) Water Quality Report:
http://www.des.state.nh.us/wmb/2000-305b.pdf

NHDES Biomonitoring Program Protocols, January 2002:
http://www.des.state.nh.us/wmb/biomonitoring/protocols.pdf

New Hampshire Biomonitoring Program general information: http://www.des.state.nh.us/wmb/biomonitoring/sites

NEW HAMPSHIRE

Contact Information

David Neils, Biomonitoring Program Coordinator
New Hampshire Department of Environmental Services (NHDES)
6 Hazen Drive ■ Concord, NH 03302-0095
Phone 603/271-8865 ■ Fax 603/271-7894
email: dneils@des.state.nh.us

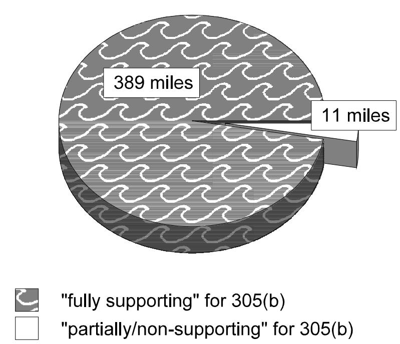
Programmatic Elements

Use of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
	✓	monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
	✓	promulgated into state water quality standards as biocriteria
		support of antidegradation
	✓	evaluation of discharge permit conditions
		TMDL assessment and monitoring
	✓	other: Ecological Risk Assessments
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(special projects and specific river basins or watersheds)*
	✓	fixed station (i.e., water quality monitoring stations) *(special projects only)*
		probabilistic by stream order/catchment area
		probabilistic by ecoregion, or statewide
		rotating basin
		other:

Stream Miles

Total miles *(State based determination)*	**10,881**
Total perennial miles	8,636
Total miles assessed for biology	**400**
fully supporting for 305(b)	389
partially/non-supporting for 305(b)	11
listed for 303(d)	0
number of sites sampled *(on an annual basis)*	130
number of miles assessed per site*	~3

400 Miles Assessed for Biology



*NHDES will be doing random sampling in the future. For now, 150 meters are assessed and extrapolated to a broader area, roughly three miles per site, though this number does vary.

Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Class system (A, B, C)	
ALU designations in state water quality standards	One designation: Fishable	
Narrative Biocriteria in WQS	There aren't any written formal/informal numeric procedures to support narrative biocriteria decisions yet because they are very subjective. Presently, data is being analyzed using New York's metrics.	
Numeric Biocriteria in WQS	under development	
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
		cause and effect determinations
	✓	permitted discharges
		monitoring (e.g., improvements after mitigation)
		watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	none	

Reference Site/Condition Development

Number of reference sites	**40 total**	
Reference site determinations	✓	site-specific
		paired watersheds
		regional (aggregate of sites)
	✓	professional judgment
		other:
Reference site criteria	Generally use best professional judgment. Least disturbed sites are determined following some stratification of characteristics (ArcView coverage, hazardous waste sites, etc.) – it is very visual.	
Characterization of reference sites within a regional context *Not applicable**		historical conditions
		least disturbed sites
		gradient response
		professional judgment
		other:
Stream stratification within regional reference conditions *Not applicable**		ecoregions (or some aggregate)
		elevation
		stream type
		multivariate grouping
		jurisdictional (i.e., statewide)
		other:
Additional information		reference sites linked to ALU
		reference sites/condition referenced in water quality standards
	✓	some reference sites represent acceptable human-induced conditions

*Regional reference sites not used.

Field and Lab Methods

Assemblages assessed	✓	benthos *(<100 samples/year; single season, multiple sites - broad coverage)*
	✓	fish *(<100 samples/year; single season, multiple sites - broad coverage)*
		periphyton
	✓	other: amphibians/reptiles *(<100 samples/year; single season, multiple sites - broad coverage)*

Benthos	
sampling gear	D-frame, kick net (1 meter), multiplate, rock baskets; 500-600 micron mesh
habitat selection	multihabitat, artificial substrate
subsample size	100 count
taxonomy	genus, lowest reasonable taxa
Fish	
sampling gear	backpack electrofisher
habitat selection	multihabitat
sample processing	anomalies
subsample	none
taxonomy	species
Habitat assessments	visual based; performed with bioassessments
Quality assurance program elements	standard operating procedures; quality assurance plan; periodic meetings, training for biologists; sorting and taxonomic proficiency checks; specimen archival; certification program for bioassessment (Biologists must have a certificate of completion of USFWS Electrofishing Course)

Data Analysis and Interpretation

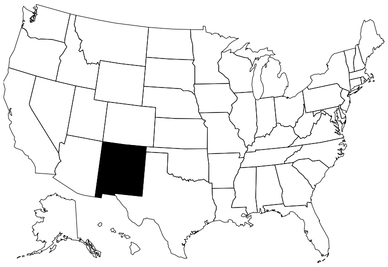
Data analysis tools and methods	✓	summary tables, illustrative graphs
		parametric ANOVAs
		multivariate analysis
	✓	biological metrics *(return single metrics - use endpoint for each single metric)*
		disturbance gradients
		other:

Multimetric thresholds	
transforming metrics into unitless scores	under development - Presently, only the raw score is tracked – there is no scale of comparison with the reference site yet.

Evaluation of performance characteristics		repeat sampling
		precision
Information not provided		sensitivity
		bias
		accuracy

Biological data	
Storage	EDAS
Retrieval and analysis	EDAS

NEW MEXICO



Contact Information

Seva J. Joseph, Environmental Specialist
New Mexico Environment Department (NMED)
1190 Saint Francis Drive ■ Santa Fe, NM 87502-0110
Phone 505/827-0573 ■ Fax 505/827-0160
email: seva_joseph@nmenv.state.nm.us
NMED Surface Water Quality Bureau: http://www.nmenv.state.nm.us/swqb/swqb.html

Program Description

Starting in 1998 the New Mexico Environment Department's (NMED) Surface Water Quality Bureau (SWQB) had a goal of monitoring all watersheds in the state on a 5-year cycle. NMED has recently begun to survey fish populations to supplement the data from the NM Department of Game and Fish. NMED uses RBP collection methods and is currently working on assessment methods suitable for the depauperate fish population of New Mexico. The SWQB coordinates with the NM Department of Game and Fish to obtain the most current fishery assessments in the watersheds.

The benefits of this approach are:

- It provides a systematic, detailed review of water quality data and allows for a more efficient use of valuable monitoring resources;
- It provides information at a scale where implementation of corrective activities is feasible;
- With an established order of rotation and predictable sampling in each basin, it is easier to coordinate efforts with other programs and water quality entities, and program efficiency is enhanced and the basis for management decisions is improved.

Documentation and Further Information

Water Quality and Water Pollution Control in New Mexico, 2000 305(b):
http://www.nmenv.state.nm.us/swqb/305b_2000.html

State of New Mexico Standards for Interstate and Intrastate Surface Waters, December 16, 2001:
http://www.nmenv.state.nm.us/NMED_regs/swqb/20_6_4_nmac.html

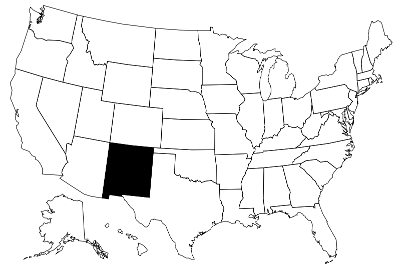
Surface Water Quality Bureau Library: http://www.nmenv.state.nm.us/swqb/links.html#WPS_Library

For a list of and links to *Reports and Publications*, go to:
http://www.nmenv.state.nm.us/gwb/Technical%20resources/TSS.html#Reports

For a *Table of Contents* containing ALL Technical Reports and other information, go to:
http://www.nmenv.state.nm.us/gwb/Technical%20resources/TSS.html

For a list of and links to *Biological Databases*, go to:
http://www.nmenv.state.nm.us/gwb/Technical%20resources/TSS.html#Biological

NEW MEXICO



Contact Information

Seva J. Joseph, Environmental Specialist
New Mexico Environment Department (NMED)
1190 Saint Francis Drive ■ Santa Fe, NM 87502-0110
Phone 505/827-0573 ■ Fax 505/827-0160
email: seva_joseph@nmenv.state.nm.us

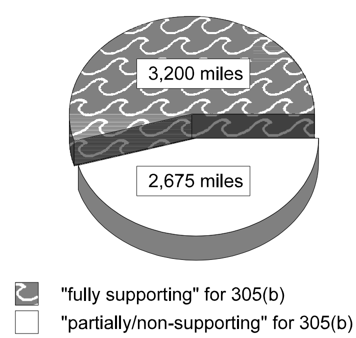
Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
	✓	monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
	✓	promulgated into state water quality standards as biocriteria
		support of antidegradation
		evaluation of discharge permit conditions
	✓	TMDL assessment and monitoring
		other:
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(special projects only)*
	✓	fixed station (i.e., water quality monitoring stations) *(comprehensive use throughout jurisdiction)*
		probabilistic by stream order/catchment area
	✓	probabilistic by ecoregion, or statewide *(special projects only)*
	✓	rotating basin *(comprehensive use throughout jurisdiction)*
		other:

Stream Miles

Total miles *(State based determination)*	**110,741**
Total perennial miles	8,682
Total miles assessed for biology	**5,875**
fully supporting for 305(b)	3,200
partially/non-supporting for 305(b)*	2,675
listed for 303(d)*	–
number of sites sampled *(on an annual basis)*	30
number of miles assessed per site	–

5,875 Miles Assessed for Biology



*A total of 3,080 miles are partially/non-supporting when miles with "impacts observed" are included. NMED is currently working on a 303(d) list.

Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Fishery Based Uses and Warm Water vs. Cold Water	
ALU designations in state water quality standards	Five designations: Coldwater Fishery, High Quality Coldwater Fishery, Limited Warmwater Fishery, Marginal Coldwater Fishery, and Warmwater Fishery	
Narrative Biocriteria in WQS	none	
Numeric Biocriteria in WQS	none	
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
	✓	cause and effect determinations
		permitted discharges
	✓	monitoring (e.g., improvements after mitigation)
	✓	watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	none	

Reference Site/Condition Development

Number of reference sites	**200 total**	
Reference site determinations		site-specific
		paired watersheds
		regional (aggregate of sites)
	✓	professional judgment
		other:
Reference site criteria	The least disturbed sites are picked according to best professional judgment (based on chemistry, quantitative habitat measurements, visual indicators, etc). There are plans to shift to RIVPACS as biocriteria are developed during the next few years.	
Characterization of reference sites within a regional context *Not applicable*		historical conditions
		least disturbed sites
		gradient response
		professional judgment
		other:
Stream stratification within regional reference conditions		ecoregions (or some aggregate)
	✓	elevation *(preliminary ecoregions are based on elevation and other habitat parameters)*
		stream type
		multivariate grouping
		jurisdictional (i.e., statewide)
		other:
Additional information		reference sites linked to ALU
		reference sites/condition referenced in water quality standards
	✓	some reference sites represent acceptable human-induced conditions

Field and Lab Methods

Assemblages assessed	✓	benthos *(30 samples/year; single season, multiple sites - watershed level)*
	✓	fish *(30 samples/year; single season, multiple sites - watershed level)*
	✓	periphyton* *(9 samples/year; single observation, limited sampling)*
	✓	other: phytoplankton *(9 samples/year; single observation, limited sampling)*

Benthos	
sampling gear	Hess, D-frame, kick net (1 meter); 500-600 micron mesh
habitat selection	riffle/run (cobble)
subsample size	300 count
taxonomy	combination (it depends on the family--some to genus, some to species level)
Fish	
sampling gear	backpack and bank electrofisher; 1/4" mesh
habitat selection	multihabitat
sample processing	length measurement and anomalies
subsample	batch
taxonomy	species
Periphyton*	
sampling gear	**natural substrate:** collect by hand; **artificial substrate:** periphytometer
habitat selection	richest habitat and multihabitat
sample processing	taxonomic identification
taxonomy	diatoms only
Habitat assessments**	visual based, hydrogeomorphology; and the RBP assessment is conducted with the bioassessment. NMDE may also conduct a Rosgen type hydrogeomorphological assessment, including pebble counts, independently of the bioassessment.
Quality assurance program elements	standard operating procedures, quality assurance plan, sorting proficiency checks and specimen archival

*Periphyton is collected primarily from lakes. It is only collected from streams in response to a specific problem or when looking at a certain impairment – sampling is very minimal (<10).

**Up to this point bioassessments have been conducted as described in the EPA's RBP. These methods are just now starting to be refined for regional applicability.

Data Analysis and Interpretation

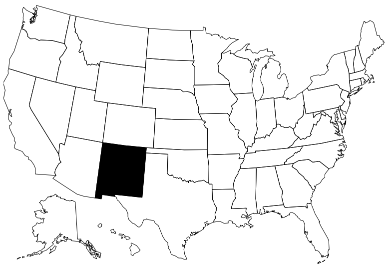
Data analysis tools and methods	✓	summary tables, illustrative graphs
		parametric ANOVAs
		multivariate analysis
	✓	biological metrics *(aggregate metrics into an index)*
		disturbance gradients
		other:

Multimetric thresholds	
transforming metrics into unitless scores	95th percentile of reference population
defining impairment in a multimetric index	95th percentile of reference population

Evaluation of performance characteristics		repeat sampling
		precision
Not currently evaluated		sensitivity
		bias
		accuracy

Biological data	
Storage	Just recently started using MS Access. All historic data (1977 - 1999) are in STORET
Retrieval and analysis	In the process of moving from STORET to MS Access; some data are also in Excel

NEW MEXICO



Contact Information

Seva J. Joseph, Environmental Specialist
New Mexico Environment Department (NMED)
1190 Saint Francis Drive ■ Santa Fe, NM 87502-0110
Phone 505/827-0573 ■ Fax 505/827-0160
email: seva_joseph@nmenv.state.nm.us
NMED Surface Water Quality Bureau: http://www.nmenv.state.nm.us/swqb/swqb.html

Program Description

Starting in 1998 the New Mexico Environment Department's (NMED) Surface Water Quality Bureau (SWQB) had a goal of monitoring all watersheds in the state on a 5-year cycle. NMED has recently begun to survey fish populations to supplement the data from the NM Department of Game and Fish. NMED uses RBP collection methods and is currently working on assessment methods suitable for the depauperate fish population of New Mexico. The SWQB coordinates with the NM Department of Game and Fish to obtain the most current fishery assessments in the watersheds.

The benefits of this approach are:

- It provides a systematic, detailed review of water quality data and allows for a more efficient use of valuable monitoring resources;
- It provides information at a scale where implementation of corrective activities is feasible;
- With an established order of rotation and predictable sampling in each basin, it is easier to coordinate efforts with other programs and water quality entities, and program efficiency is enhanced and the basis for management decisions is improved.

Documentation and Further Information

Water Quality and Water Pollution Control in New Mexico, 2000 305(b):
http://www.nmenv.state.nm.us/swqb/305b_2000.html

State of New Mexico Standards for Interstate and Intrastate Surface Waters, December 16, 2001:
http://www.nmenv.state.nm.us/NMED_regs/swqb/20_6_4_nmac.html

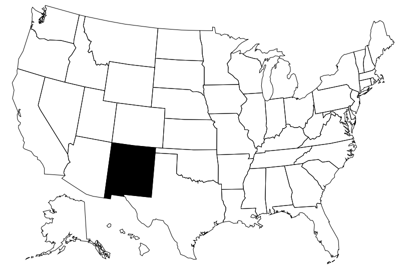
Surface Water Quality Bureau Library: http://www.nmenv.state.nm.us/swqb/links.html#WPS_Library

For a list of and links to *Reports and Publications*, go to:
http://www.nmenv.state.nm.us/gwb/Technical%20resources/TSS.html#Reports

For a *Table of Contents* containing ALL Technical Reports and other information, go to:
http://www.nmenv.state.nm.us/gwb/Technical%20resources/TSS.html

For a list of and links to *Biological Databases*, go to:
http://www.nmenv.state.nm.us/gwb/Technical%20resources/TSS.html#Biological

NEW MEXICO



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New Mexico Environment Department (NMED)
1190 Saint Francis Drive ■ Santa Fe, NM 87502-0110
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email: seva_joseph@nmenv.state.nm.us

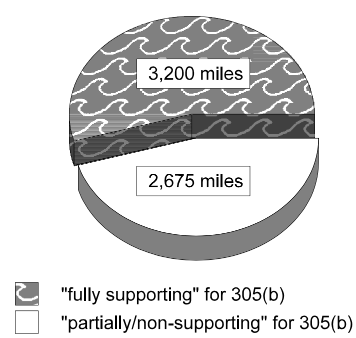
Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
	✓	monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
	✓	promulgated into state water quality standards as biocriteria
		support of antidegradation
		evaluation of discharge permit conditions
	✓	TMDL assessment and monitoring
		other:
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(special projects only)*
	✓	fixed station (i.e., water quality monitoring stations) *(comprehensive use throughout jurisdiction)*
		probabilistic by stream order/catchment area
	✓	probabilistic by ecoregion, or statewide *(special projects only)*
	✓	rotating basin *(comprehensive use throughout jurisdiction)*
		other:

Stream Miles

Total miles *(State based determination)*	**110,741**
Total perennial miles	8,682
Total miles assessed for biology	**5,875**
fully supporting for 305(b)	3,200
partially/non-supporting for 305(b)*	2,675
listed for 303(d)*	–
number of sites sampled *(on an annual basis)*	30
number of miles assessed per site	–

5,875 Miles Assessed for Biology



*A total of 3,080 miles are partially/non-supporting when miles with "impacts observed" are included. NMED is currently working on a 303(d) list.

Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Fishery Based Uses and Warm Water vs. Cold Water	
ALU designations in state water quality standards	Five designations: Coldwater Fishery, High Quality Coldwater Fishery, Limited Warmwater Fishery, Marginal Coldwater Fishery, and Warmwater Fishery	
Narrative Biocriteria in WQS	none	
Numeric Biocriteria in WQS	none	
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
	✓	cause and effect determinations
		permitted discharges
	✓	monitoring (e.g., improvements after mitigation)
	✓	watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	none	

Reference Site/Condition Development

Number of reference sites	**200 total**	
Reference site determinations		site-specific
		paired watersheds
		regional (aggregate of sites)
	✓	professional judgment
		other:
Reference site criteria	The least disturbed sites are picked according to best professional judgment (based on chemistry, quantitative habitat measurements, visual indicators, etc). There are plans to shift to RIVPACS as biocriteria are developed during the next few years.	
Characterization of reference sites within a regional context *Not applicable*		historical conditions
		least disturbed sites
		gradient response
		professional judgment
		other:
Stream stratification within regional reference conditions		ecoregions (or some aggregate)
	✓	elevation *(preliminary ecoregions are based on elevation and other habitat parameters)*
		stream type
		multivariate grouping
		jurisdictional (i.e., statewide)
		other:
Additional information		reference sites linked to ALU
		reference sites/condition referenced in water quality standards
	✓	some reference sites represent acceptable human-induced conditions

Field and Lab Methods

Assemblages assessed	✓ benthos *(30 samples/year; single season, multiple sites - watershed level)* ✓ fish *(30 samples/year; single season, multiple sites - watershed level)* ✓ periphyton* *(9 samples/year; single observation, limited sampling)* ✓ other: phytoplankton *(9 samples/year; single observation, limited sampling)*
Benthos	
sampling gear	Hess, D-frame, kick net (1 meter); 500-600 micron mesh
habitat selection	riffle/run (cobble)
subsample size	300 count
taxonomy	combination (it depends on the family--some to genus, some to species level)
Fish	
sampling gear	backpack and bank electrofisher; 1/4" mesh
habitat selection	multihabitat
sample processing	length measurement and anomalies
subsample	batch
taxonomy	species
Periphyton*	
sampling gear	**natural substrate:** collect by hand; **artificial substrate:** periphytometer
habitat selection	richest habitat and multihabitat
sample processing	taxonomic identification
taxonomy	diatoms only
Habitat assessments**	visual based, hydrogeomorphology; and the RBP assessment is conducted with the bioassessment. NMDE may also conduct a Rosgen type hydrogeomorphological assessment, including pebble counts, independently of the bioassessment.
Quality assurance program elements	standard operating procedures, quality assurance plan, sorting proficiency checks and specimen archival

*Periphyton is collected primarily from lakes. It is only collected from streams in response to a specific problem or when looking at a certain impairment – sampling is very minimal (<10).

**Up to this point bioassessments have been conducted as described in the EPA's RBP. These methods are just now starting to be refined for regional applicability.

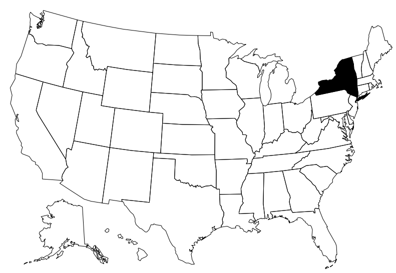
Data Analysis and Interpretation

Data analysis tools and methods	✓ summary tables, illustrative graphs ☐ parametric ANOVAs ☐ multivariate analysis ✓ biological metrics *(aggregate metrics into an index)* ☐ disturbance gradients ☐ other:
Multimetric thresholds	
transforming metrics into unitless scores	95th percentile of reference population
defining impairment in a multimetric index	95th percentile of reference population
Evaluation of performance characteristics *Not currently evaluated*	☐ repeat sampling ☐ precision ☐ sensitivity ☐ bias ☐ accuracy
Biological data	
Storage	Just recently started using MS Access. All historic data (1977 - 1999) are in STORET
Retrieval and analysis	In the process of moving from STORET to MS Access; some data are also in Excel

NEW YORK

Contact Information

Robert W. Bode, Research Scientist III
New York State Department of Environmental Conservation (NYSDEC)
625 Broadway ■ Albany, NY 12233-3502
Phone 518/285-5682 ■ Fax 518/285-5601
email: rwbode@gw.dec.state.ny.us
NYSDEC homepage: www.dec.state.ny.us/website/dow/index.html



Program Description

The Stream Biomonitoring Unit of the New York State Department of Environmental Conservation (NYSDEC) was formed in 1972. The primary objective of the Unit is to assess the water quality of streams and rivers in New York State using aquatic invertebrate communities. Secondary objectives include taxonomic investigations, invertebrate tissue analysis, and public outreach. The unit presently consists of five biologists: Robert Bode, Margaret Novak, Lawrence Abele, Diana Heitzman, and Alexander Smith.

The Stream Biomonitoring Unit is part of the ambient surface water monitoring team at NYSDEC. Water quality is assessed to determine the level of designated use support and the primary factors causing the impacts. In addition to community assessments, invertebrates are collected for tissue analysis to determine if elevated levels exist for metals, pesticides, PCBs, or PAHs. Biological monitoring using benthic invertebrate communities is the primary monitoring tool for the initial screening phase within the watersheds, providing a coverage of 150-200 streams each year. Additionally, biomonitoring is used to conduct multi-site intensive surveys on approximately 10 streams each year to provide baseline data and trend monitoring data or to trackdown sources of xenobiotic substances.

Assessments based on macroinvertebrate sampling are used extensively in 305(b) reports and the Priority Water List, and to a lesser extent in 303(d) reports. Assessments generally do not directly address the designated uses of drinking, swimming, or fishing, contained in the State water quality standards, although they provide sound basis for determination of aquatic life support (reported in 305b) and relate secondarily to the designated use of fish propagation and survival. Biocriteria are addressed by the Biological Impairment Criteria, which are used to define impairment by exceedances of metrics measured upstream and downstream of a discharge. The primary assessment method using benthic macroinvertebrates is based on a multimetric scale divided into four levels of impairment, ranging from non-impacted to severely impacted. Although nearly all the collection of biological data remains within the Unit, many studies are conducted in cooperation with other New York State agencies (NYS Museum), federal agencies (USGS, USEPA), neighboring states (Vermont, Massachusetts, New Jersey), and non-governmental organizations (Hudson Basin River Watch, Trout Unlimited, Nature Conservancy).

Accomplishments

- publication of a manual for the identification of larvae of Chironomidae (1980)
- development of methods for the Rapid Biological Assessment of streams (1983)
- establishment of biological impairment criteria (1990)
- publication of Percent Model Affinity, a community analysis technique (1992)
- documentation of 20-year trends in water quality in New York State (1993)
- development of Impact Source Determination, a pollution identification method (1995)

Future program directions and challenges

- continuing long-term trend monitoring
- providing maximum biomonitoring coverage of streams in New York State
- integrating more assessments with diatom and fish data
- developing invertebrate identification aids using digital photography and the NYSDEC website
- capturing biodiversity information outside of the subsampling process

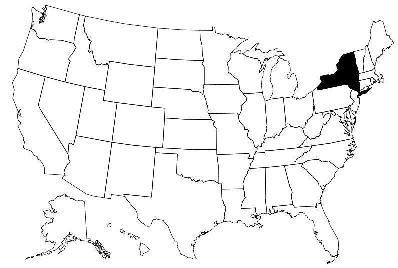
Documentation and Further Information

New York State Water Quality 2000, 305(b) Report, October 2000: http://www.dec.state.ny.us/website/dow/305b00.pdf

Draft 2002 Section 303(d) list: http://www.dec.state.ny.us/website/dow/303dcalm.pdf

Bode, R. W., M.A. Novak, and L.E. Abele, 1996. Quality assurance work plan for biological stream monitoring in New York State. New York State Department of Environmental Conservation Technical Report, 89 pages.

NEW YORK



Contact Information

Robert W. Bode, Research Scientist III
New York State Department of Environmental Conservation (NYSDEC)
625 Broadway ■ Albany, NY 12233-3502
Phone 518/285-5682 ■ Fax 518/285-5601
email: rwbode@gw.dec.state.ny.us

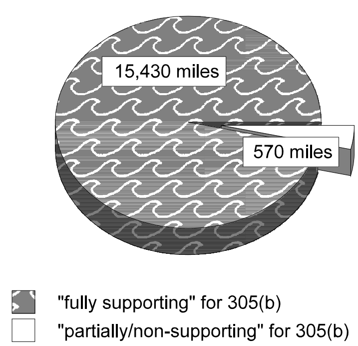
Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
	✓	monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
		promulgated into state water quality standards as biocriteria
		support of antidegradation
		evaluation of discharge permit conditions
		TMDL assessment and monitoring
		other:
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(comprehensive use throughout jurisdiction)*
	✓	fixed station (i.e., water quality monitoring stations) *(comprehensive use throughout jurisdiction)*
	✓	probabilistic by stream order/catchment area *(special projects only)*
		probabilistic by ecoregion, or statewide
	✓	rotating basin *(comprehensive use throughout jurisdiction)*
		other:

Stream Miles

Total miles *(determined using a state based program)*	**52,337**
Total perennial miles	46,266
Total miles assessed for biology*	**16,000**
fully supporting for 305(b)	15,430
partially/non-supporting for 305(b)	570
listed for 303(d)	484
number of sites sampled	800
number of miles assessed per site	20

16,000 Miles Assessed for Biology



*These numbers represent primarily stream miles (roughly 85-90%), but there are some river miles included due to program overlap in metrics, etc. It would be very difficult to separate the data for these two waterbody types. Also, there is a discrepancy between 305(b) partially/non-supporting and 303(d) stream miles because the 1998 303(d) list did not include all impaired waters, just impaired waters suitable for TMDLs. Also, the 305(b) and 303(d) lists, up until now, have been developed independent of each other.

Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Fishery Based Uses
ALU designations in state water quality standards	One designation: Fish propagation and survival
Narrative Biocriteria in WQS	none - New York does have *biological impairment criteria* (see footnote), but these are not found in the water quality standards.
Numeric Biocriteria in WQS	none
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓ assessment of aquatic resources ✓ cause and effect determinations ☐ permitted discharges ✓ monitoring (e.g., improvements after mitigation) ✓ watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to their designated ALU	none

Reference Site/Condition Development

Number of reference sites	**not applicable***
Reference site determinations	✓ site-specific ☐ paired watersheds ☐ regional (aggregate of sites) ☐ professional judgment ☐ other:
Reference site criteria	For application of biological impairment criteria, reference sites are control sites located upstream of a suspected source of impairment.
Characterization of reference sites within a regional context *Not applicable**	☐ historical conditions ☐ least disturbed sites ☐ gradient response ☐ professional judgment ☐ other:
Stream stratification within regional reference conditions *Not applicable**	☐ ecoregions (or some aggregate) ☐ elevation ☐ stream type ☐ multivariate grouping ☐ jurisdictional (i.e., statewide) ☐ other:
Additional information	☐ reference sites linked to ALU ☐ reference sites/condition referenced in water quality standards ☐ some reference sites represent acceptable human-induced conditions

*Reference sites are used in the following manner only: NYSDEC's reference sites are merely site-specific "control" sites, used strictly used for rating the water quality near a suspected source of impairment. This is done by collecting water samples at the source of impairment and upstream of the source, and then *biological impairment criteria* are applied for rating purposes. For example, if more than eight species are lost between the two samples, then the impairment criteria have been exceeded and the stream section would be considered significantly impaired. Thus the biological impairment criteria define how much change is allowed from upstream to downstream.

Field and Lab Methods

Assemblages assessed	✓	benthos *(100-500 samples/year; single season, multiple sites - watershed level)*
	✓	fish *(<100 samples/year; single season, multiple sites - not at watershed level)*
	✓	periphyton *(<100 samples/year; single season, multiple sites - not at watershed level)*
		other:

Benthos	
sampling gear	multiplate, Ponar grab sampler, dipnet; >800 micron mesh
habitat selection	riffle/run (cobble)
subsample size	100 count
taxonomy	genus, species, combination
Fish	
sampling gear	backpack electrofisher, 1/4" mesh
habitat selection	pool/glide, riffle/run (cobble)
sample processing	counts only
subsample	100 count
taxonomy	species
Periphyton	
sampling gear	**natural substrate**: suction device, brushing/scraping device (razor, toothbrush, etc.), from macrophyte surfaces; **artificial substrate**: collect by hand (multihabitat) using a knife blade and eyedropper
habitat selection	multihabitat
sample processing	taxonomic identification
taxonomy	diatoms only, species
Habitat assessments	quantitative measurements; performed with bioassessments
Quality assurance program elements	standard operating procedures; quality assurance plan; periodic meetings, training for biologists; sorting proficiency checks; taxonomic proficiency checks; specimen archival

*Water quality assessments using benthos are based on a multimetric scale divided into 4 levels of impairment ranging from non-impacted to severely impacted (see below). NYSDEC's bioassessment program had periphyton monitoring capabilities in 1999 and 2000, but this has since been dropped and it is not clear if the sampling will be continued. Fish sampling is conducted by another Division within NYSDEC for a limited number of sites per year.

Data Analysis and Interpretation

Data analysis tools and methods	✓	summary tables, illustrative graphs
		parametric ANOVAs
		multivariate analysis
	✓	biological metrics *(aggregate metrics into an index and return single metrics)*
		disturbance gradients
	✓	other: Impact Source Determination using cluster analysis

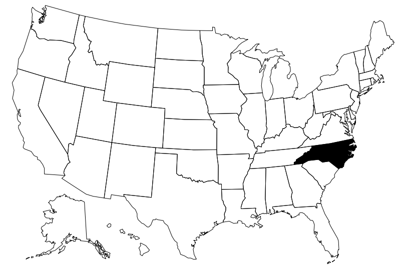
Multimetric thresholds	
transforming metrics into unitless scores	transformed into 4 impact categories, using approximately 25th, 50th, and 75th percentiles of database
defining impairment in a multimetric index	transformed into 4 impact categories using approximately 25th, 50th, and 75th percentiles**

Evaluation of performance characteristics	✓	repeat sampling *(sampling same site in different flow regime years)*
	✓	precision *(QA checks on subsampling)*
	✓	sensitivity *(comparisons with diatom sampling, fish sampling)*
	✓	bias *(replicate sampling to test for sampler differences)*
	✓	accuracy *(comparisons with toxicity testing, chemical sampling)*

Biological data	
Storage	data are entered in Excel spreadsheets, then transferred to FoxPro
Retrieval and analysis	In-house programs in FoxPro

**The impairment threshold is not defined using reference sites. Instead, NYSDEC creates impact categories using all of the data from the sites: everything >75th percentile is considered non-impacted/good.

NORTH CAROLINA



Contact Information

Trish MacPherson, Environmental Biology Supervisor II
North Carolina Department of Environmental and Natural Resources (NCDENR)
1621 Mail Service Center ■ Raleigh, NC 27699-1621
Phone 919/733-6946 ■ Fax 919/733-9959
email: trish.macpherson@ncmail.net
NC Environmental Sciences Branch homepage: http://www.esb.enr.state.nc.us/

Program Description

Benthic Macroinvertebrates
The Biological Assessment Unit of NCDENR uses aquatic macroinvertebrates as one type of indicator of biological integrity in streams and rivers. A swamp-sampling method is under development with sampling occurring in winter/early spring. North Carolina biologists first began collecting data in the late 1970s, and began using consistent sampling in 1983. Collection methods include a standard qualitative method (applicable for most between-site and/or between-date comparisons and used for all evaluations of impaired streams - those on the state 303(d) list), and the EPT method (an abbreviated version of the regular qualitative technique used to quickly determine between-site differences in water quality). Benthic samples are processed on site at each location. Another collection method is used for swamp streams. The boat sampling technique for nonwadeable freshwater rivers is an adaptation of the standard qualitative method.

Bioclassification criteria have been developed that are based on the number of intolerant EPT taxa present and the relative pollution tolerance of each taxa, as summarized in a Biotic Index for standard evaluation (EPT uses taxa richness only). Stream and river reaches are then given a final bioclassification of either Excellent, Good, Good/Fair, Fair or Poor. These bioclassifications, which have been developed for major ecoregions, are used to assess the various impacts of both point source discharges and nonpoint source runoff.

Beginning in 1991, the benthos summer sampling effort was directed toward specific river basins in given years based on the NPDES permitting schedule. This basin-wide monitoring is generally conducted three years prior to the year of permit renewal for the basin. This allows biological data to be incorporated in basin assessment, and subsequently into the management plan for each basin. Benthos data, by sub-basin, is incorporated into an Environmental Sciences Branch assessment report that also includes a review of pertinent data and information from other sources.

Between 110 and 130 wadeable sites are sampled for benthos each year during basinwide monitoring, and additional sites are sampled for special studies. The resulting information is used to document both spatial and temporal changes in water quality and to complement water chemistry analyses, fish community data, and habitat evaluations. In addition to assessing the effects of water pollution, biological information is also used to define High Quality or Outstanding Resource Waters, support enforcement of stream standards, and measure improvements associated with management actions. The results of biological investigations have been an integral part of North Carolina's basinwide monitoring program. Benthos data is the primary source for use support determinations.

Fish Community
To the public, the condition of the fishery is one of the most meaningful indicators of ecological integrity. Fish occupy the upper levels of the aquatic food web and are both directly and indirectly affected by chemical and physical changes in the environment. The Biological Assessment Unit employs a standard method for assessing streams' biological integrity by examining the structure and health of fish communities. This assessment incorporates information about species richness and composition, trophic composition, fish abundance, and fish condition. Criteria for the 12 metrics used in the North Carolina Index of Biological Integrity (NCIBI) are based on reference site data collected from groupings of river basins with similar fauna. The reference site sampling began in 1999, and fish community samples are now given a bioclassification similar to the benthos sites. Approximately 90 basinwide fish sites are sampled annually. Fish community data are used in the same ways as benthos data.

Use Support
North Carolina has moved toward assessing use support for each use class. Benthos and fish data are used for the evaluation of aquatic life standards. Biological data are typically given more weight than chemical data for use support. Sites with data from more than one trophic level are evaluated on a site specific basis for use support.

Documentation and Further Information

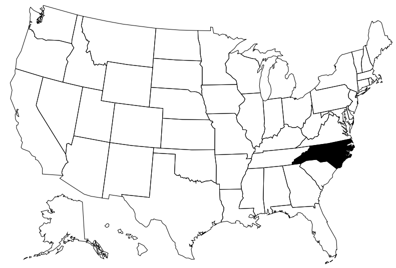
North Carolina 2000 305(b) Report: http://h2o.enr.state.nc.us/bepu/download.html

SOPs Biological Monitoring, Stream Fish Community Assessment & Fish Tissue:
http://www.esb.enr.state.nc.us/BAUwww/IBI%20Methods%202001.pdf

SOPs for Benthic Macroinvertebrates: http://www.esb.enr.state.nc.us/BAUwww/benthossop.pdf

Benthic Macroinvertebrate Sampling and Narrative Criteria: http://www.esb.enr.state.nc.us/BAUwww/benthosdata.pdf

NORTH CAROLINA



Contact Information

Trish MacPherson, Environmental Biology Supervisor II
North Carolina Department of Environmental and Natural Resources (NCDENR)
1621 Mail Service Center ■ Raleigh, NC 27699-1621
Phone 919/733-6946 ■ Fax 919/733-9959
email: trish.macpherson@ncmail.net

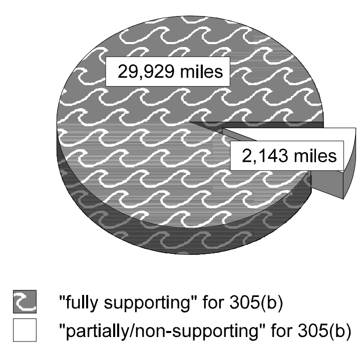
Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
	✓	monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
	✓	promulgated into state water quality standards as biocriteria
	✓	support of antidegradation
	✓	evaluation of discharge permit conditions
	✓	TMDL assessment and monitoring
	✓	other: 303(d) listing
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(comprehensive use throughout jurisdiction)*
	✓	fixed station (i.e., water quality monitoring stations) *(comprehensive use throughout jurisdiction)*
		probabilistic by stream order/catchment area
		probabilistic by ecoregion, or statewide
	✓	rotating basin *(comprehensive use throughout jurisdiction)*
		other:

Stream Miles

Total miles *(State based determinations)*	**37,672**
Total perennial miles	–
Total miles assessed for biology*	**32,072**
fully supporting for 305(b)	29,929
partially/non-supporting for 305(b)	2,143
listed for 303(d)	2,143
number of sites sampled *(on an annual basis)***	350
number of miles assessed per site	91.6

32,072 Miles Assessed for Biology



*Presently, biological sites are not separated from chemical for reporting purposes. However, Aquatic Life usages will be based primarily on biological assessment in the future. The 303(d) list is due before all assessments were completed (roughly 99% of partially/non supporting waters for 305(b) list). Thus, the number of miles assessed using biological data can't be confirmed because so many sources of information are used to make use support assessments. It can be assumed that using the current methodology of breaking out use support ratings by category (i.e., aquatic life), all the waters assessed in this category could be added up into miles. However, this method has only been applied to 6 of the 17 basins in North Carolina. NCDENR may have these numbers in the next few years.

**Best professional estimate of the number of sites sampled since the program's inception is 5000 benthos, 600 fish and 4000 phytoplankton samples (this is very good coverage of sites within river basins for mainstem and major tributaries).

Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Class System (A,B,C)	
ALU designations in state water quality standards	"Aquatic life propagation and maintenance of biological integrity..." applies as a best usage for Class C and Class WS-I waters.	
Narrative Biocriteria in WQS	Procedures used to support narrative biocriteria located in SOPs for biological assessment	
Numeric Biocriteria in WQS	none (Located in SOPs for biological assessment but not in water quality standards.)	
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
	✓	cause and effect determinations
	✓	permitted discharges
	✓	monitoring (e.g., improvements after mitigation)
	✓	watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	Biological data have been used to pinpoint degraded areas and to validate improvement after management activities have been completed.	

Reference Site/Condition Development

Number of reference sites	**300 total**	
Reference site determinations		site-specific
		paired watersheds
	✓	regional (aggregate of sites)
		professional judgment
		other:
Reference site criteria	Must achieve an excellent bioclassification or meet certain land use criteria (percent forest, no major dischargers, etc). Benthos reference sites: EPT criteria and biotic index criteria; fish reference sites: IBI criteria.	
Characterization of reference sites within a regional context		historical conditions
	✓	least disturbed sites
		gradient response
		professional judgment
		other:
Stream stratification within regional reference conditions	✓	ecoregions (or some aggregate)
	✓	elevation
	✓	stream type
		multivariate grouping
		jurisdictional (i.e., statewide)
		other:
Additional information	✓	reference sites linked to ALU
		reference sites/condition referenced in water quality standards
	✓	some reference sites represent acceptable human-induced conditions

Field and Lab Methods

Assemblages assessed	✓	benthos *(100-500 samples/year; multiple seasons, multiple sites – broad coverage for watershed level)*
	✓	fish *(<100 samples/year; multiple seasons, multiple sites – broad coverage for watershed level)*
	✓	periphyton, *(<100 samples/year; single observation, limited sampling)*
	✓	other: phytoplankton *(>500 samples/year; multiple seasons, multiple sites – broad coverage for watershed level)* and macrophytes *(<100 samples/year; single observation, limited sampling*)

Benthos	
sampling gear	collect by hand, sandbag, fine-mesh samplers made with net between PVC pipe joins, dipnet, kick net (1 meter); 200-400 micron mesh
habitat selection	multihabitat
subsample size	entire sample, aimed at >10 organisms/taxon (from qualitative field picking)
taxonomy	genus, species
Fish	
sampling gear	backpack electrofisher, boat electrofisher, seine; 1/8" mesh
habitat selection	multihabitat
sample processing	length measurement, anomalies
subsample	none
taxonomy	species, subspecies
Periphyton	
sampling gear	**natural substrate**: brushing/scraping device (razor, toothbrush, etc.), collect by hand; **artificial substrate**: collect by hand, bring rock back to lab
habitat selection	richest habitat
sample processing	taxonomic identification
taxonomy	diatoms only, species level
Habitat assessments	visual based, performed with bioassessments
Quality assurance program elements	standard operating procedures, quality assurance plan, periodic meetings and training for biologists, taxonomic proficiency checks, specimen archival, certification program for bioassessment

Data Analysis and Interpretation

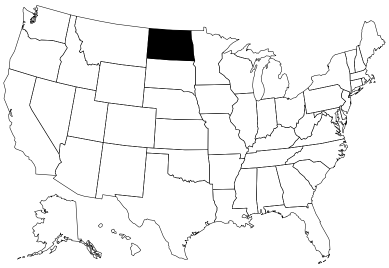
Data analysis tools and methods	✓	summary tables, illustrative graphs
	✓	parametric ANOVAs
		multivariate analysis
	✓	biological metrics *(aggregate metrics into an index and return single metrics - use endpoint for each single metric)*
	✓	disturbance gradients
		other:

Multimetric thresholds	
transforming metrics into unitless scores	reference data set used to set bounds for metrics - percent will vary with metric
defining impairment in a multimetric index	reference data set used to set bounds for metrics - percent will vary with metric

Evaluation of performance characteristics	✓	repeat sampling *(seasonal, multiyear data)*
	✓	precision *(to look for subtle differences in water quality)*
	✓	sensitivity *(different teams sample the same site)*
	✓	bias *(overlap sites with different crews)*
	✓	accuracy *(compare bioassessments with chemical & toxicity data)*

Biological data	
Storage	Fourth Dimension used for benthos data, MS Access used for fish and phytoplankton data
Retrieval and analysis	In house database

NORTH DAKOTA



Contact Information

Michael J. Ell, Environmental Scientist
North Dakota Department of Health (NDHD)
1200 Missouri Avenue, P.O. Box 5520 ■ Bismarck, ND 58506
Phone 701/328-5214 ■ Fax 701/328-5200
email: mell@state.nd.us
NDHD Division of Water Quality homepage: http://www.health.state.nd.us/ndhd/environ/wq/

Program Description

The primary goal of North Dakota's biological monitoring and assessment program is to develop a set of scientifically defensible ecological indicators that can be used to assess the extent to which the state's rivers and streams are meeting their designated aquatic life uses. Once developed, these indicators can also be used to set restoration goals when developing total maximum daily loads (TMDLs) and/or Section 319 nonpoint source pollution project implementation plans.

The North Dakota Department of Health (NDHD) initiated its biological monitoring and assessment program in 1993 and 1994 as part of an interagency project to develop a multimetric index of biological integrity (IBI) for fish in the Lake Agassiz Plain ecoregion, Red River of the North Basin. In addition to the Department of Health, other agencies involved in the project were the Minnesota Pollution Control Agency, Minnesota Department of Natural Resources, EPA Region V, and the USGS – Red River National Water Quality Assessment (NAWQA) project team. The project resulted in a 12 metric IBI for fish which distinguished among headwater, moderate, and large sized rivers.

Since 1995, NDHD has conducted biological monitoring in each of the state's four major river basins. The Department's biological monitoring and assessment efforts continued in the Red River of the North Basin in 1995 and 1996. In addition to fish, the Department began sampling macroinvertebrates in 1995. In 1997 and 1998, monitoring and assessment efforts were expanded to the Souris River and James River basins, respectively, and in 1999 and 2000 the Department sampled the Missouri River Basin. In addition to fish and macroinvertebrate samples collected at each site, NDHD also conducted a habitat assessment following EPA's Rapid Bioassessment Protocol.

Preliminary multimetric IBIs have been developed for fish and macroinvertebrates in the Red River Basin and for fish in the Souris River Basin. These IBIs have been used to assess aquatic life use support for the 2000 Section 305(b) report. As these IBIs are refined and as additional IBIs are developed for the remaining river basins, it is the Department's intent to include these biological assessments in future Section 305(b) reports as well as in the development of Section 303(d) TMDL lists.

NDHD is currently collaborating with North Dakota State University and EPA Region VIII in a two year pilot project to evaluate the response of the benthic periphyton community to varying summer growing season nutrient levels with the goal of developing regional nutrient criteria. Based on the results of this pilot project, NDHD may include periphyton in future biological monitoring and assessment activities, especially in relation to nutrient enrichment and eutrophication.

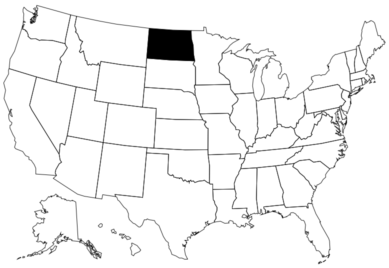
The Department is also a collaborator with EPA in the EMAP Western Pilot Project. The EMAP Western Pilot is currently in the third year of a four year project. By collaborating in this 12 state project, the Department hopes to integrate EMAP sampling design as well as EMAP sampling protocols into future biological monitoring and assessment projects. When NDHD's commitment to this project is completed in 2004, it's the Department's plan to begin its rotating basin monitoring program with the Red River Basin.

Documentation and Further Information

North Dakota Water Quality Assessment 1998 - 1999, 2000 305(b) Report:
http://www.health.state.nd.us/ndhd/environ/wq/2000_305b/2000_305b.pdf

For links to numerous NDHD surface water quality/management publications, including *Standards of Quality for Waters of the State, Chapter 33-16-02* and *North Dakota Unified Watershed Assessment, FY1999*, go to:
http://www.health.state.nd.us/ndhd/environ/wq/

NORTH DAKOTA



Contact Information

Michael J. Ell, Environmental Scientist
North Dakota Department of Health (NDHD)
1200 Missouri Avenue, P.O. Box 5520 ■ Bismarck, ND 58506
Phone 701/328-5214 ■ Fax 701/328-5200
email: mell@state.nd.us

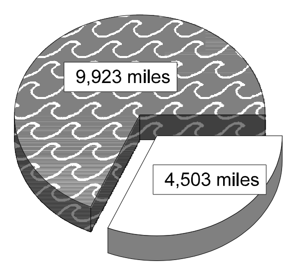
Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
	✓	monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
	✓	promulgated into state water quality standards as biocriteria
		support of antidegradation
		evaluation of discharge permit conditions
	✓	TMDL assessment and monitoring
		other:
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(special projects only)*
		fixed station (i.e., water quality monitoring stations)
		probabilistic by stream order/catchment area
		probabilistic by ecoregion, or statewide
	✓	rotating basin *(specific river basins or watersheds)*
		other:

Stream Miles

Total miles *(determined using RF3)*	**54,427**
Total perennial miles	unknown
Total miles assessed for biology*	**14,426**
fully supporting for 305(b)	9,923
partially/non-supporting for 305(b)	4,503
listed for 303(d)	–
number of sites sampled *(on an annual basis)***	150
number of miles assessed per site	–

14,426 Miles Assessed for Biology



*Both stream and river miles were assessed for biological, chemical and physical effects. As reported in ND's 2000 305(b) report, approximately 68.8 percent (9,923 miles) of rivers and streams assessed for this report fully support the beneficial use designated as aquatic life. The remaining 31.2 percent of rivers and streams (4,503 miles) either partially supporting or did not support their aquatic life uses.

**According to ND's 2000 305(b) report, "In 1997, 1998, and 1999, the department focused its intensive basin survey efforts on the Souris River Basin, the James River Basin, and the Lake Sakakawea subbasin, respectively. In addition to chemical monitoring, biological monitoring was conducted at approximately 50 sites in each basin each year."

Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Single Aquatic Life Use	
ALU designations in state water quality standards	North Dakota has several classes described (Class I, Ia, II, and III) but the ALU is basically the same for all classes.	
Narrative Biocriteria in WQS	A narrative biological goal is contained in ND's water quality standards. There are no formal/informal numeric procedures used to support narrative biocriteria.	
Numeric Biocriteria in WQS	none	
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
	✓	cause and effect determinations
		permitted discharges
		monitoring (e.g., improvements after mitigation)
	✓	watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	Nonpoint source project implementation plans	

Reference Site/Condition Development

Number of reference sites	**~75 total**	
Reference site determinations		site-specific
		paired watersheds
	✓	regional (aggregate of sites)
		professional judgment
		other:
Reference site criteria	Reference sites are the best sites of the whole population sampled, determined by habitat condition of sites and fish IBI.	
Characterization of reference sites within a regional context		historical conditions
	✓	least disturbed sites
		gradient response
		professional judgment
		other:
Stream stratification within regional reference conditions	✓	ecoregions (or some aggregate)
		elevation
	✓	stream type
		multivariate grouping
		jurisdictional (i.e., statewide)
	✓	other: river basin
Additional information		reference sites linked to ALU
		reference sites/condition referenced in water quality standards
	✓	some reference sites represent acceptable human-induced conditions

Field and Lab Methods

Assemblages assessed	✓	benthos *(100 - 500 samples/year; single season, multiple sites - watershed level)*
	✓	fish *(<100 samples/year; single season, multiple sites - watershed level)*
	✓	periphyton *(<100 samples/year; multiple seasons, multiple sites - broad coverage for watershed level)*
		other:

Benthos	
sampling gear	D-frame; 500-600 micron mesh
habitat selection	multihabitat
subsample size	300 count
taxonomy	lowest practical, usually genus
Fish	
sampling gear	boat and longline electrofishers, pram unit (tote barge)
habitat selection	multihabitat
sample processing	length measurement, biomass - batch, anomalies
subsample	none
taxonomy	species
Periphyton	
sampling gear	**natural substrate**: suction device
habitat selection	riffle/run (cobble)
sample processing	taxonomic identification
taxonomy	diatoms only
Habitat assessments	visual based and hydrogeomorphology; performed with bioassessments
Quality assurance program elements	standard operating procedures, quality assurance plan and specimen archival

Data Analysis and Interpretation

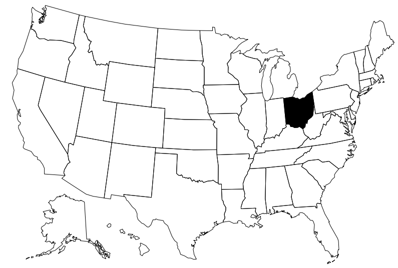
Data analysis tools and methods	✓	summary tables, illustrative graphs
		parametric ANOVAs
		multivariate analysis
	✓	biological metrics *(multimetric index under development)*
	✓	disturbance gradients
		other:

Multimetric thresholds	
transforming metrics into unitless scores	95^{th} percentile of all sites
defining impairment in a multimetric index	"power analysis"

Evaluation of performance characteristics	✓	repeat sampling *(replicate sampling within and among years)*
		precision
		sensitivity
		bias
		accuracy

Biological data	
Storage	Fish and habitat assessment data are in an MS Access 97 database maintained by the Department. Macroinvertebrate data are in EDAS.
Retrieval and analysis	Macroinvertebrate data are analyzed by EDAS, and plots generated by SAS. Fish data are analyzed with queries developed in-house.

OHIO



Contact Information

Jeffrey E. DeShon, Acting Manager - Ecological Assessment Section
Ohio Environmental Protection Agency (OHEPA)
4675 Homer Ohio Lane ■ Graveport, OH 43125
Phone 614/836-8780 ■ Fax 614/836-8795
email: jeff.deshon@epa.state.oh.us
OHEPA Division of Surface Water,Statewide Biological and Water Quality Monitoring and Assessment homepage: http://www.epa.state.oh.us/dsw/bioassess/ohstrat.html

Program Description

The Ohio EPA has been sampling biological communities in Ohio streams and rivers with standardized sampling protocols since the mid 1970s. Biological criteria was incorporated into the Ohio water quality standards (WQS; Ohio Administrative Code 3745-1) regulations in February 1990 (effective May 1990). These criteria consist of numeric values for the Index of Biotic Integrity (IBI) and Modified Index of Well-Being (MIwb), both of which are based on fish assemblage data, and the Invertebrate Community Index (ICI), which is based on macroinvertebrate assemblage data. Criteria for each index are specified for each of Ohio's five ecoregions (as described by Omernik 1987), and are further organized by organism group, index, site type, and aquatic life use designation. These criteria, along with the existing chemical and whole effluent toxicity evaluation methods and criteria, figure prominently in the monitoring and assessment of Ohio's surface water resources.

Ohio EPA employs biological, chemical, and physical monitoring and assessment techniques in biosurveys in order to meet three major objectives: 1) determine the extent to which use designations assigned in the Ohio WQS are either attained or not attained; 2) determine if use designations assigned to a given waterbody are appropriate and attainable; and 3) determine if any changes in key ambient biological, chemical, or physical indicators have taken place over time, particularly before and after the implementation of point source pollution controls or best management practices. Biosurvey data are processed, evaluated, and synthesized in a biological and water quality report. Each biological and water quality study contains a summary of major findings and recommendations for revisions to WQS, future monitoring needs, or other actions that may be needed to resolve existing impairment of designated uses. While the principal focus of a biosurvey is on the status of aquatic life uses, the status of other uses such as recreation and water supply, as well as human health concerns, are also addressed.

Documentation and Further Information

Year 2000 Ohio Water Resource Inventory, 305(b) Report: http://www.epa.state.oh.us/dsw/documents/Ohio305B2000.pdf

FWPCA Section 303(d) TMDL Priority List for FFY 1999-2000: http://www.epa.state.oh.us/dsw/tmdl/303dnotc.html

The State of the Aquatic Ecosystem: Ohio Rivers and Streams, 1998 Status: http://www.epa.state.oh.us/dsw/documents/fs8mas98.pdf

The Role of Biological Criteria in Water Quality Monitoring, Assessment, and Regulation, 1995: http://www.epa.state.oh.us/dsw/documents/instbusl.pdf

Using Biological Criteria to Validate Applications of Water Quality Criteria: Dissolved and Total Recoverable Metals, February 1997: http://www.epa.state.oh.us/dsw/documents/gli_bio.pdf

Rankin, E.T. 1989. *The qualitative habitat evaluation index (QHEI): rationale, methods, and application*. Division of Water Quality Planning & Assessment, Ecological Assessment Section, Columbus, Ohio.

Biological and Water Quality Reports, list of documents: http://www.epa.state.oh.us/dsw/document_index/psdindx.html

Biocriteria manuals are currently only available as hard copies upon emailed or written request. Information on obtaining copies can be found at http://www.epa.state.oh.us/dsw/document_index/printdoc.html. The biocriteria manuals are titled as follows:

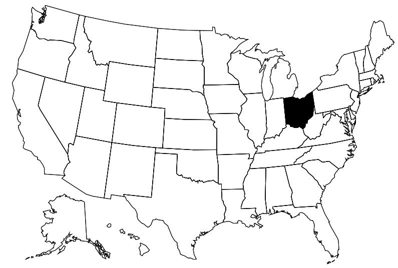
Ohio Environmental Protection Agency. 1987a. *Biological criteria for the protection of aquatic life: Volume I. The role of biological data in water quality assessment*. Division of Water Quality Monitoring & Assessment, Surface Water Section, Columbus, Ohio.

Ohio Environmental Protection Agency. 1987b. *Biological criteria for the protection of aquatic life: Volume II. Users manual for biological field assessment of Ohio surface waters*. Division of Water Quality Monitoring & Assessment, Surface Water Section, Columbus, Ohio.

Ohio Environmental Protection Agency. 1989b. *Addendum to Biological criteria for the protection of aquatic life: Volume II. Users manual for biological field assessment of Ohio surface waters*. Division of Water Quality Planning & Assessment, Ecological Assessment Section, Columbus, Ohio.

Ohio Environmental Protection Agency. 1989c. *Biological criteria for the protection of aquatic life: Volume III. Standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities*. Division of Water Quality Planning & Assessment, Ecological Assessment Section, Columbus, Ohio.

OHIO



Contact Information

Jeffrey E. DeShon, Acting Manager - Ecological Assessment Section
Ohio Environmental Protection Agency (OHEPA)
4675 Homer Ohio Lane ■ Graveport, OH 43125
Phone 614/836-8780 ■ Fax 614/836-8795
email: jeff.deshon@epa.state.oh.us

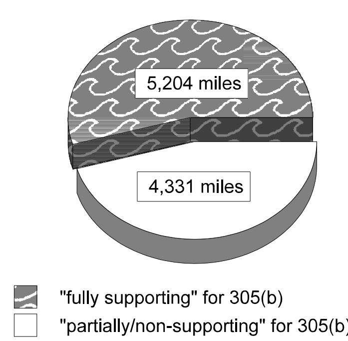
Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
	✓	monitoring the effectiveness of BMPs
	✓	ALUS determinations/ambient monitoring
	✓	promulgated into state water quality standards as biocriteria
	✓	support of antidegradation
	✓	evaluation of discharge permit conditions
	✓	TMDL assessment and monitoring
		other:
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(special projects, specific river basins or watersheds, and comprehensive use throughout jurisdiction)*
	✓	fixed station (i.e., water quality monitoring stations) *(specific river basins or watersheds)*
		probabilistic by stream order/catchment area
		probabilistic by ecoregion, or statewide
	✓	rotating basin *(special projects, specific river basins or watersheds, and comprehensive use throughout jurisdiction)*
	✓	other: geometric design *(specific river basins or watersheds and comprehensive use throughout jurisdiction)*

Stream Miles

Total miles *(based on the USEPA RF3 map of perennial stream miles as determined for Ohio)*	**29,113**
Total perennial miles	29,113
Total miles assessed for biology	**9,535**
fully supporting for 305(b)	5,204
partially/non-supporting for 305(b)	4,331
listed for 303(d)*	2,052
number of sites sampled *(1999-2000)*	1,100
number of miles assessed per site *(1999-2000)*	2.5

9,535 Miles Assessed for Biology



*The 2,052 miles are from Ohio's 1998 303(d) list, which is based on the 1996 305(b) statistics and includes data collected through 1994. OHEPA has recently taken a different approach to assessment and listing that will be reflected in upcoming 303(d) listings. The Agency now discourages the use of attainment statistics based on monitored stream miles in favor of a watershed level approach that provides an indication of the attainment status of watersheds in total (in essence, a measure of square miles of watersheds fully, partially, or not supporting ALU).

Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Class System (A,B,C) - Tiered
ALU designations in state water quality standards	Seven designations: Warmwater Habitat, Exceptional Warmwater Habitat, Coldwater Habitat, Modified Warmwater Habitat, Seasonal Salmonid, Limited Warmwater Habitat (being phased out), Limited Resource Water
Narrative Biocriteria in WQS	Procedures used to support narrative biocriteria located in Ohio WQS, http://www.epa.state.oh.us/dsw/rules/3745-1.html
Numeric Biocriteria in WQS	Also found in Ohio WQS, see above link

Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
	✓	cause and effect determinations
	✓	permitted discharges
	✓	monitoring (e.g., improvements after mitigation)
	✓	watershed based management

Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	There are many instances where bioassessments documented before and after conditions based on POTW improvements. Biosurvey data and biocriteria thresholds are the primary arbiters in the determination of aquatic life use attainment status; results are used to determine 305(b) aquatic life use attainment statistics and to drive the 303(d) listing/delisting and TMDL development process.

Reference Site/Condition Development

Number of reference sites		**500 total** (including modified reference sites)
Reference site determinations		site-specific
		paired watersheds
	✓	regional (aggregate of sites)
		professional judgment
		other:
Reference site criteria*		Representative of best watershed conditions within an ecoregion given the background activities prevalent in society.
Characterization of reference sites within a regional context		historical conditions
	✓	least disturbed sites
		gradient response
		professional judgment
		other:
Stream stratification within regional reference conditions	✓	ecoregions (or some aggregate)
		elevation
		stream type
		multivariate grouping
		jurisdictional (i.e., statewide)
		other:
Additional information	✓	reference sites linked to ALU
	✓	reference sites/condition referenced in water quality standards *(listed in Biocriteria Manuals, which are referenced in WQS)*
	✓	some reference sites represent acceptable human-induced conditions

*All reference sites were originally screened to eliminate sites with evidence of substantial human disturbance. This was accomplished by examining maps of human population density and current and past land uses, compiling a watershed disturbance ranking, and noting the size and location of point source discharges. Additional site-specific factors considered in the selection of a reference site included (1) the amount, if any, of stream channel modification, (2) the condition of the vegetative riparian buffer zone, (3) water volume, (4) channel morphology characteristics, (5) substrate character and condition, (6) presence of obvious color/odor problems, (7) amount of instream woody debris, and (8) the general representativeness of the site within the ecoregion.

Field and Lab Methods

Assemblages assessed	✓	benthos *(100-500 samples/year; single season, multiple sites - broad coverage)*
	✓	fish *(100-500 samples/year; single season, multiple sites - broad coverage)*
		periphyton
		other:

Benthos	
sampling gear	collect by hand, multiplate: 200-400 micron mesh
habitat selection	multihabitat and artificial substrate
subsample size	entire sample (presort with subsampling)
taxonomy	combination (lowest practical with current knowledge)
Fish	
sampling gear	backpack electrofisher (in small streams only), boat electrofisher, pram unit (tote barge), and longline method using electrofishing unit and 100 meter line
habitat selection	multihabitat
sample processing	biomass - individual and batch, anomalies
subsample	batch (for weight only)
taxonomy	species
Habitat assessments	visual based; performed with bioassessments
Quality assurance program elements	standard operating procedures, quality assurance plan, periodic meetings and training for biologists, taxonomic proficiency checks, specimen archival, and a certification program for bioassessment has been developed for the OHEPA Voluntary Action Program (i.e., Brownfields Redevelopment)

Data Analysis and Interpretation

Data analysis tools and methods	✓	summary tables, illustrative graphs
		parametric ANOVAs
		multivariate analysis
	✓	biological metrics *(aggregate metrics into an index)*
		disturbance gradients
		other:

Multimetric thresholds	
transforming metrics into unitless scores	95^{th} percentile of reference population
defining impairment in a multimetric index	25^{th} percentile of reference population (ecoregion Warmwater Habitat and Modified Warmwater Habitat); 75^{th} percentile of reference population (statewide Exceptional Warmwater Habitat); EPA RBP Guidelines

Evaluation of performance characteristics	✓	repeat sampling *(many sites - including reference sites - with multiple-year collections to track temporal variability)*
	✓	precision *(multiple samples occasionally collected from the same site on the same date, especially at potential litigation sites)*
	✓	sensitivity *(studies have been done to determine the possible range of variation in index scores at a given sampling location on a given sampling date)*
		bias
		accuracy

Biological data	
Storage	In initial stages of modernization and migration to MS Access
Retrieval and analysis	Custom programs to calculate indices, other summarized data, 305(b) statistics, etc.

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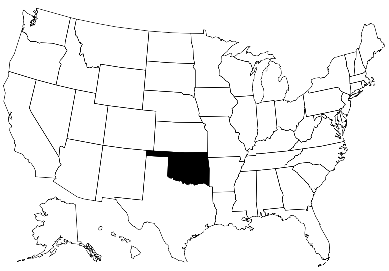

Contact Information

Charles Potts, Senior Environmental Specialist
Oklahoma Water Resources Board (OWRB)
3800 North Classen ■ Oklahoma City, OK 73118
Phone 405/530-8800 ■ Fax 405/530-8900
email: capotts@owrb.state.ok.us
OWRB homepage: http://www.owrb.state.ok.us/

Program Description

The Oklahoma Water Resources Board (OWRB) has many monitoring programs. In 1998, the State Legislature directed the OWRB to oversee certain state water quality monitoring activities to determine compliance with Oklahoma's Water Quality Standards (OWQS). Specifically, the OWRB was charged with coordinating all monitoring under a standing cooperative agreement with the USGS, conducting a Comprehensive Beneficial Use Monitoring Program (BUMP), and developing Use Support Assessment Protocols (USAPS) to ensure the consistent data interpretation of beneficial use support. The overall goal of BUMP is to document beneficial use impairments, identify impairment sources (if possible), detect water quality trends, provide needed information for the OWQS and facilitate the prioritization of pollution control activities. River and stream monitoring is one of five key elements of BUMP.

So far, OWRB's biological monitoring is related only to special projects, such as biocriteria development or the occasional fish tissue study. However, BUMP is a developing program and there is intent to expand biological monitoring in the near future. Presently, there are fixed and rotating stations at which chemistry and flow information may be collected. The OWRB is currently monitoring almost 200 sites on a monthly basis. These sites are segregated into two discrete types of monitoring activities. The first monitoring activity is focuses on fixed station monitoring on rivers and streams. In general, at least one sample station is located in each of 67 watersheds. Following consultation with other appropriate state environmental agencies, the OWRB originally identified 84 fixed sites; that number has now grown to 100. The second component of river and stream monitoring focuses on water quality sampling stations whose location will rotate on an annual basis. Stations and identified monitoring parameters were based upon Oklahoma's 303(d) list and the monitoring requirements of other state environmental agencies. Monitoring parameters are specific for each stream segment.

Oklahoma DEQ's fish monitoring program has been discontinued but provided a wealth of information concerning statewide fish distribution. Improvements in Oklahoma's water quality monitoring programs are being developed and implemented in order to provide more consistent and reliable information related to the condition of aquatic resources (including quality habitat alteration, and impacts of polluted runoff and point source discharges). Unfortunately, much of the monitoring information in Oklahoma is fragmentary and incompatible because it is collected through programs that are designed and conducted for differing objectives.

Documentation and Further Information

The State of Oklahoma Water Quality Assessment Report, 2000 Edition, November 2000:
http://www.deq.state.ok.us/WQDnew/305b_303d/2000_305b_Report_Final.pdf

Status of Water Quality Monitoring in Oklahoma, 2000 Final Report to the Oklahoma Legislature:
www.owrb.state.ok.us/reports/OkWqStatus2000.pdf

Oklahoma Water Resources Board, Chapter 46 of Implementation of Oklahoma's WQS, effective August 2001:
http://www.owrb.state.ok.us/rules/Chap46.pdf

SOP for Field Sampling Efforts of the OK Water Resources Board Beneficial Use Monitoring Program, June 2001:
http://www.owrb.state.ok.us/reports/BUMP_SOPFY-01.pdf

Oklahoma's Nonpoint Source Management Program and Nonpoint Source Assessment Report, FINAL DRAFT:
http://www.okcc.state.ok.us/Divisions/Water_Quality/Reports/REPORT078.pdf

Conduct your own "Biological Monitoring" search for additional documents using: http://www.soonersearch.odl.state.ok.us/

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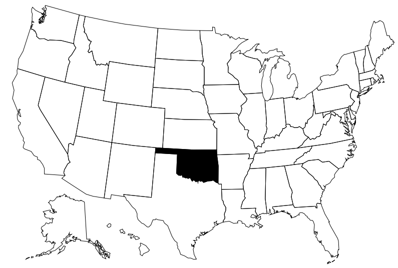

Contact Information

Charles Potts, Senior Environmental Specialist
Oklahoma Water Resources Board (OWRB)
3800 North Classen ■ Oklahoma City, OK 73118
Phone 405/530-8800 ■ Fax 405/530-8900
email: capotts@owrb.state.ok.us

Programmatic Elements

Uses of bioassessment within overall water quality program*		problem identification (screening)
		nonpoint source assessments
		monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
	✓	promulgated into state water quality standards as biocriteria
		support of antidegradation
		evaluation of discharge permit conditions
		TMDL assessment and monitoring
		other:
Applicable monitoring designs		targeted (i.e., sites selected for specific purpose)
		fixed station (i.e., water quality monitoring stations)
		probabilistic by stream order/catchment area
	✓	probabilistic by ecoregion, or statewide *(comprehensive use throughout jurisdiction)*
		rotating basin
		other:

*Several possibilities exist, but currently only use-support decisions and use assignments are done with bioassessments.

Stream Miles

Total miles *(State based determination - waterbody identifications)*	**78,778**
Total perennial miles	22,386
Total miles assessed for biology	**13,313**
fully supporting for 305(b)**	–
partially/non-supporting for 305(b)**	–
listed for 303(d)**	–
number of sites sampled	3,391
number of miles assessed per site	~4 (site specific)

**Much of Oklahoma's efforts are still in the development stages. The new 305(b) and 303(d) are not complete and there have been significant changes in protocol since last completed; thus the data from past reports are no longer relevant. The new 305(b) and 303(d) reports should be complete sometime in 2002.

Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	ALU subcategories	
ALU designations in state water quality standards	Habitat Limited Aquatic Community (least restrictive), Warm Water A.C., Cool Water A.C. (most restrictive), Trout Fishery (anti-degradation limitation)	
Narrative Biocriteria in WQS	Formal/informal numeric procedures used to support narrative biocriteria exist for specific ecoregions only.	
Numeric Biocriteria in WQS	Only for specific ecoregions; biological use-support thresholds found in 785:46-15 (WQS implementation).	
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
		cause and effect determinations
		permitted discharges
		monitoring (e.g., improvements after mitigation)
		watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	none	

Reference Site/Condition Development

Number of reference sites	**66 - 132 total** (will increase as number of ecoregions are completed)	
Reference site determinations		site-specific
		paired watersheds
	✓	regional (aggregate of sites)
		professional judgment
	✓	other: least impacted, no point sources
Reference site criteria	Reference sites are defined by the least impacted version of a stream type in a particular ecoregion. Specific criteria is under development.	
Characterization of reference sites within a regional context		historical conditions
	✓	least disturbed sites
		gradient response
		professional judgment
		other:
Stream stratification within regional reference conditions	✓	ecoregions (or some aggregate)
		elevation
	✓	stream type
		multivariate grouping
		jurisdictional (i.e., statewide)
		other:
Additional information	✓	reference sites linked to ALU
		reference sites/condition referenced in water quality standards
	✓	some reference sites represent acceptable human-induced conditions

Field and Lab Methods

Assemblages assessed	✓	benthos *(<100 samples/year; single observation, limited sampling)*
	✓	fish *(<100 samples/year; single observation, limited sampling)*
		periphyton
		other:

Benthos	
sampling gear	dipnet, kick net (1 meter); 500-600 micron mesh
habitat selection	riffle/run (cobble) and woody debris
subsample size	100 count
taxonomy	genus
Fish	
sampling gear	backpack electrofisher, seine; 1/4" mesh
habitat selection	all habitats contained within the "representative" reach of 200 - 400 meters
sample processing	anomalies and taxonomic identification
subsample	none
taxonomy	species
Habitat assessments	quantitative measurements; performed independent of bioassessments (see *Oklahoma Water Resource Board Technical Report 99-3* for more information)
Quality assurance program elements	standard operating procedures, quality assurance plan, taxonomic proficiency checks and specimen archival

Data Analysis and Interpretation

Data analysis tools and methods	✓	summary tables, illustrative graphs
		parametric ANOVAs
		multivariate analysis
	✓	biological metrics *(aggregate metrics into an index)*
		disturbance gradients
		other:

Multimetric thresholds	
transforming metrics into unitless scores	cumulative distribution function (ecoregion dependent)
defining impairment in a multimetric index	cumulative distribution function (ecoregion dependent)

Evaluation of performance characteristics	✓	repeat sampling *(site validation collections and habitat assessments)*
		precision
		sensitivity
		bias
		accuracy

Biological data	
Storage	MS Access and/or Excel formats
Retrieval and analysis	application dependent, spreadsheet driven (no large statistical treatment yet); in the process of pulling existing data from other agencies to help develop a program

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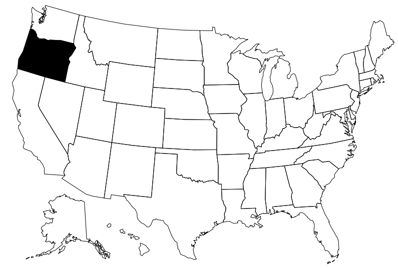

Contact Information

Rick Hafele, Manager - Biomonitoring Section
Oregon Department of Environmental Quality (ORDEQ)
2020 SW 4th Avenue, Suite 400 ■ Portland, OR 97201
Phone 503/229-5349 ■ Fax 503/229-6957
email: hafele.rick@deq.state.or.us
ORDEQ Water Quality Program homepage: http://www.deq.state.or.us/wq/

Program Description

Oregon DEQ (ORDEQ) has a history of using biological data in water quality assessments. Since the early 1990's the biomonitoring program has grown from two full time staff to nine current permanent staff, and over 15 during the summer field season. The principle objectives of the biomonitoring program are to:

- Assess the status of stream conditions and fish and macroinvertebrate assemblages across the state,
- Identify trends in stream conditions and biological assemblages,
- Identify the primary chemical and physical parameters impairing biological assemblages,
- Assess the effectiveness of restoration projects and management activities designed to improve stream conditions, and
- Help standardize protocols for biological assessments throughout the state and region

Increased concern over nonpoint sources of pollution and the listing of numerous salmon species as threatened or endangered has focused more attention on the importance of biological information in the State. In 1991 Oregon DEQ adopted narrative biocriteria into state water quality standards. ORDEQ is currently developing numeric biocriteria and expects to have numeric standards adopted by 2004.

Most biological data are collected using a probabilistic sampling design. A reference site network is also being developed and sampled. ORDEQ has worked closely with EPA and other state agencies in developing its monitoring strategy. Over 400 sites have been sampled for biological, chemical and physical parameters (approximately 150 sites per year). Currently biological data are incorporated into the State's 305(b) report and 303(d) list. Other biological data are used in NPDES permit assessments, CWA Section 401 permit applications, and beneficial use assessments.

Maintaining a commitment to long-term funding is one of the primary challenges of any state monitoring effort. Data management and data quality are also key issues that require ongoing efforts to maintain an effective program. Finally, integrating biological data into the overall water quality program (i.e. TMDLs) is an ongoing challenge and an area for improvement in the future. To view current ORDEQ biomonitoring technical reports, go to: http://www.deq.state.or.us/lab/Biomon/bio_rpt.htm

Documentation and Further Information

Oregon's 2000 Water Quality Status Assessment Report, Section 305(b) Report:
http://www.deq.state.or.us/wq/305bRpt/305bReport00a.pdf

ORDEQ Water Quality Limited Streams 303(d) List information (including Listing Criteria, etc.):
http://www.deq.state.or.us/wq/303dlist/303dpage.htm

Oregon Water Quality Standards homepage: http://www.deq.state.or.us/wq/standards/wqstdshome.htm

Quality Assurance Guidelines:
http://www.deq.state.or.us/lab/qa/NPDES%20and%20WPCF%20Self-Monitoring%20Laboratories.pdf

Mrazik, S. 1999. *Reference site selection: a six step approach for selecting reference sites for biomonitoring and stream evaluation studies*. Oregon Department of Environmental Quality, Biomonitoring Section.

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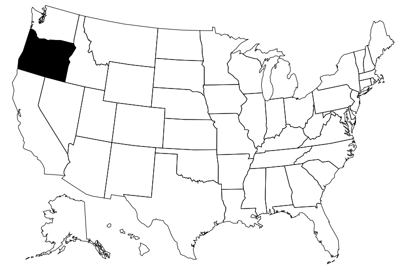


Contact Information

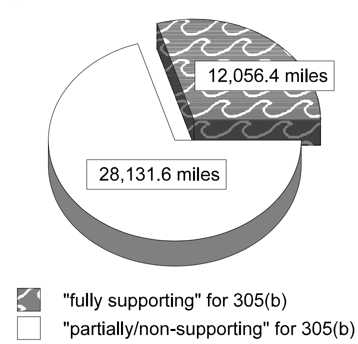
Rick Hafele, Manager - Biomonitoring Section
Oregon Department of Environmental Quality (ORDEQ)
2020 SW 4th Avenue, Suite 400 ■ Portland, OR 97201
Phone 503/229-5349 ■ Fax 503/229-6957
email: hafele.rick@deq.state.or.us

Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
	✓	monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
	✓	promulgated into state water quality standards as biocriteria
		support of antidegradation
	✓	evaluation of discharge permit conditions
	✓	TMDL assessment and monitoring
	✓	other: 401 permits and restoration effectiveness monitoring
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(special projects only)*
		fixed station (i.e., water quality monitoring stations)
	✓	probabilistic by stream order/catchment area *(specific river basins or watersheds)*
	✓	probabilistic by ecoregion, or statewide *(comprehensive use throughout jurisdiction)*
		rotating basin
		other:

Stream Miles

Total miles *(determined using RF3 and National Hydrography Database)*	**114,823**
Total perennial miles	51,695
Total miles assessed for biology*	**40,188**
fully supporting for 305(b)	12,056.4
partially/non-supporting for 305(b)	28,131.6
listed for 303(d)**	unknown
number of sites sampled *(on an annual basis)****	150+
number of miles assessed per site	–



*Most of the biological monitoring is based on a probabilistic sampling design in order to calculate the total stream miles represented by the data.

**ORDEQ is in the process of drafting a new 303(d) list (as of March 2002). If ORDEQ were to provide data based on past 303(d) lists, the number of miles listed would be considerably smaller than the 28,131 miles that are "partially/non-supporting" for 305(b) because 303(d) lists are *not* based on a probabilistic sampling design.

***Over 400 total sites have been sampled.

Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Fishery Based Uses	
ALU designations in state water quality standards	Four designations: Salmonid Passage; Salmonid rearing; Salmonid spawning; Protection of resident fish and aquatic life	
Narrative Biocriteria in WQS	applied using a numeric approach found in 303(d) listing criteria, http://www.deq.state.or.us/wq/303dlist/303dpage.htm	
Numeric Biocriteria in WQS	under development	
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
	✓	cause and effect determinations
	✓	permitted discharges
	✓	monitoring (e.g., improvements after mitigation)
		watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	The best example is a stream restoration project in Eastern Oregon that is trying to restore habitat and water quality to support salmonid spawning and rearing. Bioassessment data have been an ongoing part of this project's evaluation.	

Reference Site/Condition Development

Number of reference sites	**200 total**	
Reference site determinations		site-specific
		paired watersheds
	✓	regional (aggregate of sites)
	✓	professional judgment
	✓	other: see criteria below
Reference site criteria	Reference sites must fall into the lowest level of human disturbance based on a set of GIS information and field results including land use, road density and habitat (GIS data and best professional judgment are used to identify 5th field watersheds with minimal human disturbance). Once potential watersheds have been identified, stream monitoring sites are randomly selected from within those watersheds. Field reconnaissance confirms if they are suitable reference sites.	
Characterization of reference sites within a regional context		historical conditions
	✓	least disturbed sites
		gradient response
		professional judgment
	✓	other: minimally disturbed*
Stream stratification within regional reference conditions	✓	ecoregions (or some aggregate)
	✓	elevation
	✓	stream type
	✓	multivariate grouping
		jurisdictional (i.e., statewide)
	✓	other: gradient; latitude and longitude; conductivity; watershed area
Additional information		reference sites linked to ALU
	✓	reference sites/condition referenced in water quality standards
	✓	some reference sites represent acceptable human-induced conditions

*Oregon has three classes of reference sites: A - Sites with no human disturbance. These sites represent "natural" conditions and are generally found in wilderness areas or very remote regions of the state, B - Sites with minimal human disturbance. These sites represent conditions expected to occur without or with very minimal human activity, and C - Sites with human disturbance that measurably alters stream conditions. These are the best available (least disturbed) sites.

Field and Lab Methods

Assemblages assessed	✓	benthos *(100-500 samples/year; single season, multiple sites - broad coverage)*
	✓	fish *(100-500 samples/year; single season, multiple sites - broad coverage)*
	✓	periphyton *(<100 samples/year; single season, multiple sites - watershed level)* *NOTE: ORDEQ samples periphyton for some projects, but not at the majority of sites.*
	✓	other: amphibians and reptiles *(100-500 samples/year; single season, multiple sites - broad coverage)*

Benthos	
sampling gear	D-frame; 500-600 micron mesh
habitat selection	riffle/run (cobble)
subsample size	500 count
taxonomy	combination - typically genus/species. A regional (multistate) taxonomy workgroup meets to set taxonomic level standards.
Fish/Amphibians	
sampling gear	backpack electrofisher
habitat selection	multihabitat
sample processing	length measurement and anomalies
subsample	none
taxonomy	species
Periphyton	
sampling gear	**natural substrate**: brushing/scraping device (razor/toothbrush, etc.)
habitat selection	riffle/run (cobble)
sample processing	taxonomic identification
taxonomy	all algae
Habitat assessments	quantitative measurements; performed with bioassessments
Quality assurance program elements	standard operating procedures, quality assurance plan, periodic meetings and training for biologists, and specimen archival

Data Analysis and Interpretation

Data analysis tools and methods	✓	summary tables, illustrative graphs
	✓	parametric ANOVAs
	✓	multivariate analysis
	✓	biological metrics *(aggregate metrics into an index)*
	✓	disturbance gradients
		other:

Multimetric thresholds	
transforming metrics into unitless scores	25th percentile of reference population
defining impairment in a multimetric index	Cumulative distribution function
Multivariate thresholds	
defining impairment in a multivariate index	Significant departure from mean of reference population

Evaluation of performance characteristics	✓	repeat sampling *(a minimum of 10% of sites are sampled twice each field season)*
	✓	precision *(Signal-to-noise analysis)*
	✓	sensitivity *(Multivariate model sensitivity checked by rerunning model on subset of reference sites)*
		bias
		accuracy

Biological data	
Storage	Data are stored in an agency database using MS Access. Macroinvertebrate data are also being stored in a regional database (multi-agency and multi-state).
Retrieval and analysis	SAS and Statistica

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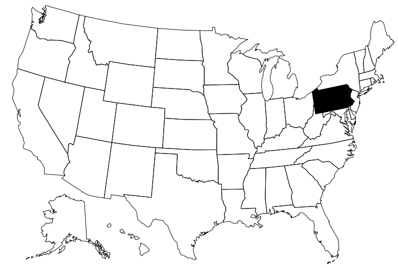

Contact Information

Daniel Bogar, Water Pollution Biologist II
Pennsylvania Department of Environmental Protection (PA DEP)
P.O. Box 8467 ■ Harrisburg, PA 17105-8467
Phone 717/787-9637 ■ Fax 717/772-3249
email: dbogar@state.pa.us
PA DEP Office of Water Management homepage:
http://www.dep.state.pa.us/dep/deputate/watermgt/watermgt.htm

Program Description

The basics of Pennsylvania's current water quality monitoring program began in the late 1960s and has included elements of bioassessment in some form since its inception. The primary objectives of the water quality monitoring program are to define surface water quality status and trends and to evaluate compliance with discharge permit limits.

The State of Pennsylvania uses biological assessments in several program areas. The Statewide Surface Water Assessment Program (SSWAP), started in 1997, was developed to assess all 83,000 miles of streams in the state. The first comprehensive statewide assessment is scheduled for completion by 2007. After five seasons, approximately two thirds of Pennsylvania's surface waters have been assessed. Assessments are based on an evaluation of the instream habitat and macroinvertebrate community composition. All assessed streams are determined to be either impaired or unimpaired and a source and cause is listed for the former. These data are compiled into an MS Access database and GIS stream layer that is updated yearly and submitted to USEPA as part of the 305(b) report. Impaired reaches are placed on the 303(d) list and scheduled for follow-up TMDLs. Due to increasing complexities in the TMDL program, the assessment field methodology will be refined and enhanced in order to satisfy data needs for TMDL development.

Pennsylvania's Antidegradation Program also uses biological assessments based on a modified version of USEPA's Rapid Bioassessment Protocols (RBP) methodology to define aquatic life use designations of candidate streams. Biological samples are collected, subsampled, identified, and selected metrics are generated and analyzed. Candidate streams are compared to reference streams to determine if they qualify for designation as High Quality or Exceptional Value Waters. To alleviate the problem of site-specific reference site variability, staff biologists are currently working to develop a set of regionalized Reference Condition scores that can be compared to candidate streams.

Biological assessments are also an important component of the Surface Water Quality Monitoring Network (WQN). Biological samples are collected at 26 fixed stations three times per year (spring, summer, and fall) and once a year (summer) at 123 additional stations using the same RBP methodology referenced above. These data, in conjunction with bimonthly water chemistry samples, are used to monitor long-term trends in water quality on the major streams in the Commonwealth.

Fish are collected at approximately 35 WQN stations each year. Fillets from these fish are analyzed for contaminants such as heavy metals and pesticides. This tissue analysis is used to generate consumption advisories for fish living in any contaminated surface waters.

In order to more effectively meet its water quality objectives, Pennsylvania has fostered several cooperative bioassessment partnerships. Through contracts with the PA DEP, the Pennsylvania Fish and Boat Commission (PFBC), Susquehanna River Basin Commission (SRBC), and Interstate Commission on the Potomac River Basin (ICPRB) assist with SSWAP assessments. The Department plans to contract with the USGS to collect WQN samples. There are also cooperative efforts with citizen monitoring groups for water quality monitoring data collection and 305(b) reporting purposes.

While Pennsylvania's bioassessment efforts have increased in recent years (Statewide Surface Waters Assessment program), additional bioassessment challenges are being tackled. Department biologists are currently working to develop fish-based bioassessment methodologies for larger streams, refine lake assessments for 303(d) reporting purposes, and bioassessments of specialized habitats; such as limestone, glide/pool dominated, and non-wadeable waters.

Documentation and Further Information

Commonwealth of Pennsylvania 2000 Water Quality Assessment 305(b) Report:
http://www.dep.state.pa.us/dep/deputate/watermgt/Wqp/WQStandards/305_wq2000_narr.htm

Commonwealth of Pennsylvania 2001 305(b) UPDATE:
http://www.dep.state.pa.us/dep/deputate/watermgt/Wqp/WQStandards/305_wq2001_narr.htm

DRAFT 2002 Section 303(d) Report, List of Impaired Waterbodies, June 2002:
http://www.dep.state.pa.us/dep/deputate/watermgt/Wqp/WQStandards/303d-Report.htm

Pennsylvania's Surface Water Quality Monitoring Network (WQN), revised 2001:
http://www.dep.state.pa.us/dep/deputate/watermgt/wqp/wqstandards/Facts/BK0636-1.pdf

Water Quality Assessment and Standards Fact Sheets:
http://www.dep.state.pa.us/dep/deputate/watermgt/wqp/wqstandards/Facts/Pubs-c.htm

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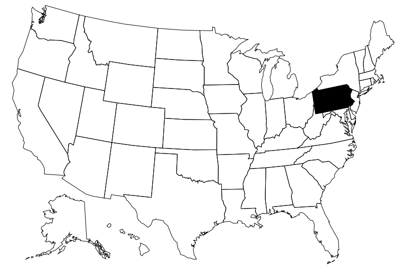


Contact Information

Daniel Bogar, Water Pollution Biologist II
Pennsylvania Department of Environmental Protection (PA DEP)
P.O. Box 8467 ■ Harrisburg, PA 17105-8467
Phone 717/787-9637 ■ Fax 717/772-3249
email: dbogar@state.pa.us

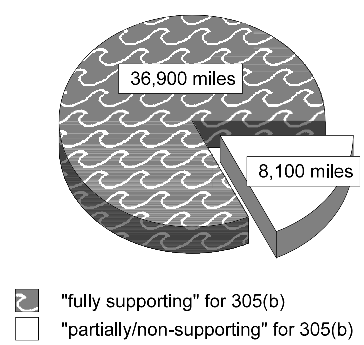
Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
	✓	monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
		promulgated into state water quality standards as biocriteria
	✓	support of antidegradation
	✓	evaluation of discharge permit conditions
	✓	TMDL assessment and monitoring
		other:
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(special projects only)*
	✓	fixed station (i.e., water quality monitoring stations) *(comprehensive use throughout jurisdiction)*
		probabilistic by stream order/catchment area
		probabilistic by ecoregion, or statewide
	✓	rotating basin *(special projects only)*
		other:

Stream Miles

Total miles *(determined using 1/24,000 scale streams GIS coverage)*	**83,000**
Total perennial miles	–
Total miles assessed for biology	**45,000**
fully supporting for 305(b)	36,900
partially/non-supporting for 305(b)	8,100
listed for 303(d)	8,100
number of sites sampled	7,435
number of miles assessed per site*	–

45,000 Miles Assessed for Biology



*Stations are placed at the mouths of major tributaries and on mainstems; towns are bracketed (upstream/downstream) depending on landuse observed while in field.

Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Fishery Based Uses	
ALU designations in state water quality standards	Four designations: Cold water fishes, Warm water fishes, Migratory fishes, Trout stocking	
Narrative Biocriteria in WQS	none - Antidegradation protocols used to support general aquatic life standard are under development, not statutory - found in Chapter 93 of Statutory Code.	
Numeric Biocriteria in WQS	none	
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
	✓	cause and effect determinations
	✓	permitted discharges
	✓	monitoring (e.g., improvements after mitigation)
	✓	watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	none	

Reference Site/Condition Development

Number of reference sites	**~100 total**	
Reference site determinations		site-specific
	✓	paired watersheds
	✓	regional (aggregate of sites)
		professional judgment
		other:
Reference site criteria	Based on stream classification in the antidegradation program, land use, and habitat: primarily forested, no water quality criteria violations, excellent habitat, and minimal siltation.	
Characterization of reference sites within a regional context		historical conditions
		least disturbed sites
		gradient response
		professional judgment
	✓	other: minimally disturbed
Stream stratification within regional reference conditions		ecoregions (or some aggregate)
		elevation
		stream type
		multivariate grouping
		jurisdictional (i.e., statewide)
	✓	other: drainage area, land use, use designations, gradient, size and other regionalization other than ecoregion
Additional information	✓	reference sites linked to ALU
		reference sites/condition referenced in water quality standards
		some reference sites represent acceptable human-induced conditions

Field and Lab Methods

Assemblages assessed	✓	benthos *(100-500 samples/year; multiple seasons, multiple sites - broad coverage for watershed level*)
	✓	fish* *(<100 samples/year; single season, multiple sites - not at watershed level)*
		periphyton
	✓	other: phytoplankton *(<100 samples/year; single season, multiple sites - not at watershed level)*

Benthos	
sampling gear	multiplate, D-frame and kick net (1 meter); >800 micron mesh
habitat selection	riffle/run (cobble)
subsample size	100 count
taxonomy	genus
Fish*	
sampling gear	backpack and boat electrofishers
habitat selection	multihabitat
sample processing	length measurement and anomalies
subsample	none
taxonomy	species
Habitat assessments	visual based; performed with bioassessments
Quality assurance program elements	standard operating procedures, quality assurance plan, periodic meetings and training for biologists, taxonomic proficiency checks, specimen archival

*Pennsylvania Fish & Boat Commission provides fish data to PA DEP. For more information, contact Rick Spear, PA Fish & Boat Commission, 450 Robinson Lane, Bellefonte, PA 16823, Phone: 814/359-5233, e-mail: rspear@state.pa.us.

Data Analysis and Interpretation

Data analysis tools and methods	✓	summary tables, illustrative graphs
	✓	parametric ANOVAs
	✓	multivariate analysis
	✓	biological metrics *(return single metrics - use endpoint for each single metric)*
	✓	disturbance gradients
		other:

Multimetric thresholds	
transforming metrics into unitless scores	Still in the process of evaluating the best approach (considering 75th and 95th percentile of reference population and cumulative distribution function)
defining impairment in a multimetric index	Still in the process of evaluating the best approach (considering 75th and 95th percentile of reference population and cumulative distribution function)
Multivariate thresholds	
defining impairment in a multivariate index	In the process of evaluating the best approach

Evaluation of performance characteristics	✓	repeat sampling *(two or three separate samples in the same riffle)*
		precision
		sensitivity
		bias
		accuracy

Biological data	
Storage	MS Access
Retrieval and analysis	SAS

RHODE ISLAND

Contact Information

Robert Richardson, Senior Environmental Scientist
Rhode Island Department of Environmental Management (RIDEM)
235 Promenade Street ■ Providence, RI 02908-5767
Phone 401/222-4700 x7240 ■ Fax 401/222-3564
email: rrichard@doa.state.ri.us
RIDEM Office of Water Resources homepage:
http://www.state.ri.us/dem/programs/benviron/water/index.htm

Program Description

The importance of biological assessments in the evaluation of water quality has long been recognized in Rhode Island. Biological assessments are used to supplement physical and chemical water quality monitoring data. More specifically, the biological data can be used to identify long-term trends in water quality which reflect water pollution abatement efforts and/or needs. The Rhode Island Department of Environmental Management (RIDEM), Office of Water Resources (OWR) has two types of biological monitoring programs. Multiple plate artificial substrates have been used to evaluate the biological community in deep rivers since 1974. In addition, EPA's Rapid Bioassessment Protocol (RBP) (USEPA 1989) has been used since 1991 for the assessment of the biological integrity of various shallow river sites in the state.

Artificial Substrate Monitoring
The Fullner multiple-plate artificial substrate with 14 plates has been used by the Office of Water Resources for over 20 years to assess instream biological communities. Stations selected for this biological monitoring include those used for USGS trend chemical sampling to more closely relate chemical and biological data. This method has the advantage of providing a uniform sampling habitat for each station, thus reducing the problem caused by varying types of river bottom and depth. Macroinvertebrates collected on the artificial substrates are classified according to their tolerance of pollutants.

Rapid Bioassessment Protocol Monitoring
RBP monitoring involves an integrated assessment, comparing habitat (physical structure, flow regime) and biological measures with defined reference site conditions. Since 1992, a network of 45 stream riffle-area sites have been surveyed by Roger Williams University in cooperation with and contracted by RIDEM. Each site is visited during the spring-summer season and macroinvertebrates are sampled (minimum 100 organisms per site visit where feasible). Data are analyzed using RBP I and II protocols, which include varying degrees of field and laboratory organism identification.

The streams sampled within the state range from first order to fifth order. Eight of the streams are considered to be first order, eighteen second order, twelve third order, four fourth order and three are of the fifth order. Lower order streams are quite dependent upon the immediate characteristics of the watershed. In other words, runoff is a direct-affect component versus one of many components within a higher order stream. It is important to note that the 1993, 1995 and 1997 sampling events took place during drought conditions, which may have resulted in fewer riffles, lower dilution and lack of runoff. This probably affected the types of organisms collected and resulted in an altered picture of the stations based from that seen in other years. This information was taken into account during the evaluation of the biological assessments.

Initial bioassessment work involved establishing and field testing the RBPs in Rhode Island streams and rivers. In addition, refinement of the protocol over the past 4 years has established the presence of two sub-ecoregions within the state: coastal areas and inland areas. Incorporation of the presence of these two sub-ecoregions into selection of reference sites and application of the protocols will continue. The habitat/physical parameters and biological metrics of each station were compared to those of the selected reference station and given an overall bioassessment score.

Documentation and Further Information

The State of the State's Waters Rhode Island Section 305(b) Report, September 2000:
http://www.state.ri.us/dem/pubs/305b/index.htm

State of Rhode Island 2000 303(d) List of Impaired Waters, November 2000: http://www.state.ri.us/dem/pubs/303d/303d00.pdf

Water Quality Regulations (including WQS), amended June 2000:
http://www.state.ri.us/dem/pubs/regs/REGS/WATER/h20qlty.pdf

RHODE ISLAND

Contact Information

Robert Richardson, Senior Environmental Scientist
Rhode Island Department of Environmental Management (RIDEM)
235 Promenade Street ■ Providence, RI 02908-5767
Phone 401/222-4700 x7240 ■ Fax 401/222-3564
email: rrichard@doa.state.ri.us

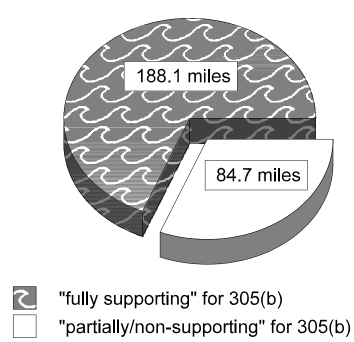
Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
	✓	monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
	✓	promulgated into state water quality standards as biocriteria
		support of antidegradation
	✓	evaluation of discharge permit conditions
	✓	TMDL assessment and monitoring
		other:
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(specific river basins or watersheds and comprehensive use throughout jurisdiction)*
	✓	fixed station (i.e., water quality monitoring stations) *(specific river basins or watersheds and comprehensive use throughout jurisdiction)*
		probabilistic by stream order/catchment area
	✓	probabilistic by ecoregion, or statewide *(comprehensive use throughout jurisdiction)*
		rotating basin
		other:

Stream Miles

Total miles *(determined using state based GIS coverage)*	**1,498**
Total perennial miles	979
Total miles assessed for biology*	**272.8**
fully supporting for 305(b)*	188.1
partially/non-supporting for 305(b)*	84.7
listed for 303(d)*	78.5
number of sites sampled *(on an annual basis)***	~62
number of miles assessed per site	site specific

272.8 Miles Assessed for Biology



*These numbers represent the miles assessed for ALUS using biology or a combination of biological and chemical data. The miles listed for 303(d) were taken from the RI draft 2002 303(d) list for biodiversity impairments.

**Roughly 62 sites are monitored on an annual basis, though this number does vary (10 = artificial substrate; 45 - 50 = RBP). Fifty-five additional sites were sampled in 2000 as part of a random sampling design for the EPA.

Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Single Aquatic Life Use and Class System (A,B,C)	
ALU designations in state water quality standards	One designation: fish and wildlife habitat	
Narrative Biocriteria in WQS	No formal/informal numeric procedures are used to support narrative biocriteria; however, there is a qualitative and/or narrative scale of condition.	
Numeric Biocriteria in WQS	none	
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
	✓	cause and effect determinations
	✓	permitted discharges
	✓	monitoring (e.g., improvements after mitigation)
	✓	watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	Super-fund sites and Rhode Island Pollutant Elimination Discharge System (RIPDES) permit toxic elimination	

Reference Site/Condition Development

Number of reference sites	**2 total**	
Reference site determinations	✓	site-specific
		paired watersheds
		regional (aggregate of sites)
	✓	professional judgment
		other:
Reference site criteria	Minimally impaired/disturbed (best reference site in New England) – natural conditions, bank erosion, land use, etc. High Quality unimpaired condition for RBP or site-specific for special site studies.	
Characterization of reference sites within a regional context	✓	historical conditions
		least disturbed sites
		gradient response
		professional judgment
	✓	other: minimally disturbed*
Stream stratification within regional reference conditions	✓	ecoregions (or some aggregate)
		elevation
		stream type
		multivariate grouping
		jurisdictional (i.e., statewide)
		other:
Additional information	✓	reference sites linked to ALU
		reference sites/condition referenced in water quality standards
		some reference sites represent acceptable human-induced conditions

*Rhode Island's reference sites are considered minimally disturbed. The Wood River reference site (most widely used) will likely remain minimally disturbed because its watershed is largely contained within State Park boundaries. RI allows for about a 20% variation from that target for compliance. However, special watershed projects may be asking an upstream or downstream question and, therefore, may be required to find a least disturbed site within the unique segment for comparison.

Field and Lab Methods

Assemblages assessed	✓	benthos *(<100 samples/year; single season, multiple sites - broad coverage)*
	✓	fish *(sampled once in conjunction with USEPA: < 100 samples; single observation)*
		periphyton
	✓	other: macrophytes *(<100 samples/year; single season, multiple sites - broad coverage)*

Benthos	
sampling gear	collect by hand, multiplate, D-frame; 200-400 micron mesh
habitat selection	riffle/run (cobble), artificial substrate
subsample size	100 count
taxonomy	combination
Habitat assessments	visual based; performed with bioassessments
Quality assurance program elements	standard operating procedures, periodic meetings and training for biologists, taxonomic proficiency checks, and specimen archival

Data Analysis and Interpretation

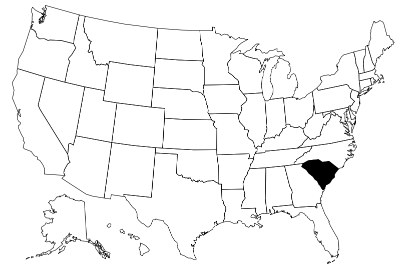
Data analysis tools and methods	✓	summary tables, illustrative graphs
		parametric ANOVAs
		multivariate analysis
	✓	biological metrics *(aggregate metrics into an index)*
		disturbance gradients
		other:

Multimetric thresholds	
transforming metrics into unitless scores	25^{th} percentile of reference population
defining impairment in a multimetric index	75^{th} percentile of reference population - standard random sampling design, EPT index, RBPs

Evaluation of performance characteristics	✓	repeat sampling
		precision
		sensitivity
	✓	bias
		accuracy

Biological data	
Storage	databases, spreadsheets
Retrieval and analysis	EDAS

SOUTH CAROLINA



Contact Information

James Glover, PhD, Aquatic Biologist
South Carolina Department of Health and Environmental Control (SC DHEC)
2600 Bull Street ■ Columbia, SC 29201
Phone 803/898-4081 ■ Fax 803/898-4200
email: GloverJB@columb32.DHEC.state.sc.us
SC DHEC Bureau of Water homepage: http://www.scdhec.net/water/

Program Description

Biologists at the South Carolina Department of Health and Environmental Control use aquatic macroinvertebrates as bioindicators to make assessments of water quality. The program began in the early 1970s with the first technical report printed in 1972. Currently, flowing streams and rivers are the primary waterbodies that are assessed. South Carolina's monitoring efforts can be divided into two categories: ambient monitoring and special studies. Both fixed sites and randomly selected sites are chosen each year for the ambient monitoring work. Fixed sites are sampled once every five years on a rotating basin schedule. Special studies usually involve a point source discharge or a nonpoint source perturbation such as a logging operation. Upstream and downstream sites are selected for sampling when conducting special studies. Agency staff may carry out the special studies or they may be required by the industry as part of a permit or consent order. In the latter case, state certified consultants conduct the studies with the resulting reports reviewed by agency scientists.

South Carolina's program is modeled after that of North Carolina's, which was developed in the 1970s and 1980s. A timed qualitative multihabitat approach is taken for sampling macroinvertebrates. Organisms are picked in the field and returned to the laboratory for identification to the lowest practical taxonomic level – usually genus or species. Two metrics are calculated to produce an assessment: the EPT Index, and the NC Biotic Index. These two metrics are standardized on a scale of 1 to 5 and averaged to produce a final score. The Bioclassification of the stream is based on this score. The numeric criteria developed in SC are dependant on the ecoregion within which the stream is located. There are separate criteria for the mountains, piedmont, and coastal plain regions of the state. For special studies, impact is determined by the change in the bioclassification score from the upstream control site to the downstream test site. A rigorous quality control/quality assurance program has been developed and implemented for sampling, identification of organisms, and data entry.

Documentation and Further Information

The 2002 Section 305(b) Water Quality Assessment Report for South Carolina, March 2000:
http://www.scdhec.net/eqc/water/pubs/305b.pdf

State of South Carolina 303(d) List for 2000, EPA approved in May 2000:
http://www.scdhec.net/eqc/water/pubs/303d2000.pdf (for the DRAFT 2002 303(d) List and 1998 303(d) List, go to http://www.scdhec.net/eqc/water/html/tmdl.html#303d)

The Environmental Investigations Standard Operating Procedures and Quality Assurance Manual. 2001. SC DHEC.

State of South Carolina Monitoring Strategy for Calendar Year 2002, January 2002:
http://www.scdhec.net/eqc/water/pubs/strategy.pdf

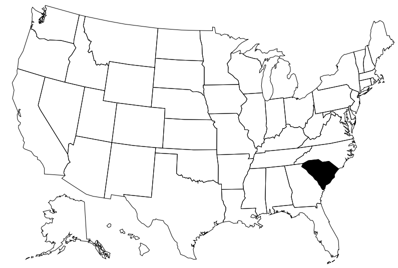
Antidegradation Implementation for Water Quality in South Carolina, July 1998:
http://www.scdhec.net/eqc/water/pubs/antideg.pdf

Watershed Water Quality Management Strategy Program Description: http://www.scdhec.net/water/shed/prog.html

For a list of and links to additional SC DHEC *Bureau of Water* water quality publications, go to
http://www.scdhec.net/eqc/admin/html/eqcpubs.html#wqreports

DRAFT July 1998. *Standard Operating Procedures and Quality Control Procedures for Macroinvertebrate Sampling*. Technical Report No. 004-98. Prepared by South Carolina Bureau of Water, Division of Water Monitoring, Assessment and Protection, Aquatic Biology Section.

SOUTH CAROLINA



Contact Information

James Glover, PhD, Aquatic Biologist
South Carolina Department of Health and Environmental Control (SC DHEC)
2600 Bull Street ■ Columbia, SC 29201
Phone 803/898-4081 ■ Fax 803/898-4200
email: GloverJB@columb32.DHEC.state.sc.us

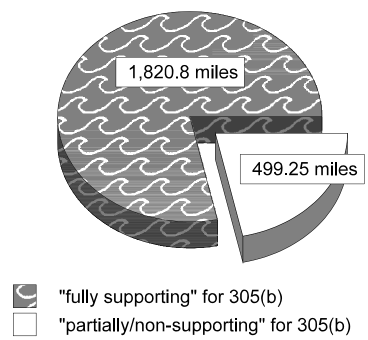
Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
	✓	monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
	✓	promulgated into state water quality standards as biocriteria
	✓	support of antidegradation
	✓	evaluation of discharge permit conditions
	✓	TMDL assessment and monitoring
		other:
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(comprehensive use throughout jurisdiction)*
	✓	fixed station (i.e., water quality monitoring stations) *(comprehensive use throughout jurisdiction)*
	✓	probabilistic by stream order/catchment area *(comprehensive use throughout jurisdiction)*
	✓	probabilistic by ecoregion, or statewide *(comprehensive use throughout jurisdiction)*
	✓	rotating basin *(specific river basins or watersheds)*
		other:

Stream Miles

Total miles *(determined using RF3)*	**35,461**
Total perennial miles	25,729
Total miles assessed for biology*	**2,320**
fully supporting for 305(b)	1,820.8
partially/non-supporting for 305(b)	499.25
listed for 303(d)	499.25
number of sites sampled *(on an annual basis)*	80
number of miles assessed per site	–

2,320 Miles Assessed for Biology



*These miles, listed in the 2000 205(b) report, were assessed based on a combination of physical/chemical **and** biological/habitat data. The following subset of the 2,320 total combined miles contains stream miles assessed based **solely** on biological/habitat: 678.6 total miles assessed, 563.98 miles "fully supporting" for 305(b), and 114.6 miles "partially/non-supporting" for 305(b) and listed for 303(d).

Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Class System (A,B,C) and Warm Water vs. Cold Water
ALU designations in state water quality standards	Three designations: Freshwater, Trout - 3 types, Saltwater
Narrative Biocriteria in WQS	Procedures used to support narrative biocriteria are not included in SC water quality standards, but are available in the monitoring program SOP.
Numeric Biocriteria in WQS	none (South Carolina has limited numeric biociteria/indices used to evaluate ALU, which are not included in state water quality standards – see monitoring program SOP.)

Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
	✓	cause and effect determinations
	✓	permitted discharges
	✓	monitoring (e.g., improvements after mitigation)
	✓	watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU		Biocriteria can affect permitting decisions if a watershed is listed on the 303(d) list for biological impacts.

Reference Site/Condition Development

Number of reference sites	**30 total**	
Reference site determinations		site-specific
		paired watersheds
	✓	regional (aggregate of sites)
		professional judgment
		other:
Reference site criteria		The best sites are selected from a habitat and organismal point of view. Faunal characteristics and land use data from GIS are also considered (see newly-amended R.61-68.F.I.d. for more information).
Characterization of reference sites within a regional context		historical conditions
	✓	least disturbed sites
		gradient response
		professional judgment
		other:
Stream stratification within regional reference conditions	✓	ecoregions (or some aggregate)
		elevation
	✓	stream type
		multivariate grouping
		jurisdictional (i.e., statewide)
		other:
Additional information	✓	reference sites linked to ALU
	✓	reference sites/condition referenced in water quality standards *(found in R61-68.F.I.d.)*
	✓	some reference sites represent acceptable human-induced conditions

Field and Lab Methods

Assemblages assessed	✓	benthos *(100-500 samples/year; multiple seasons, multiple sites – broad coverage for watershed level)*
		fish
		periphyton
		other:

Benthos	
sampling gear	collect by hand, brass sieve, D-frame, kick net (1 meter); 500-600 micron mesh
habitat selection	multihabitat
subsample size	entire sample
taxonomy	combination and species when possible
Habitat assessments	visual based; performed with bioassessments
Quality assurance program elements	standard operating procedures, quality assurance plan, periodic meetings and training for biologists, taxonomic and sampling proficiency checks, specimen archival, data entry checks, certification program for bioassessment

Data Analysis and Interpretation

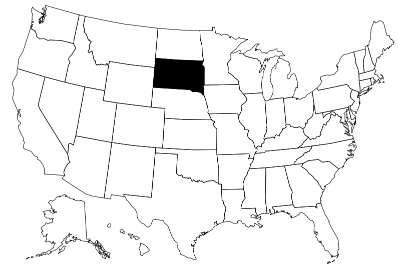
Data analysis tools and methods	✓	summary tables, illustrative graphs
		parametric ANOVAs
		multivariate analysis
	✓	biological metrics *(aggregate metrics into an index)*
		disturbance gradients
		other:

Multimetric thresholds	
transforming metrics into unitless scores	cumulative distribution function
defining impairment in a multimetric index	cumulative distribution function - follow guidelines outlined in following document: Lenat. 1993. *A biotic index for the southeastern United States, derivation and list of tolerance values, with criteria for assigning water quality ratings*. Journal of the North American Benthological Society. 12:279-290

Evaluation of performance characteristics		repeat sampling
	✓	precision *(replicate sampling of same stream, 10% each year)*
		sensitivity
		bias
	✓	accuracy *(compare faunal results with land use data and discharge presence or absence)*

Biological data	
Storage	MS FoxPro for Windows and Excel
Retrieval and analysis	FoxPro

SOUTH DAKOTA



Contact Information

Gene Stueven, Environmental Senior Scientist
South Dakota Department of Environment and Natural Resources (SD DENR)
Joe Foss Buildings 523 East Capitol ■ Pierre, SD 57501
Phone 605/773-4254 ■ Fax 605/773-4068
email: gene.stueven@state.sd.us
SD DENR Surface Water Quality website:
http://www.state.sd.us/denr/DES/Surfacewater/surfwprg.htm

Program Description

Currently, the South Dakota Department of Environment and Natural Resources (SD DENR) Water Resources Assistance Program (WRAP) collects biological data in addition to chemical and physical parameters for TMDL assessments. These bioassessments are useful in determining the impact of contaminants as well as detecting chronic water quality impairments that may not be discovered by ambient chemical and physical grab samples. Of the 9,937 total stream miles, approximately 4 miles have been biologically assessed (60 sites assessed; 150 meters per site). SD DENR has not yet established biological criteria for use in water quality standards.

The Water Resource Assistance Program evaluates benthic macroinvertebrate community structure in streams using both the EMAP protocol and USEPA's Rapid Bioassessment Protocols (RBPs) in conjunction with assessments of stream habitats. All biological samples are identified to the lowest possible level of taxonomic resolution. Biological data are entered into the STORET database and are summarized using multimetric indices and descriptive statistics. SD DENR intends to use the biological data to identify potential reference sites for determining the condition of water quality and the integrity of the biological community. WRAP is beginning to sample periphyton communities to determine if they are a better biological indicator of water quality.

Documentation and Further Information

Stueven, E., A. Wittmuss, and R.L. Smith. 2000. *Standard Operating Procedures for Field Samplers. Revision 4.0, January 2000*. South Dakota Department of Environment and Natural Resources, Water Resource Assistance Program. Pierre, SD.

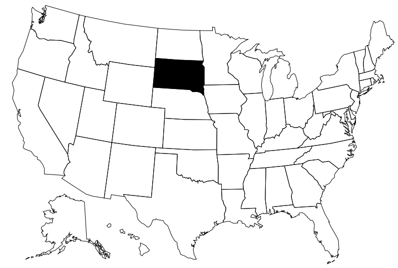
Ecoregion Targeting of Impaired Lakes in South Dakota (May 2000)

The 2000 South Dakota Report to Congress, 305(b) Water Quality Assessment, http://www.state.sd.us/denr/Documents/SD_2000_305b.pdf

The 1998 South Dakota 303(d) Waterbody List and Supporting Documentation, http://www.state.sd.us/denr/303(d)/98sd303d.pdf

South Dakota Surface Water Quality Standards, http://legis.state.sd.us/rules/rules/7451.htm

SOUTH DAKOTA



Contact Information

Gene Stueven, Environmental Senior Scientist
South Dakota Department of Environment and Natural Resources (SD DENR)
Joe Foss Buildings 523 East Capitol ■ Pierre, SD 57501
Phone 605/773-4254 ■ Fax 605/773-4068
email: gene.stueven@state.sd.us

Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
	✓	monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
	✓	promulgated into state water quality standards as biocriteria
		support of antidegradation
		evaluation of discharge permit conditions
	✓	TMDL assessment and monitoring
		other:
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(special projects, specific river basins or watersheds)*
		fixed station (i.e., water quality monitoring stations)
		probabilistic by stream order/catchment area
		probabilistic by ecoregion, or statewide
		rotating basin
		other:

Stream Miles

Total miles *(determined using RF3, National Hydrography Database, and state based determination)*	**9,937**
Total perennial miles	1,932
Total miles assessed for biology*	**3.73**
fully supporting for 305(b)	n/a
partially/non-supporting for 305(b)	n/a
listed for 303(d)	n/a
number of sites sampled *(on an annual basis)*	~60
number of miles assessed per site	~.093 *(150 meters)*

*South Dakota reports only chemical data in 305(b) reports and 303(d) listings. Currently, biological data is only collected during TMDL assessments. South Dakota's DENR plans to use the biological data to locate reference sites and conditions based on ecoregions as well as to establish biocriteria.

Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Warm Water vs. Cold Water	
ALU designations in state water quality standards	Five designations: Cold Water Permanent, Cold Water Marginal, Warm Water Permanent, Warm Water Semi-Permanent, Warm Water Marginal	
Narrative Biocriteria in WQS	No formal/informal numeric procedures exist to support narrative biocriteria	
Numeric Biocriteria in WQS	none	
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
		cause and effect determinations
		permitted discharges
	✓	monitoring (e.g., improvements after mitigation)
	✓	watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	none	

Reference Site/Condition Development*

Number of reference sites	**~31 total**	
Reference site determinations *Under development*		site-specific
		paired watersheds
		regional (aggregate of sites)
	✓	professional judgment
		other:
Reference site criteria	Under development. Criteria used for defining reference sites include: EMAP protocol, habitat, chemical, and aquatic life.	
Characterization of reference sites within a regional context *Under development*		historical conditions
	✓	least disturbed sites
		gradient response
		professional judgment
		other:
Stream stratification within regional reference conditions *Under development*	✓	ecoregions (or some aggregate)
		elevation
		stream type
		multivariate grouping
		jurisdictional (i.e., statewide)
		other:
Additional information *Under development*		reference sites linked to ALU
		reference sites/condition referenced in water quality standards
	✓	some reference sites represent acceptable human-induced conditions

*The responses above characterize how reference sites will most likely be determined in the future. Twenty-seven sites have been assessed in South Dakota as reference for the EMAP data set. South Dakota's DENR samples ~4 sites as reference and will be working on establishing formal reference sites and criteria for streams and rivers. Lake reference sites and criteria have already been developed.

Field and Lab Methods

Assemblages assessed	✓	benthos *(100 - 500 samples/year; single season, multiple sites - not at watershed level)*
		fish
	✓	periphyton *(<100 samples/year; single season, multiple sites - not at watershed level)*
		other:

Benthos	
sampling gear	D-frame, multiplate, rock baskets; 500 - 600 micron mesh
habitat selection	multihabitat
subsample size	300 count
taxonomy	combination
Periphyton	
sampling gear	**natural substrate**: brushing/scraping device (razor, toothbrush, etc.) **artificial substrate**: microslides or other suitable substratum
habitat selection	multihabitat
sample processing	chlorophyll *a* / phaeophytin, taxonomic identification
taxonomy	species level
Habitat assessments	visual based, quantitative measurements, hydrogeomorphology; performed with bioassessments
Quality assurance program elements	standard operating procedures, quality assurance plan, periodic meetings and training for biologists, taxonomic proficiency checks, specimen archival

Data Analysis and Interpretation

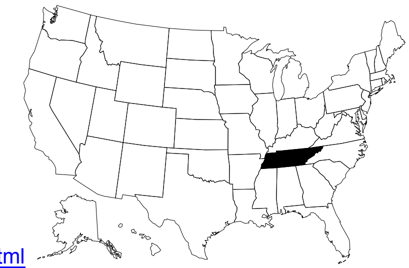
Data analysis tools and methods	✓	summary tables, illustrative graphs
		parametric ANOVAs
		multivariate analysis
	✓	biological metrics *(multimetric index under development)*
		disturbance gradients
		other:

Multimetric thresholds	
transforming metrics into unitless scores	25th percentile of reference population, natural breaks
defining impairment in a multimetric index	25th percentile of reference population

Evaluation of performance characteristics *Not currently evaluated*		repeat sampling
		precision
		sensitivity
		bias
		accuracy

Biological data	
Storage	STORET
Retrieval and analysis	Statistica, EDAS

TENNESSEE



Contact Information

Gregory M. Denton, Manager - Planning and Standards
Tennessee Department of Environment & Conservation (TDEC)
7th Floor L&C Annex, 401 Church Street ■ Nashville, TN 37243-1534
Phone 615/532-0699 ■ Fax 615/532-0046
email: gregory.denton@state.tn.us
TDEC Division of Water Pollution Control: http://www.state.tn.us/environment/wpc/index.html

Program Description

The Tennessee Department of Environment and Conservation's (TDEC) Division of Water Pollution Control (WPC), has an extensive bioassessment program. Benthic macroinvertebrate surveys are one of the primary tools used in assessing surface waters in the state. Biological data are instrumental in determining use-support and generating both the 305(b) and 303(d) reports. In-stream macroinvertebrate monitoring is included in many NPDES permits. Bioassessments are also used in the anti-degradation evaluation process. Biological data are used to measure improvements in water quality resulting from clean-up and habitat restoration efforts. Over 2,100 macroinvertebrate surveys have been conducted by TDEC since 1996.

TDEC has eight field offices each with at least two benthic biologist positions. In addition, there is a central laboratory facility in the Department of Health with seven aquatic biologists under contract to TDEC. These nine offices conduct the majority of macroinvertebrate stream surveys. Data from other agencies including the Tennessee Valley Authority (TVA), US Army Corps of Engineers (USACE), and USGS are also incorporated into the program.

In 1995, TDEC initiated an ecoregion delineation project resulting in the identification of 25 ecological subregions. Ninety-eight reference streams were targeted for monitoring. The macroinvertebrate community in these streams was sampled seasonally for three years and on a five-year cycle by watershed starting in 1999. These data were used to develop regional numeric biocriteria that have been proposed for inclusion in the 2002 triennial review of water quality standards. The proposed numeric criteria are already being used to help interpret narrative criteria. In addition, reference stream data were used to develop guidelines for biological reconnaissance as a screening tool during watershed assessments.

Future goals of the bioassessment program include:

- Continue to monitor ecoregional reference streams and locate additional streams to further refine biocriteria and better identify reference condition.
- Conduct additional bioassessments as means to increase TDEC's percentage of assessed streams for national reporting purposes.
- Develop a macroinvertebrate tolerance index specific to Tennessee.
- Develop biocriteria for large rivers, wetlands and reservoirs.
- Continue to use benthic data as a measure of improvement in water quality.

Documentation and Further Information

Arnwine, D.H. and G. M. Denton. 2001. *Development of Regionally-Based Interpretations of Tennessee's Existing Biological Integrity Criteria*. Tennessee Department of Environment and Conservation, Division of Water Pollution Control. Nashville. TN

Arnwine D.H. and G. M. Denton. 2001. *Habitat of Least Impacted Streams in Tennessee*, Tennessee Department of Environment and Conservation, Division of Water Pollution Control, Nashville, TN

Arnwine, D.H., J.I. Broach, L.K. Cartwright and G.M. Denton. 2000. *Tennessee Ecoregion Project*. Tennessee Department of Environment and Conservation, Division of Water Pollution Control. Nashville, TN.

Denton, G.M., A.D. Vann, and S.H. Wang. 2000.*The status of Water Quality in Tennessee: Year 2000 305(b) Report*. Tennessee Department of Environment and Conservation, Division of Water Pollution Control. Nashville, TN.

Griffith, G.E., J.M. Omernik and S. Azevedo. 1997. *Ecoregions of Tennessee*. EPA/600/R-97/022. NHREEL, Western Ecological Division, U.S. Environmental Protection Agency, Corvalis, Oregon.

Quality System Standard Operating Procedure for Macroinvertebrate Stream Surveys. 2002. Tennessee Department of Environment and Conservation, Division of Water Pollution Control. Nashville. TN.

DRAFT Year 2002 303(d) List, July 2002: http://www.state.tn.us/environment/wpc/2002303ddraft.pdf

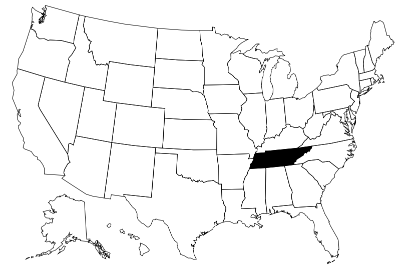
TDEC General Water Quality Criteria, rev. October 1999: http://www.state.tn.us/sos/rules/1200/1200-04/1200-04-03.pdf

TDEC Use Classifications for Surface Waters, rev. October 1999: http://www.state.tn.us/sos/rules/1200/1200-04/1200-04-04.pdf

2001 Triennial Review of Water Quality Standards, Staff Proposal: http://www.state.tn.us/environment/wpc/tr_wqs.pdf

Other TDEC publications, including 305(b) reports, can be found online at: http://www.state.tn.us/environment/wpc/publicat.htm

TENNESSEE



Contact Information

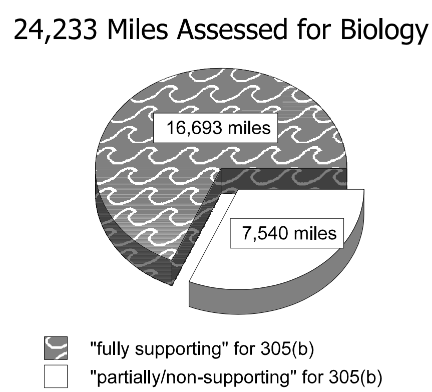
Gregory M. Denton, Manager - Planning and Standards
Tennessee Department of Environment & Conservation (TDEC)
7th Floor L&C Annex, 401 Church Street ■ Nashville, TN 37243-1534
Phone 615/532-0699 ■ Fax 615/532-0046
email: gregory.denton@state.tn.us

Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
	✓	monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
	✓	promulgated into state water quality standards as biocriteria
	✓	support of antidegradation
	✓	evaluation of discharge permit conditions
	✓	TMDL assessment and monitoring
		other:
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(comprehensive use throughout jurisdiction)*
	✓	fixed station (i.e., water quality monitoring stations) *(comprehensive use throughout jurisdiction)*
		probabilistic by stream order/catchment area
	✓	probabilistic by ecoregion, or statewide *(special projects only)*
	✓	rotating basin *(comprehensive use throughout jurisdiction)*
		other:

Stream Miles

Total miles *(Determined using RF3)*	**60,187**
Total perennial miles	–
Total miles assessed for biology	**24,233**
fully supporting for 305(b)	16,693
partially/non-supporting for 305(b)*	7,540
listed for 303(d)*	14,333
number of sites sampled	2,202
number of miles assessed per site	–



*The stream miles “partially/non-supporting” for 305(b) are significantly less than the stream miles listed for 303(d) because the last 303(d) list was revised in 1998 while the 305(b) reflects assessments through 2000. The 2002 draft 303(d) and 305(b) reports are in agreement.

Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Single Aquatic Life Use
ALU designations in state water quality standards	One designation: Fish and Aquatic Life
Narrative Biocriteria in WQS	Formal/informal numeric procedures used to support narrative biocriteria are found in the *Development of Regionally-Based Numeric Interpretations of Tennessee's Narrative Biological Integrity Criterion* (see documentation).
Numeric Biocriteria in WQS	under development (Tennessee water quality standards will be changed in 2002 to reflect proposed numeric criteria for 15 bioregions. Numeric biocriteria, proposed for inclusion in the new WQS are as follows, "Multimetric index using 7 metrics - TR, EPT, %EPT, %OC, NCBI, %DOM and % Clingers*. Scoring criteria is based on 25% of reference condition. Reference condition is based on ecoregion reference data at the 90th percentile. Ecoregions have been grouped into 15 bioregions. Expected index score is calibrated to each bioregion and by season where appropriate.")

Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
	✓	cause and effect determinations
	✓	permitted discharges
	✓	monitoring (e.g., improvements after mitigation)
	✓	watershed based management

Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	Nonpoint source section, field offices - office by office use, not systematic/statewide use

*TR = total richness; EPT = Ephemeroptera (mayflies), Plecoptera (stoneflies), Trichoptera (caddisflies); OC = Orthocladiinae of Chironomidae; NCBI = North Carolina Biotic Index; DOM = dominant taxa.

Reference Site/Condition Development

Number of reference sites	**98 total**	
Reference site determinations		site-specific
		paired watersheds
	✓	regional (aggregate of sites)
		professional judgment
		other:
Reference site criteria	Reference database of chemical, habitat and biometrics based on monitoring of regional reference sites since 1996. Reference sites must fall within 90th percentile for chemical, biological and habitat parameters compared to existing reference database. Disturbed sites are those under 75% comparable to reference condition for biological and habitat, above the 90th percentile (reference) for nutrients (and show impaired biology), or exceed numeric criteria for other specified parameters.	
Characterization of reference sites within a regional context		historical conditions
	✓	least disturbed sites
		gradient response
		professional judgment
		other:
Stream stratification within regional reference conditions	✓	ecoregions (or some aggregate)
		elevation
		stream type
		multivariate grouping
		jurisdictional (i.e., statewide)
		other:
Additional information	✓	reference sites linked to ALU
	UD	reference sites/condition referenced in water quality standards *(WQS under revision)*
	✓	some reference sites represent acceptable human-induced conditions

Field and Lab Methods

Assemblages assessed	✓	benthos *(100-500 samples/year; single season, multiple sites - watershed level)*
		fish
		periphyton
		other:
Benthos		
sampling gear	dipnet and kick net (1 meter); 500 - 600 micron mesh	
habitat selection	riffle/run used for biocriteria in high gradient streams; rooted bank used for biocriteria in low gradient streams (Note that four jab multihabitat bioreconnaissances are used for general water quality assessments, not comparable to biocriteria)	
subsample size	200 count	
taxonomy	genus	
Habitat assessments	visual based; performed with bioassessments	
Quality assurance program elements	standard operating procedures, quality assurance plan, periodic meetings and training for biologists, sorting and taxonomic proficiency checks, specimen archival	

Data Analysis and Interpretation

Data analysis tools and methods	✓	summary tables, illustrative graphs
	✓	parametric ANOVAs
	✓	multivariate analysis
	✓	biological metrics *(aggregate metrics into an index)*
		disturbance gradients
		other:
Multimetric thresholds		
transforming metrics into unitless scores	90^{th} or 10^{th} percentile of reference population depending on direction of metric	
defining impairment in a multimetric index	25% of 90^{th} (or 10^{th}) percentile of reference population	
Multivariate thresholds		
defining impairment in a multivariate index	Used for development of initial criteria, not for current assessments	
Evaluation of performance characteristics	✓	repeat sampling *(replicate samples at 10% of reference sites by different teams)*
	✓	precision *(two samples collected at 10% of sites by two teams)*
	✓	sensitivity *(standard level of identification, compare metric scores to known impacts)*
	✓	bias *(compared different sample/habitat types)*
	✓	accuracy *(10% of samples QC for taxonomy and sorting efficiency)*
Biological data		
Storage	MS Access; semi-quantitative samples (taxa lists and metric scores) are stored in EDAS database and bioreconnaissance results are stored in Water Quality Database (taxa lists are in paper files). The eventual goal is for data to be sent to STORET. Assessment results are stored in an Assessment Database.	
Retrieval and analysis	EDAS, Statview, and multivariate statistical package	

TEXAS

Contact Information

Charles Bayer, Aquatic Scientist
Texas Commission on Environmental Quality (TCEQ)*
P.O. Box 13087 ■ Austin, Texas 78711-3087
Phone 512/239-4583 ■ Fax 512/239-4420
email: cbayer@tnrcc.state.tx.us
website: http://www.tceq.state.tx.us/

Roy Kleinsasser, River Studies Program Leader
Texas Parks and Wildlife Department (TPWD)
505 Staples Road ■ San Marcos, TX 78666
Phone 512/353-3480
email: leroy.kleinsasser@tpwd.state.tx.us
website: http://www.tpwd.state.tx.us

Program Description

Since the late 1980s, biological assessments have been employed for use attainability analyses (UAAs) and the development of an index of biological integrity (IBI) for rivers and streams. A tidal streams IBI is in the preliminary stages of development. Recently, a new emphasis has been placed on bioassessments relative to 303(d) listed waterbodies. For the most part, the new data have not been fully evaluated and work is continuing to expand in this area. Also, for the first time, the draft 2002 Water Quality Inventory includes bioassessments to determine the support of aquatic life uses.

The Texas Parks and Wildlife Department (TPWD) has been a major provider of fish community data for many of the UAAs and the development of the IBI. Other providers include various river authorities in the state.

***NOTE: On September 1, 2002, the Texas Natural Resources Conservation Commission (TNRCC) formally changed its name and began doing business as the Texas Commission on Environmental Quality (TCEQ).**

Documentation and Further Information

Draft 2002 Texas Water Quality Monitoring and Assessment Report (Integrated 305(b) report and 303(d) list):
http://www.tnrcc.state.tx.us/water/quality/02_twqmar/index.html

Texas Water Quality Inventory (SFR-050/00), includes *Volume I: Surface Water, Groundwater and Finished Drinking Water Assessments and Water Quality Management Programs:*
http://www.tnrcc.state.tx.us/admin/topdoc/sfr/050_00/050_00.html#1

Revisions to the Texas Surface Water Quality Standards and Implementation Procedures:
http://www.tnrcc.state.tx.us/permitting/waterperm/wqstand/revisions.html

Surface Water Quality Monitoring Procedures Manual (Chapter 7: Biological Sampling Procedures and Chapter 8: Stream Habitat Assessment Procedures), August 1999, GI-252:
http://www.tnrcc.state.tx.us/admin/topdoc/gi/252.html

Monitoring and Receiving Water Assessment Procedures Manuals:
http://www.tnrcc.state.tx.us/water/quality/data/wqm/index.html#manuals

Surface Water Quality Monitoring Program information:
http://www.tnrcc.state.tx.us/water/quality/data/wqm/index.html

Leppo, E.W., M.T. Barbour, and J. Gerritsen. 2001. *An evaluation of the stream habitat assessment approach used by TNRCC*. Prepared for: Texas Natural Resource and Conservation Commission, Austin, Texas and USEPA Region 6, Dallas, Texas.

TEXAS

Contact Information

Charles Bayer, Aquatic Scientist
Texas Commission on Environmental Quality (TCEQ)
P.O. Box 13087 ■ Austin, Texas 78711-3087
Phone 512/239-4583 ■ Fax 512/239-4420
email: cbayer@tnrcc.state.tx.us

Roy Kleinsasser, River Studies Program Leader
Texas Parks and Wildlife Department (TPWD)
505 Staples Road ■ San Marcos, TX 78666
Phone 512/353-3480
email: leroy.kleinsasser@tpwd.state.tx.us

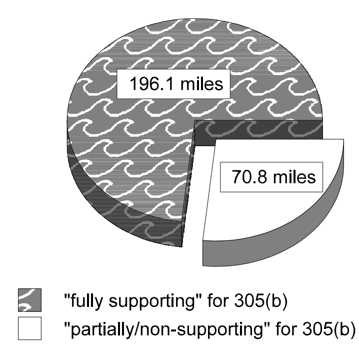
Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
		nonpoint source assessments
		monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
	✓	promulgated into state water quality standards as biocriteria
		support of antidegradation
	✓	evaluation of discharge permit conditions
	✓	TMDL assessment and monitoring
		other:
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(special projects, specific river basins or watersheds, and comprehensive use throughout jurisdiction)*
	✓	fixed station (i.e., water quality monitoring stations) *(specific river basins or watersheds and comprehensive use throughout jurisdiction)*
		probabilistic by stream order/catchment area
	✓	probabilistic by ecoregion, or statewide *(special projects only)*
		rotating basin
		other:

Stream Miles

Total miles *(State based determination)*	**191,228**
Total perennial miles	40,194
Total miles assessed for biology*	**266.9**
fully supporting for 305(b)	196.1
partially/non-supporting for 305(b)	70.8
listed for 303(d)	–
number of sites sampled *(on an annual basis)**	30
number of miles assessed per site	–

266.9 Miles Assessed for Biology



*68,611.78 total miles were surveyed and 63,102.68 total miles were assessed. Of these, 266.9 miles were assessed using biology. 30 sites were surveyed and 16 sites were assessed.

Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Class System (A,B,C)	
ALU designations in state water quality standards	Five designations: Exceptional, High, Intermediate, Limited, and Oyster waters	
Narrative Biocriteria in WQS	Procedures used to support narrative biocriteria located in the *Water Quality Standards Implementation Procedures Receiving Water Assessment Procedures Manual* (see documentation)	
Numeric Biocriteria in WQS	none	
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
	✓	cause and effect determinations
	✓	permitted discharges
	✓	monitoring (e.g., improvements after mitigation)
		watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	Trinity River Segment 0805 was elevated from a limited aquatic life use to a high aquatic life use designation. EPA Region 6 considers Texas' high and exceptional aquatic life use designations as meeting the 101(a) goals of the Clean Water Act.	

Reference Site/Condition Development

Number of reference sites	**72 total**	
Reference site determinations	✓	site-specific
	✓	paired watersheds
	✓	regional (aggregate of sites)
	✓	professional judgment
		other:
Reference site criteria	no point source discharge, land use patterns, limited human impact, least disturbed sites determined using best professional judgment	
Characterization of reference sites within a regional context		historical conditions
	✓	least disturbed sites
		gradient response
		professional judgment
		other:
Stream stratification within regional reference conditions	✓	ecoregions (or some aggregate)
		elevation
		stream type
		multivariate grouping
		jurisdictional (i.e., statewide)
		other:
Additional information	✓	reference sites linked to ALU
		reference sites/condition referenced in water quality standards
	✓	some reference sites represent acceptable human-induced conditions

Field and Lab Methods

Assemblages assessed	✓	benthos *(<100 samples/year; multiple seasons, multiple sites – broad coverage for watershed level)*
	✓	fish *(<100 samples/year; multiple seasons, multiple sites – broad coverage for watershed level)*
		periphyton
		other:

Benthos	
sampling gear	surber, multiplate, lopping shears for collecting woody debris, D-frame, kick net; 500-600 micron mesh
habitat selection	riffle/run (cobble), artificial substrate and woody debris
subsample size	100 count and entire sample
taxonomy	combination
Fish	
sampling gear	backpack and boat electrofisher, trawl and gill net (particularly for tidal streams), seine; 1/8", 3/16" and 1/4" mesh
habitat selection	multihabitat
sample processing	length measurement, batch, anomalies
subsample	none
taxonomy	species
Habitat assessments	quantitative measurements; performed with bioassessments
Quality assurance program elements	standard operating procedures, quality assurance plan, periodic meetings and training for biologists, taxonomic proficiency checks, specimen archival

Data Analysis and Interpretation

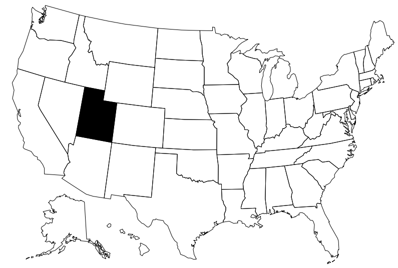
Data analysis tools and methods	✓	summary tables, illustrative graphs
	✓	parametric ANOVAs
		multivariate analysis
	✓	biological metrics *(aggregate metrics into an index)*
		disturbance gradients
		other:

Multimetric thresholds	
transforming metrics into unitless scores	95th percentile of reference population
defining impairment in a multimetric index	50th percentile of reference population (follow EPA RBP guidelines)

Evaluation of performance characteristics		repeat sampling
		precision
Not currently evaluated		sensitivity
		bias
		accuracy

Biological data	
Storage	TCEQ's TRACS database and hard copies; STORET is under development
Retrieval and analysis	At this time, the hard copies are primarily used for evaluation of biological data. Spreadsheets are also used.

UTAH



Contact Information

Thomas W. Toole, Environmental Scientist
Richard Denton, Manager
Utah Department of Environmental Quality (UDEQ)
288 N. 1460 W., P.O. Box 144870 ■ Salt Lake City, UT 84114-4870
Phone 801/538-6146 ■ Fax 801/538-6016
email: ttoole@utah.gov and rdenton@utah.gov
UDEQ Division of Water Quality homepage: http://waterquality.utah.gov/

Program Description

Prior to 2001, The Utah Division of Water Quality (DWQ) Biological Assessment program was limited to benthic macroinvertebrate data collected at 18 long-term monitoring sites. They have been sampled since 1978 with the exception of about five years in which the allocation of the 18 samples were used to supplement water chemistry and physical data collected in the five-year basin rotation monitoring plan. These samples were collected to ascertain long-term water quality and to be used in determining trends. In addition, benthic macroinvertebrate samples were collected at 16 Nonpoint Source Project sites to assess the effects of BMP implementation. These data have been incorporated into several NPS reports to determine what improvements in water quality have occurred. Data collected from the 18 long-term monitoring sites and the NPS projects have been used in making beneficial use assessments (305(b)) and listing waters on the 303(d) list.

In 2001, the DWQ reviewed its bio-monitoring program and decided that a major effort was needed to improve and develop new components of its water quality assessment program. During this review, an inventory of benthic macroinvertebrate data collected by DWQ, the U.S. Bureau of Land Management (BLM), and the U.S. Forest Service (USFS) was completed. Upon completion of this review, the DWQ contacted the BLM and USFS and requested all of the benthic macroinvertebrate data that they had collected from 1990 through 1997 be sent to DWQ for entering into STORED. These data, along with DWQ's, were entered into STORET. Data collected since 1997 have been stored electronically and a program to electronically transfer these data into STORET is being developed. These data will be evaluated as to their usefulness in establishing reference sites and the development of metrics to be used in assessing beneficial use support.

In 2001, the DWQ negotiated an agreement to complete the E-MAP sampling for EPA within the State. Experience obtained from this work would allow environmental scientists (field and staff) to learn and evaluate the methods used in the E-MAP protocol. This experience could then be used to develop a bioassessment protocol for assessing waters within the State.

Concurrent with doing the E-MAP work, the Division decided to commit additional resources to develop reference sites for bioassess-ment work. It was decided that the DWQ would select and try to sample up to 60 potential reference sites during the next 2-3 years. Water chemistry, fish, benthic macroinvertebrate, periphyton, and physical habitat data will be collected at these sites. The selection of sites were based upon the different ecoregions within the state and the need for low elevation, low-gradient stream reference sites.

DWQ is also assisting the EPA Corvallis Lab in reviewing and selecting reference sites that were initially selected using GIS techniques. Approximately 100 sites were initially selected and the number has been reduced to 20 sites. The DWQ is assisting in sampling these sites. Information obtained from this program will be evaluated and possibly incorporated into the Division's bio-assessment program.

The DWQ has committed to developing a set of reference sites and metrics that can be used to ensure that the waters of the State are assessed in a scientifically sound and standard method. Work is also going on to evaluate other assessment methods such as RIVPACS in assessing beneficial use support.

Documentation and Further Information

Utah Water Quality Assessment Report to Congress, September 2000 and Year 2000 Water Quality Inventory, 305(b) Assessment: http://www.waterquality.utah.gov/2000_305b_fact.pdf

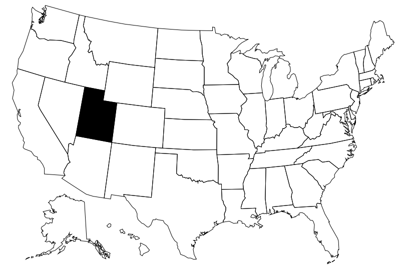
Utah Division of Water Quality's 2000 Water Quality Monitoring Program::
http://www.waterquality.utah.gov/monitoring/complete_monitor_plan_2000.pdf

Utah's 2000 303(d) List of Waters, October 2000: http://www.waterquality.utah.gov/documents/approved_2000_303d.pdf

DRAFT, Utah's 2002 303(d) List of Waters: http://www.waterquality.utah.gov/documents/2002303dinternet.pdf

Quality Assurance and Standard Operating Procedures Manual. Utah Department of Environmental Quality, Division of Water Quality. 1993. Utah Department of Environmental Quality, Salt Lake City, UT.

UTAH



Contact Information

Thomas W. Toole, Environmental Scientist
Richard Denton, Manager
Utah Department of Environmental Quality (UDEQ)
288 N. 1460 W., P.O. Box 144870 ■ Salt Lake City, UT 84114-4870
Phone 801/538-6859 or -6055 ■ Fax 801/538-6016
email: ttoole@deq.state.ut.us and rdenton@deq.state.ut.us

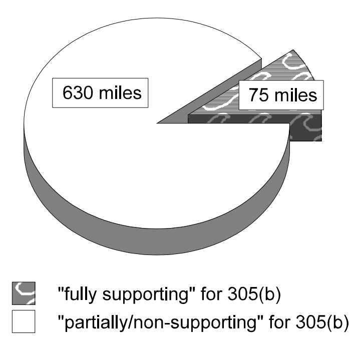
Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
	✓	monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
		promulgated into state water quality standards as biocriteria
		support of antidegradation
		evaluation of discharge permit conditions
	✓	TMDL assessment and monitoring
		other:
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(special projects, specific river basins or watersheds and comprehensive use throughout jurisdiction)*
	✓	fixed station (i.e., water quality monitoring stations) *(special projects, specific river basins or watersheds and comprehensive use throughout jurisdiction)*
		probabilistic by stream order/catchment area
		probabilistic by ecoregion, or statewide
	✓	rotating basin *(specific river basins or watersheds and comprehensive use throughout jurisdiction)*
		other:

Stream Miles

Total miles *(determined using the National Hydrography database and state based determination)*	**85,916**
Total perennial miles	14,000+
Total miles assessed for biology*	**705**
fully supporting for 305(b)	75
partially/non-supporting for 305(b)	630
listed for 303(d)	300
number of sites sampled *(on an annual basis)*	~56
number of miles assessed per site	12.6

705 Miles Assessed for Biology



*Biological data were used along with water chemistry data to assess the above listed miles. The biological assessment was done using benthic macroinvertebrates and used a weight-of-evidence assessment because reference sites were not used. Diversity indices, the Biotic Condition Index, and the number of sediment and nutrient tolerant taxa were used to determine beneficial use support when the pollution indicator value for total phosphorus was exceeded.

Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Class System (A,B,C)	
ALU designations in state water quality standards	Five designations*	
Narrative Biocriteria in WQS	none - Procedures used to support general aquatic life statement in WQS are not standardized, but are primarily based on best professional judgment using some metrics.	
Numeric Biocriteria in WQS	none	
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
		cause and effect determinations
		permitted discharges
	✓	monitoring (e.g., improvements after mitigation)
	✓	watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	Used primarily in assessing 319 nonpoint source projects including assessment, implementation of BMPs, and evaluation of water quality	

*The designations are as follows: 3A - cold water species of game fish and other cold water aquatic life, including the necessary aquatic organisms in their food web. 3B - warm water species of game fish and other warm water aquatic life, including the necessary aquatic organisms in their food web. 3C - Nongame fish and other aquatic life including the necessary aquatic organisms in their food chain. 3D - Waterfowl, shore birds and other water-oriented wildlife not included in Classes 3A, 3B, or 3C, including the necessary aquatic organisms in their food chain. 3E - Severely habitat-limited waters.

Reference Site/Condition Development**

Number of reference sites	**not applicable**	
Reference site determinations		site-specific
		paired watersheds
		regional (aggregate of sites)
		professional judgment
		other:
Reference site criteria		
Characterization of reference sites within a regional context		historical conditions
		least disturbed sites
		gradient response
		professional judgment
		other:
Stream stratification within regional reference conditions		ecoregions (or some aggregate)
		elevation
		stream type
		multivariate grouping
		jurisdictional (i.e., statewide)
		other:
Additional information		reference sites linked to ALU
		reference sites/condition referenced in water quality standards
		some reference sites represent acceptable human-induced conditions

**Utah is currently working with the EMAP to develop reference sites.

Field and Lab Methods

Assemblages assessed	✓	benthos *(<100 samples/year; multiple seasons, multiple sites – broad coverage for watershed level)*
		fish
	UD	periphyton *(A periphyton program is under development and will be used primarily in nutrient-impacted streams. Dr. Sam Rushforth, at Utah Valley State College, is assisting in the development of this program.)*
		other:

Benthos	
sampling gear	rock baskets and Hess; 200-400 micron mesh
habitat selection	riffle/run (cobble) and artificial substrate
subsample size	300 count
taxonomy	combination
Habitat assessments	quantitative measurements, and a few nonpoint source project sites have pebble counts, channel profiles and riparian condition evaluated on a very limited basis; performed with bioassessments
Quality assurance program elements	standard operating procedures and quality assurance plan

Data Analysis and Interpretation

Data analysis tools and methods	✓	summary tables, illustrative graphs
		parametric ANOVAs
		multivariate analysis
	✓	biological metrics *(return single metrics - use endpoint for each single metric)*
		disturbance gradients
	✓	other: some tolerance information is used in the evaluation

Multimetric thresholds*	
transforming metrics into unitless scores	BCI Methods described by USFS are used to differentiate higher quality waters, less discriminating in impaired waters.

Evaluation of performance* characteristics		repeat sampling
		precision
Not currently evaluated		sensitivity
		bias
		accuracy

Biological data**	
Storage	Data are currently being loaded into STORET
Retrieval and analysis	SAS (metrics are calculated by the contracting laboratory using spreadsheets or another computer program–language not known)

*EPA is currently having a contractor review benthic macroinvertebrate data to determine what metrics might apply to various regions of the State. Any metrics presently being used are those produced by the contracting laboratory and best professional judgement is used in the interpretation. No metric sensitivity analyses, regional biases, or other evaluations have been done to this point.

**EPA's Assessment Database is being used to store and retrieve assessment information for Utah's 305(b) report. Some indexing of waterbodies still needs to be done, but this should be completed during fiscal year 2002.

VERMONT

Contact Information

Doug Burnham, Biomonitoring and Aquatic Studies Section Chief
Vermont Department of Environmental Conservation (VTDEC)
103 South Main Street-10N ■ Waterbury, VT 05671
Phone 802/241-3784 ■ Fax 802/241-3008
email: dougb@dec.anr.state.vt.us
VTDEC Water Quality Division website: http://www.anr.state.vt.us/dec/waterq/wqdhome.htm

Program Description

The Water Quality Division of the Vermont Department of Environmental Conservation (VTDEC) has been conducting aquatic biological health assessments since the early 1970's. In 1982, the Biomonitoring and Aquatic Studies Section (BASS) was created with a focus on river and stream biological monitoring. BASS is currently staffed by five full-time aquatic biologists who participate in VTDEC water quality management programs at all levels. This "top to bottom" involvement by biologists has been critical to the extensive acceptance and use of biological assessment data within a wide variety of Departmental programs. The primary objectives of ambient monitoring activities are: 1) monitor long-term trends in water quality as revealed in changes over time to ambient aquatic biological communities; 2) evaluate potential impacts from point and nonpoint permitted direct and indirect discharges, development projects, nonpoint sources, and spills on aquatic biological communities; 3) establish a reference database that would facilitate the generation of Vermont-specific biological criteria for water quality classification and use attainment determinations; 4) support VTDEC permitting and water quality management programs requiring biological assessment data; 5) conduct special studies to assess emerging water quality and environmental management issues. Further information about VTDEC BASS is available at: http://www.anr.state.vt.us/dec/waterq/bass.htm.

Since 1985, the Department has used standardized methods for sampling fish and macroinvertebrate communities, evaluating physical habitat, processing samples, and analyzing and evaluating data. The program has led to the development of two Vermont-specific fish community Indexes of Biotic Integrity (IBI) and selected macroinvertebrate metrics. Guidelines have been developed for determining water quality classification attainment by using both macroinvertebrate community biological integrity metrics and the fish community IBI. Approximately 75-125 sites per year are assessed using fish and/or macroinvertebrate assemblages. Alkalinity, pH, conductivity, temperature and such measurements as substrate composition (pebble counts), embeddedness, canopy cover, percent and type of periphyton cover, and approximate velocity are routinely monitored. From 1985 to 2001, approximately 1,500 stream assessments were completed using macroinvertebrate and/or fish from more than 900 wadeable stream reaches. This monitoring effort is subject to a USEPA-approved quality assurance project plan. Data from the project are summarized and stored in an electronic database.

Biological data are used extensively to determine aquatic life use support and impairment. A significant proportion of Vermont's 303(d) list is made up of reaches with impaired aquatic life use determined through bioassessment. The development of biological criteria supported by the Vermont Water Quality Standards has provided a vehicle for enforceable implementation of biocriteria. Biological assessment data are used extensively in virtually all VTDEC water quality management programs, including RCRA, NPDES, CERCLA, watershed planning, 401 certification, aquatic nuisance control permitting, and 305(b). In addition to wadeable stream monitoring, BASS conducts a variety of special studies and assessment in other aquatic habitats, and is in the process of evaluating biocriteria for vernal pools and ponded waters.

VTDEC participates in collaborations with other agencies and organizations including: USEPA; USFWS; USFS; USGS; academic institutions; neighboring states; private consultants; special interest groups; and volunteer monitors. Staff also participate in public outreach activities as resources allow.

Biological criteria are the current performance standards for a large number of 303(d) waterbodies throughout the state. Future demand for biological assessments from VTDEC management programs will increase as the 303(d)/TMDL process advances and watershed planning initiatives expand statewide. The greatest challenge facing the biomonitoring program will be maintaining adequate staff resources to continue assessing 303(d) restoration management actions, providing support to watershed plan development, and providing support to various management programs within VTDEC and the Agency of Natural Resources.

Documentation and Further Information

Vermont 2000 Water Quality and Assessment, 305(b) Report

Vermont Water Quality Methodology, April 2001

Wadeable Stream Biocriteria Development for Fish and Macroinvertebrate Assemblages in Vermont Streams and Rivers

July 2, 2000 Vermont Water Quality Standards: http://www.state.vt.us/wtrboard/july2000wqs.htm

Fish Sampling and Metrics homepage: http://www.anr.state.vt.us/dec/waterq/bassfish.htm

Macroinvertebrate Sampling, Processing and Metrics homepage: http://www.anr.state.vt.us/dec/waterq/bassmacro.htm

VERMONT

Contact Information

Doug Burnham, Biomonitoring and Aquatic Studies Section Chief
Vermont Department of Environmental Conservation (VTDEC)
103 South Main Street-10N ■ Waterbury, VT 05671
Phone 802/241-3784 ■ Fax 802/241-3008
email: dougb@dec.anr.state.vt.us

Programmatic Elements

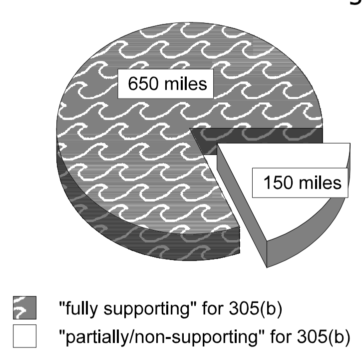
Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
	✓	monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
	✓	promulgated into state water quality standards as biocriteria
	✓	support of antidegradation
	✓	evaluation of discharge permit conditions
	✓	TMDL assessment and monitoring
	✓	other: bioassessments used for all aquatic life use support evaluations
Applicable monitoring designs*	✓	targeted (i.e., sites selected for specific purpose) *(comprehensive use throughout jurisdiction)*
	✓	fixed station (i.e., water quality monitoring stations) *(comprehensive use throughout jurisdiction)*
	✓	probabilistic by stream order/catchment area *(special projects only)*
		probabilistic by ecoregion, or statewide
	✓	rotating basin *(specific river basins or watersheds)*
		other:

*The majority of biological sampling conducted by VTDEC is targeted and in the context of rotating basin elements. Fixed station and special projects are also significant elements. Some monitoring required by discharge permits or basin plans related to TMDL's is done by consultants. Consultants generating biological monitoring data for aquatic life use support determinations consistent with Vermont Water Quality Standards or for compliance with discharge permit limitations are required to meet QA/QC requirements and submit to QA oversight by VTDEC biologists.

Stream Miles

Total miles *(State based determination)*	**7,099**
Total perennial miles	7,099
Total miles assessed for biology*	**~800**
fully supporting for 305(b)	~650
partially/non-supporting for 305(b)	~150
listed for 303(d)	~150
number of sites sampled *(total number with available biological monitoring data)*	1,193
number of miles assessed per site	–

800 Miles Assessed for Biology



*The latest 305(b) report was used to estimate some of these numbers. 305(b) reports total stream miles assessed by "evaluation" and "monitoring". The majority of VTDEC sites that are "monitored" are monitored for biology. The total miles reported as assessed in the last “statewide” assessment report in 2000 was 5,261, with 4,411 miles "evaluated" and 850 miles "monitored". Roughly 800 of the 850 miles "monitored" were monitored using biology (similarly with use support categories).

Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Class System (A,B,C)	
ALU designations in state water quality standards	Three designations related to changes from reference condition: minimal, minor, and moderate change from the reference condition.	
Narrative Biocriteria in WQS	VTDEC procedures used to support narrative biocriteria are independent of WQS.	
Numeric Biocriteria in WQS	none (Numeric biocriteria are currently found in VTDEC procedural documents.)	
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
	✓	cause and effect determinations
	✓	permitted discharges
	✓	monitoring (e.g., improvements after mitigation)
	✓	watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	Used extensively throughout management programs including: NPDES, 305(b), 303(d), basin planning, point and nonpoint source management, aquatic nuisance control, RCRA, CERCLA.	

Reference Site/Condition Development

Number of reference sites	**150 total**	
Reference site determinations	✓	site-specific
		paired watersheds
	✓	regional (aggregate of sites)
	✓	professional judgment
		other:
Reference site criteria	Reference sites are defined using the best professional judgment of biologists based on the level of human activity and potential for that activity to affect the aquatic resource. There are no quantitative criteria, but general considerations may include: very good riparian condition at site; predominantly forested watershed; outside the influence of assessed activity; least disturbed condition.	
Characterization of reference sites within a regional context	✓	historical conditions
		least disturbed sites
		gradient response
	✓	professional judgment
	✓	other: minimally disturbed*
Stream stratification within regional reference conditions		ecoregions (or some aggregate)
		elevation
	✓	stream type
	✓	multivariate grouping
		jurisdictional (i.e., statewide)
		other:
Additional information	✓	reference sites linked to ALU
	✓	reference sites/condition referenced in water quality standards
		some reference sites represent acceptable human-induced conditions

*This language is included in the definition of reference condition in the Vermont Water Quality Standards, effective July 2, 2000.

Field and Lab Methods

Assemblages assessed	✓	benthos *(100-500 samples/year; single season, multiple sites - broad coverage)*
	✓	fish *(<100 samples/year; single season, multiple sites - broad coverage)*
	✓	periphyton *(Periphyton and algae in rivers and streams are sampled qualitatively for descriptive purposes only. Some indirect discharge permits require quantitative periphyton and macroinvertebrate sampling with artificial substrates in order to determine compliance with permit conditions. Compliance criteria are independent of WQS.)*

Benthos	
sampling gear	rock baskets, kick net (18x9 rectangular net, 500 micron mesh)
habitat selection	riffle/run (cobble) and woody debris (varies according to stream category)
subsample size	must be minimum 300 animals AND 25% of sample.
taxonomy	lowest possible taxon - genus, species and combination (specified level in SOPs and C185)
Fish	
sampling gear	backpack electrofisher
habitat selection	multihabitat
sample processing	length measurement and anomalies
subsample	none
taxonomy	species
Habitat assessments	visual based and hydrogeomorphology - performed with and independent of bioassessments; pebble counts currently implemented quite extensively in conjunction with bioassessments
Quality assurance program elements	standard operating procedures; quality assurance plan; periodic meetings and training for biologists; sorting and taxonomic proficiency checks; specimen archival; sending voucher specimens to experts for identification confirmation

Data Analysis and Interpretation

Data analysis tools and methods	✓	summary tables, illustrative graphs
	✓	parametric ANOVAs
	✓	multivariate analysis
	✓	biological metrics *(aggregate metrics into an index and return single metrics - use endpoint for each single metric)*
		disturbance gradients
		other:

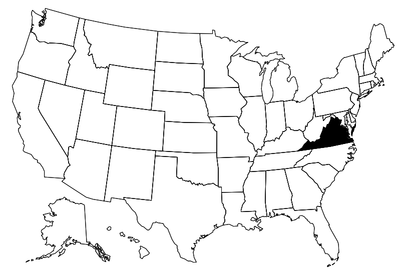
Multimetric thresholds*	
transforming metrics into unitless scores	Combination of reference distribution, impaired site distribution, and best professional judgement; do not use unitless scores.
defining impairment in a multimetric index	Cumulative distribution function
Multivariate thresholds*	
defining impairment in a multivariate index	Significant departure from mean of reference population

Evaluation of performance characteristics	✓	repeat sampling *(long term fixed station sampling)*
	✓	precision *(field replication)*
		sensitivity
		bias
	✓	accuracy *(sample processing and analysis QA)*

Biological data	
Storage	Data are stored and managed in MS Access data base. Various programs used to analyze sub-sets include: Excel, Sigma-Plot/Stat and PC-ORD
Retrieval and analysis	MS Access database calculates metrics and generates event summary reports. Data can be moved from Access to other programs for project-specific analyses. Commonly used programs include: Excel, Sigma-Plot/Stat, PC-ORD

*Benthos data are used to generate individual metrics, which are considered individually. Fish assemblage data are used to generate metrics for a multimetric Index of Biotic Integrity. Water Quality Standard thresholds (deviations from the reference condition) are based on BPJ evaluations of metric distribution patterns in both reference and non-reference sites.

VIRGINIA



Contact Information

Alex M. Barron, Environmental Program Planner
Virginia Department of Environmental Quality (DEQ)
P.O. Box 10009 ■ Richmond, VA 23240
Phone 804/698-4119 ■ Fax 804/698-4116
email: ambarron@deq.state.va.us
DEQ Water Programs homepage: http://www.deq.state.va.us/water/

Program Description

The Virginia Department of Environmental Quality (DEQ) Biological Monitoring Program (BMP) utilizes the study of bottom dwelling macroinvertebrate communities to determine overall water quality. Changes in water quality generally alter the kinds and numbers of these animals living in streams or other waterbodies. Like physical and chemical water quality monitoring data, biological monitoring data are used to assess water quality for support of aquatic life designated use and the Clean Water Act "fishable and swimmable" goals.

The BMP is composed of 150 to 170 stations that are examined annually during the spring and fall. Qualitative and semiquantitative biological monitoring has been conducted by the agency since the early 1970s. The USEPA Rapid Bioassessment Protocol (RBP) II was employed beginning in the fall of 1990 to utilize standardized and repeatable methodology. The RBPs produce water quality ratings of nonimpaired, slightly impaired, moderately impaired and severely impaired instead of the former ratings of good, fair and poor.

Currently, there are approximately 70 organizations throughout the Commonwealth with active citizen water quality monitoring programs. Biological parameters measured by citizen monitors often include benthic macroinvertebrates, fecal coliform bacteria, and/or chlorophyll *a*. A statewide organization, the Izaak Walton League of America Virginia Save Our Streams Program (IWLA VA SOS), took the lead in establishing relations with DEQ and the Department of Conservation and Recreation (DCR) to develop a statewide citizen monitoring program. IWLA VA SOS has a benthic macroinvertebrate citizen monitoring protocol that is widely used by many affiliate organizations. In 2000, VA SOS completed a two-year study, funded by DEQ, evaluating this protocol and developing a new protocol to more closely correlate with professional methods developed by EPA and used by DEQ.

Documentation and Further Information

Water Quality Assessment and Impaired Waters Report (combined 2002 305b and 303d), July 2002:
http://www.deq.state.va.us/water/305b.html

2000 Water Quality Assessment 305(b) Report: http://www.deq.state.va.us/water/00-305b.html

Water Quality Assessment Guidance Manual for 2002, 305(b) and 303(d) reports, July 2002:
http://www.deq.state.va.us/pdf/water/wqassessguide.pdf

2001 Ambient Water Quality Monitoring Plan:
http://www.deq.state.va.us/water/my01rpt.html

Watershed Maps of *Virginia Impaired Water Segments, 303(d) TMDL Priority List*:
http://www.deq.state.va.us/watermaps/

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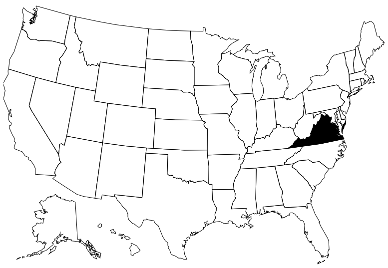

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Virginia Department of Environmental Quality (DEQ)
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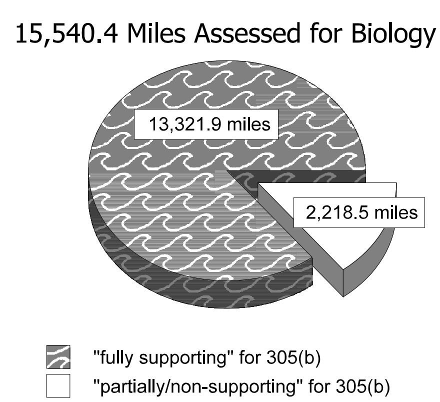
Phone 804/698-4119 ■ Fax 804/698-4116
email: ambarron@deq.state.va.us

Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
		monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
		promulgated into state water quality standards as biocriteria
	✓	support of antidegradation
	✓	evaluation of discharge permit conditions
	✓	TMDL assessment and monitoring
		other:
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(special projects only)*
	✓	fixed station (i.e., water quality monitoring stations) *(comprehensive use throughout jurisdiction)*
		probabilistic by stream order/catchment area
	✓	probabilistic by ecoregion, or statewide *(comprehensive use throughout jurisdiction)*
		rotating basin
		other:

Stream Miles

Total miles *(determined using the National Hydrography Database)*	**50,329**
Total perennial miles	50,329
Total miles assessed for biology*	**15,540.4**
fully supporting for 305(b)*	13,321.9
partially/non-supporting for 305(b)*	2,218.5
listed for 303(d)*	2,218.5
number of sites sampled *(on an annual basis)**	150 -170
number of miles assessed per site	–



*The numbers listed above were extracted from Virginia's 2002 combined 305(b)/303(d) report and represent stream and river miles assessed (evaluated and monitored) for aquatic life using chemical, physical and biological parameters. However, of the 2,218.5 total miles partially/non-supporting for 305(b), 661.4 miles were determined to be impaired based solely on biological (benthic) data.

Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Single Aquatic Life Use	
ALU designations in state water quality standards	Three designations (apply to all State waters): recreational uses, e.g., swimming and boating; the propagation and growth of a balanced, indigenous population of aquatic life, including game fish, which might reasonably be expected to inhabit them; and the production of marketable resources, e.g. fish and shellfish.	
Narrative Biocriteria in WQS	none - Virginia has no formal/informal numeric procedures to support general aquatic life statement found in WQS	
Numeric Biocriteria in WQS	none	
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria) *Information not provided*		assessment of aquatic resources
		cause and effect determinations
		permitted discharges
		monitoring (e.g., improvements after mitigation)
		watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	Several TMDLs are addressing ALUS restoration because of poor bioassessment scores.	

Reference Site/Condition Development

Number of reference sites	**information not provided**	
Reference site determinations	✓	site-specific
	✓	paired watersheds
		regional (aggregate of sites)
	✓	professional judgment
		other:
Reference site criteria	No reference site criteria. Reference sites are defined as best available, least impaired.	
Characterization of reference sites within a regional context *Information not provided*		historical conditions
		least disturbed sites
		gradient response
		professional judgment
		other:
Stream stratification within regional reference conditions *Information not provided*		ecoregions (or some aggregate)
		elevation
		stream type
		multivariate grouping
		jurisdictional (i.e., statewide)
		other:
Additional information		reference sites linked to ALU
		reference sites/condition referenced in water quality standards
	✓	some reference sites represent acceptable human-induced conditions

Field and Lab Methods

Assemblages assessed	✓	benthos *(300-400 samples/year; multiple seasons, multiple sites – broad coverage for watershed level)*
		fish
		periphyton
		other:

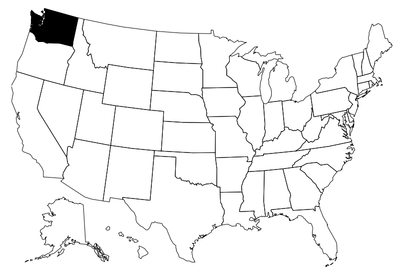
Benthos	
sampling gear	D-frame, kick net (1 meter); 500-600 micron mesh
habitat selection	richest habitat and riffle/run (cobble)
subsample size	100 count
taxonomy	family
Habitat assessments	visual based; performed with bioassessments
Quality assurance program elements	standard operating procedures, quality assurance plan, periodic meetings and training for biologists, specimen archival

Data Analysis and Interpretation

Data analysis tools and methods	✓	summary tables, illustrative graphs
		parametric ANOVAs
		multivariate analysis
		biological metrics
		disturbance gradients
		other:
Evaluation of performance characteristics *Information not provided*		repeat sampling
		precision
		sensitivity
		bias
		accuracy

Biological data	
Storage	EDAS
Retrieval and analysis	EDAS

WASHINGTON



Contact Information

Robert W. Plotnikoff, Freshwater Monitoring Unit Supervisor
Washington State Department of Ecology
P.O. Box 47710, 300 Desmond Drive ■ Olympia, WA 98504-7710
Phone 360/407-6687 ■ Fax 360/407-6884
email: rplo461@ecy.wa.gov
Stream Biological Monitoring website:
http://www.ecy.wa.gov/programs/eap/fw_benth/fwb_intr.html

Program Description

Washington State's Biological Monitoring Program has been operated by the Washington Department of Ecology since 1993. The program has served as a focal point for technical assistance and as a reference for data comparison. Its primary objectives are: 1) to continually describe the spatial and temporal features of biotic communities in wadeable streams, 2) describe and then validate biological expectations for appropriate spatial classifications (e.g., ecoregions), 3) develop guidance and criteria that evaluate human-induced disturbance in biological communities, and 4) expand where biological information is used in water quality and resource management. Although field data collection methodology has remained consistent, data storage and analytical products have improved in their capacity and sophistication.

The Freshwater Monitoring Unit within the Department of Ecology has engaged in biological monitoring activities for more than twelve years and has made its information available online for public use. The primary objectives in continuing to develop this program are to: 1) proceed with calibration of ten biometrics that will be based on reference conditions within each of eight ecoregions, 2) continue assistance in development of RIVPACS (River Invertebrate Prediction and Classification System) models for western and eastern Washington streams with researchers at Utah State University (Dr. C. Hawkins), and 3) locate and visit additional reference sites outside of the ranges currently being monitored.

Interpretive tools developed from these efforts are being placed into the ALUS framework under development by the USEPA (contact Susan Jackson). WA is able to use the knowledge and tools developed through former biological monitoring efforts to create a meaningful matrix of expectations as diagramed by ALUS so that incremental improvements in stream quality, based on biological signatures, can be tracked. The first step toward adoption of biocriteria will be the construction of a guidance that outlines analytical products and biological expectations for streams within each ecoregion of Washington State. Biological evaluation tools such as RIVPACS scores, biometric scores, index scores, and indicator taxa are currently being assembled for inclusion in the guidance.

Biological information is currently being included in the 303(d) listing process to directly evaluate impairment. WA has amassed an adequate data bank for describing reference conditions that serves as an effective and defensible means for comparison. The Freshwater Monitoring Unit issued a report titled "Condition of Freshwaters in Washington State for the Year 2000" that evaluates data from water quality monitoring, biological monitoring, lakes monitoring, and nuisance aquatic plant monitoring. This report was intended as a template for future reviews of environmental information, like the 305(b) report, and will eventually satisfy reporting content of the current required data summaries as well as new guidance like CALM (Consolidated Assessment and Listing Methodology).

Many of the water quality problems of interest to the Department of Ecology's Regional Offices are related to habitat destruction due to human influence. This is one of the areas in which collaborative work with volunteer monitoring groups, local governments, state agencies, tribes, and other federal agencies is promoted.

One important partnership has been with the USEPA and the Environmental Monitoring and Assessment Program (EMAP). The Department of Ecology has engaged both EMAP and R-EMAP (Regional Environmental Monitoring and Assessment Program) since 1994. The acquisition of both knowledge and equipment in operating this program has provided impetus to implement the probabilistic monitoring design in the Ambient River and Stream Water Quality Monitoring Program. WA is working with the Colville Tribe in expanding the description of reference conditions for northeastern Washington and with the Yakima Tribe, county, and federal agencies in evaluating the effects of floodplain gravel mining along the Yakima River. WA is especially encouraged by several volunteer monitoring groups, like Streamkeepers of Clallam County, whose organizers have assembled teams of personnel that generate useful biological, chemical, and flow data.

Documentation and Further Information

2000 Washington State Water Quality Assessment - Section 305(b) Report: http://www.ecy.wa.gov/pubs/0010058.pdf

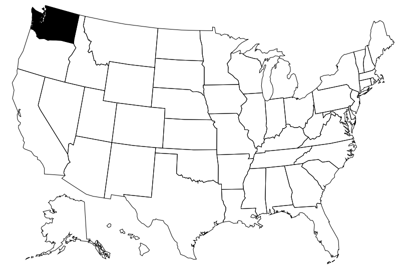
DRAFT 2002 303(d) List of Impaired and Threatened Waters, May 2002:
http://www.ecy.wa.gov/programs/wq/303d/2002-revised/listpolicydraftfinal7.pdf

Condition of Freshwaters in Washington State for the Year 2000: http://www.ecy.wa.gov/pubs/0103025.pdf

Water Quality Standards for Surface Waters of the State of Washington: http://www.ecy.wa.gov/pubs/wac173201a.pdf

For a comprehensive list of Stream Biological Monitoring Publications available online and/or by mail, go to:
http://www.ecy.wa.gov/programs/eap/fw_benth/fwb_pubs.html

WASHINGTON



Contact Information

Robert W. Plotnikoff, Freshwater Monitoring Unit Supervisor
Washington State Department of Ecology
P.O. Box 47710, 300 Desmond Drive ■ Olympia, WA 98504-7710
Phone 360/407-6687 ■ Fax 360/407-6884
email: rplo461@ecy.wa.gov

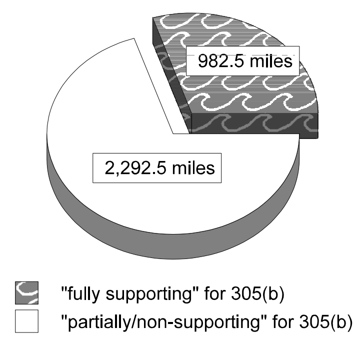
Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
	✓	monitoring the effectiveness of BMPs
		ALU determinations/ambient monitoring
	UD	promulgated into state water quality standards as biocriteria
		support of antidegradation
		evaluation of discharge permit conditions
	✓	TMDL assessment and monitoring
		other:
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(specific river basins or watersheds)*
	✓	fixed station (i.e., water quality monitoring stations) *(comprehensive use throughout jurisdiction)*
	✓	probabilistic by stream order/catchment area *(stream order as subset of ecoregion sampling)*
	✓	probabilistic by ecoregion, or statewide *(special projects and comprehensive use throughout jurisdiction)*
	✓	rotating basin *(specific river basins or watersheds)*
		other:

Stream Miles

Total miles *(State based determination)*	**73,886**
Total perennial miles	39,483
Total miles assessed for biology*	**3,275**
fully supporting for 305(b)**	982.5
partially/non-supporting for 305(b)**	2,292.5
listed for 303(d)	0
number of sites sampled	655
number of miles assessed per site	5

3,275 Miles Assessed for Biology



*Approximately 10% of the State's perennial streams are assessed for biology. The 3,275 total miles assessed for biology is an estimate derived from multiplying 655 sites by the 5 miles assessed per site.

**The “fully supporting” and “partially/non-supporting” for 305(b) stream mile estimates are based on an old assessment policy estimation process. WA most recently used EPA's National Hydrography Data Layer to create the stream segment breaks but the new data has not been generated yet.

Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Class System (A,B,C)	
ALU designations in state water quality standards	The Water Class system currently in use contains four categories: Class AA, Class A, Class B, and Class C. Class AA (extraordinary) freshwaters shall markedly and uniformly exceed the requirements for all or substantially all uses. Class A (excellent) freshwaters shall meet or exceed the requirements for all or substantially all uses. Class B (good) freshwaters shall meet or exceed requirements for most uses. Class C (fair) freshwaters shall meet or exceed the requirements of selected and essential uses.	
Narrative Biocriteria in WQS*	under development	
Numeric Biocriteria in WQS	none	
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
	✓	cause and effect determinations
	✓	permitted discharges
	✓	monitoring (e.g., improvements after mitigation)
	✓	watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	none	

*Water Classes AA, A, and B include a characteristic use designation called "Wildlife Habitat." This characteristic use designates waters of the state used by, or that directly or indirectly provide food support to fish, other aquatic life, and wildlife for any life history stage or activity. The term "biological assessment" is defined in Washington's water quality standards and is intended to be used to evaluate the condition of "Wildlife Habitat."

Reference Site/Condition Development

Number of reference sites	**187 total**	
Reference site determinations		site-specific
		paired watersheds
	✓	regional (aggregate of sites)
	✓	professional judgment
		other:
Reference site criteria	1) Least-disturbed sites that show little or no signs of human impact, 2) Relatively-unimpacted sites that show some signs of historical human influence but are at an advanced successional stage	
Characterization of reference sites within a regional context	✓	historical conditions
	✓	least disturbed sites
		gradient response
		professional judgment
	✓	other: minimally disturbed (see "relatively-unimpacted" reference site criteria)
Stream stratification within regional reference conditions	✓	ecoregions (or some aggregate)
		elevation
	✓	stream type
		multivariate grouping
		jurisdictional (i.e., statewide)
		other:
Additional information		reference sites linked to ALU
		reference sites/condition referenced in water quality standards
	✓	some reference sites represent acceptable human-induced conditions

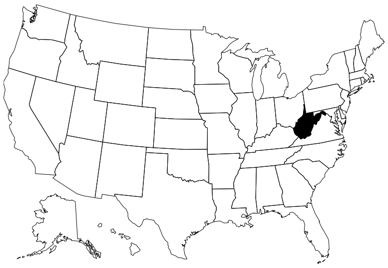
Field and Lab Methods

Assemblages assessed	✓	benthos *(100-500 samples/year; single season, multiple sites - watershed level and broad coverage)*
	✓	fish *(100-500 samples/year; single season, multiple sites - watershed level and broad coverage)*
	✓	periphyton *(<100 samples/year; single season, multiple sites - watershed level and broad coverage)*
	✓	other: macrophytes and waterfowl *(<100 samples/year; single season, multiple sites - watershed level and broad coverage)*
Benthos		
sampling gear		Surber, D-frame; 500-600 micron mesh
habitat selection		riffle/run (cobble); pool habitat may also be assessed if physical and/or chemical degradation has occurred and can be detected through a biotic response
subsample size		500 count
taxonomy		family, genus, and species
Fish		
sampling gear		backpack electrofisher; 7 millimeter mesh
habitat selection		multihabitat
sample processing		length measurement, anomalies
subsample		none - all specimens are examined and counted
taxonomy		species, life stage
Periphyton		
sampling gear		**natural substrate:** brushing/scraping device (razor, toothbrush, etc.); **artificial substrate:** collect by hand
habitat selection		multihabitat
sample processing		taxonomic identification
taxonomy		genus
Habitat assessments		visual based, quantitative measurements and hydrogeomorphology; performed with bioassessments
Quality assurance program elements		standard operating procedures, quality assurance plan, periodic meetings and training for biologists, sorting and taxonomic proficiency checks, specimen archival

Data Analysis and Interpretation

Data analysis tools and methods	✓	summary tables, illustrative graphs
		parametric ANOVAs
	✓	multivariate analysis
	✓	biological metrics *(aggregate metrics into an index)*
		disturbance gradients
Multimetric thresholds		
transforming metrics into unitless scores		25^{th} percentile of reference population
defining impairment in a multimetric index		25^{th} percentile of reference population
Multivariate thresholds		
defining impairment in a multivariate index		Significant departure from mean of reference population
Evaluation of performance characteristics	✓	repeat sampling *(multi-year sampling at gradient of sites)*
	✓	precision *(multi-year sampling at reference sites)*
		sensitivity
		bias
		accuracy
Biological data		
Storage		All biological (including habitat and chemistry) information is stored in MS Access
Retrieval and analysis		SAS, Systat, CANOCO, Primer, Cornell Ecology Programs, and Calibrate

WEST VIRGINIA



Contact Information

John Wirts, Program Manager
West Virginia Department of Environmental Protection (WV DEP)
1201 Greenbrier Street ■ Charleston, WV 25311
Phone 304/558-2108 ■ Fax 304/558-2780
email: jwirts@mail.dep.state.wv.us
WV DEP Division of Water Resources homepage: http://www.dep.state.wv.us/item.cfm?ssid=11

Dan Cincotta, Fisheries Biologist
West Virginia Division of Natural Resources (WV DNR)
P.O. Box 67 ■ Elkins, WV 26241
Phone 304/637-0245 ■ Fax 304/637-0250
email: dcincotta@dnr.state.wv.us
WV DNR Wildlife Resources Section homepage: http://www.dnr.state.wv.us/wvwildlife/default.htm

Program Description

The West Virginia Department of Environmental Protection (WV DEP) implemented the Watershed Assessment Program in 1996. This program was designed to systematically measure the water quality and biological health of the state's rivers and streams. The program has four major components: 1) Random or Probabilistic Sampling; 2) Pre-TMDL sampling; 3) Ambient WQ Monitoring; and 4) "Regular Assessments."

Benthic macroinvertebrates are collected at the "random sites," regular WAP (Watershed Assessment Program) sites, and selected Pre-TMDL sites. The program utilizes a rectangular dip net, compositing samples from two square meters and identifying a 200 organism sub-sample. WV DEP identified the "bugs" in-house to family level the first three years of the program. In 1999, WV DEP contracted out the identification work and switched to genus level identification. In 2000, a macroinvertebrate index was developed for West Virginia with support from EPA's biocriteria development program. This index provides a means to establish an impairment threshold that is based on a set of minimally disturbed reference sites.

The "Regular Assessments" were the majority of WV DEP's workload in the program's first year and continue to be a major portion of efforts. These consisted of sampling as many streams as possible (considering personnel limitations) in watersheds that were scheduled for assessment according to a 5 year cycle (5-7 watersheds per year). These assessments included the collection of water quality, habitat and macroinvertebrate data. All streams previously listed as impaired were targeted for assessment, as were a portion of all "unassessed" and "partially impaired" streams.

In 1997, the Watershed Assessment Program added a probabilistic sampling component. The first 5-year cycle was completed in 2001. The first cycle consisted of sampling 30-35 sites in each of the major watersheds (8-digit HUCs) in the state, sampling all sites in a watershed in a single year. The next 5 year cycle begins in 2002 and will have a different sampling strategy. The same effort, 150 sites, will be spread across the state each year instead of just the 5-7 watersheds being assessed that year. This will allow a summary of the condition of the state's streams to be completed every year instead of having to wait for the end of the 5-year cycle. This strategy also eliminates the problem of comparing watersheds sampled in different years that may have had drastically different climactic conditions (i.e. drought versus flood).

Periphyton will be collected at all of the random sites starting in 2002. The results of these collections will hopefully aid in the development of nutrient criteria. Streams with known eutrification problems and some of WV DEP's established reference sites may be sampled as well.

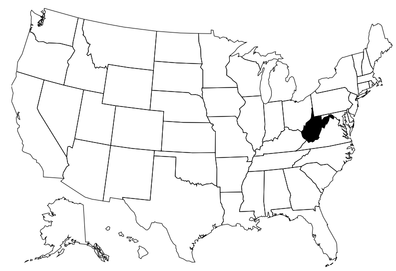
The Division of Natural Resources (DNR) is the fish and game agency of West Virginia. As part of its duties, statewide fishery surveys are conducted annually to monitor game and nongame fish populations. These surveys are not probability based as they are usually performed on target streams with ongoing programs (e.g., stockings) or due to crisis management reasons. The WV DNR has no regulatory authority relative to the state's water quality standards, but we are sometimes involved in a fish advisory capacity. The WV DNR is developing a fish Index of Biotic Integrity via a cooperative agreement with the USEPA. The IBI is being developed somewhat independently from the WQS that are utilized by WV DEP. Someday it may be used in the 305(b) program by a collaboration of agencies.

Documentation and Further Information

WV DEP Division of Water Resources list of publications, including direct links to *West Virginia Water Quality Status Assessment 305(b) Report 2000* and other 305(b) reports, multiple 303(d) listings, *West Virginia's Monitoring Strategy*, and *A Stream Condition Index for West Virginia Wadeable Streams*, 2000: http://www.dep.state.wv.us/item.cfm?ssid=11&ss1id=192

Smithson, J. 2001. Watershed assessment program. SOP. WV DEP Division of Water Resources.

WEST VIRGINIA



Contact Information

John Wirts, Program Manager
West Virginia Department of Environmental Protection (WV DEP)
1201 Greenbrier Street ■ Charleston, WV 25311
Phone 304/558-2108 ■ Fax 304/558-2780
email: jwirts@mail.dep.state.wv.us

Dan Cincotta, Fisheries Biologist
West Virginia Division of Natural Resources (WV DNR)
P.O. Box 67 ■ Elkins, WV 26241
Phone 304/637-0245 ■ Fax 304/637-0250
email: dcincotta@dnr.state.wv.us

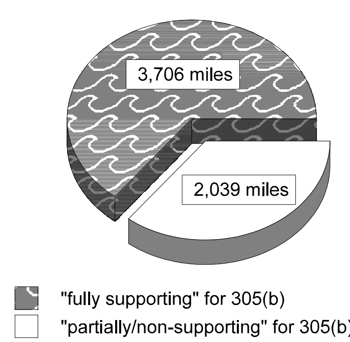
Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
	✓	monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
		promulgated into state water quality standards as biocriteria
	✓	support of antidegradation
	✓	evaluation of discharge permit conditions
	✓	TMDL assessment and monitoring
		other:
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(comprehensive use throughout jurisdiction)*
	✓	fixed station (i.e., water quality monitoring stations) *(comprehensive use throughout jurisdiction)*
		probabilistic by stream order/catchment area
	✓	probabilistic by ecoregion, or statewide *(comprehensive use throughout jurisdiction)*
	✓	rotating basin *(comprehensive use throughout jurisdiction)*
		other:

Stream Miles

Total miles *(determined using RF3 augmented with all named streams on 1:24,000 topographic map)*	**32,278**
Total perennial miles	21,114
Total miles assessed for biology	**5,745**
fully supporting for 305(b)	3,706
partially/non-supporting for 305(b)	2,039
listed for 303(d)	1,315
number of sites sampled	60-90
number of miles assessed per site	–

5,745 Miles Assessed for Biology



Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Single Aquatic Life Use
ALU designations in state water quality standards	Two designations: warmwater and coldwater
Narrative Biocriteria in WQS	none - Internal program procedures used to support general aquatic life standard
Numeric Biocriteria in WQS	none
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓ assessment of aquatic resources ✓ cause and effect determinations ✓ permitted discharges ✓ monitoring (e.g., improvements after mitigation) ✓ watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	Watershed restoration action strategies as part of the 319 grant program.

Reference Site/Condition Development

Number of reference sites	~**105 total**
Reference site determinations	☐ site-specific ☐ paired watersheds ✓ regional (aggregate of sites) ✓ professional judgment ☐ other:
Reference site criteria	The following selection criteria are used to select reference sites: (* Indicates criterion that can be determined in the field.) 1. D.O. > 5.0mg/l* 2. pH between 6.0 and 9.0* 3. Conductivity < 500 µS /cm* 4. Fecal coliform < 800 colony/100ml 5. No violations of State WQ Standards 6. No obvious sources of nonpoint pollution* 7. Epifaunal substrate / available cover score >10* 8. Channel alteration score >10* 9. Sediment deposition score >10 * 10. Bank vegetative protection score >5* 11. Undisturbed vegetation zone width score >5* 12. Total habitat score > or = 130 points* 13. Evaluation of anthropogenic activities and disturbances* 14. No known point source discharges upstream and within view of assessment site (completed after 1-13 are met)
Characterization of reference sites within a regional context	☐ historical conditions ☐ least disturbed sites ☐ gradient response ☐ professional judgment ✓ other: minimally disturbed**
Stream stratification within a regional reference conditions	☐ ecoregions (or some aggregate) ☐ elevation ☐ stream type ☐ multivariate grouping ✓ jurisdictional (i.e., statewide) ☐ other:
Additional information	☐ reference sites linked to ALU ☐ reference sites/condition referenced in water quality standards ✓ some reference sites represent acceptable human-induced conditions *(minimal)*

**WV reference sites are best described as *minimally disturbed* sites. They have to meet each of the 14 criteria mentioned above; thus there are some areas with no sites that WV DEP is comfortable calling reference.

Field and Lab Methods

Assemblages assessed	✓	benthos *(>500 samples/year, single season, multiple sites - watershed level)*
	✓	fish* *(<100 samples/year; single observation, limited sampling)*
		periphyton
		other:

Benthos	
sampling gear	D-frame, dipnet, collect by hand; 500-600 micron mesh
habitat selection	riffle/run (cobble)
subsample size	200 count
taxonomy	family, genus
Fish*	
sampling gear	seine, backpack and boat electrofishers, electric seine; 1/8" and 3/16" mesh
habitat selection	multihabitat
sample processing	length measurement, biomass - individual
subsample	none
taxonomy	species
Habitat assessments	visual based, quantitative measurements, riffle stability index; performed with bioassessments
Quality assurance program elements	standard operating procedures, quality assurance plan, periodic meetings, training for biologists, sorting proficiency checks, sorting and taxonomic proficiency checks, specimen archival

*West Virginia Division of Natural Resources is the fish and game agency of West Virginia. WV DNR duties include statewide annual fishery surveys to monitor game and nongame fish populations. These surveys are not probability based as they are ususally performed on target streams due to ongoing programs (eg. stockings) or crisis management reasons. The WV DNR has no regulatory authority relative to the state's water quality standards, but are sometimes involved in a fish advisory capacity. The WV DNR is developing a fish Index of Biotic Integrity via a cooperative agreement with the USEPA. It is being developed somewhat independently from the quality standards that are utilized by WV DEP, and may someday be used in the 305(b) program by a collaboration of agencies.

Data Analysis and Interpretation

Data analysis tools and methods	✓	summary tables, illustrative graphs
		parametric ANOVAs
		multivariate analysis
	✓	biological metrics *(aggregate metrics into an index)*
		disturbance gradients
		other:

Multimetric thresholds	
transforming metrics into unitless scores	95th percentile of total population
defining impairment in a multimetric index	5th percentile of reference sites

Evaluation of performance characteristics*	✓	repeat sampling
	✓	precision
	✓	sensitivity
	✓	bias
	✓	accuracy

Biological data	
Storage	WAPBAS (similar to EDAS)
Retrieval and analysis	WAPBAS (similar to EDAS)

***Described in *A Stream Condition Index for West Virginia Wadeable Streams* (see documentation and further information)

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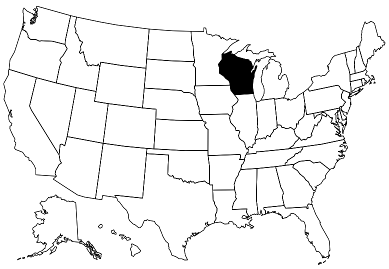

Contact Information

Mike Talbot, Chief - Monitoring Section, Bureau of Fisheries and Habitat Protection
Bob Masnado, Chief - Water Quality Standards Section, Bureau of Watershed Management
Wisconsin Department of Natural Resources (WDNR)
P.O. Box 7921 ■ Madison, Wisconsin 53707
Phone 608/266-0832 ■ Fax 608/266-2244
Phone 608/267-7662 ■ Fax 608/267-2800
email: talbom@dnr.state.wi.us and masnar@dnr.state.wi.us
WI DNR Division of Water homepage: http://www.dnr.state.wi.us/environmentprotect/water.html

Program Description

Historically, much of the water resource assessment work done by the Wisconsin Department of Natural Resources (WDNR) has focused on the evaluation of degraded watersheds or water resources with high public profile. As a result, there is a lack of data on the overall quality of Wisconsin's water resources. In addition, monitoring techniques often varied among assessment sites and over time thus making it difficult to compare data across the state or from different time periods. To address these concerns, WDNR initiated a new program in 1999, called Baseline Monitoring. Standardized assessment techniques for aquatic habitat, macroinvertebrates and fish have been developed and are being applied throughout the state. The elements of this new program are contained in a draft report on Wisconsin's Surface Water Monitoring Strategy.

The overall goals of the baseline monitoring strategy are to answer the following questions:

1. What are the use expectations for Wisconsin's water resources?
2. Are the state's waters meeting their use potential?
3. What factors are preventing the state's water resources from meeting their potential?
4. What are the statewide status and trends in the quality of Wisconsin's surface waters?

To achieve the goals of the program, the following specific set of monitoring objectives were established:

- Determine the designated attainable uses of each waterbody. Stream and lake habitat information and fisheries data collected during baseline assessments will be compared with biological criteria obtained from "least-impacted" regional reference waters to determine the water's use classification.
- Determine the level of use attainment of each waterbody. Stream habitat and fisheries data collected during baseline assessment monitoring will allow the WDNR to determine if designated uses are being attained. More emphasis is being placed on biological monitoring to determine if designated uses are being met.
- Determine why some waterbodies are not attaining their designated uses. Physical, chemical and biological data collected during baseline assessment monitoring will provide at least some of the information required to achieve this objective.

For stream biological monitoring, WDNR collects information on riparian and in-stream habitat data, aquatic insects and fish species. The aquatic insects are identified and the numbers of fish are determined using standardized collection protocols. Lake monitoring involves collecting trophic state data and fish community data using the standardized protocols.

WDNR will begin using a stratified-random sampling approach to achieve adequate coverage of the state's 55,000 miles of streams. This sampling design allows the WDNR to sample a variety of streams and lakes across the state and also provides the Department with the ability to evaluate the quality of water resources that have not been sampled. The WDNR collects over 400 aquatic invertebrate samples per year. However, under the baseline monitoring that was initiated last year, the WDNR is now annually assessing about 600 stream sites. In the future, maps showing the location of biological sampling sites will be available.

Documentation and Further Information

Wisconsin Water Quality Report to Congress, 2000 305(b): http://www.dnr.state.wi.us/org/water/wm/watersummary/WQ.pdf

Wisconsin's Unified Watershed Assessment: http://www.dnr.state.wi.us/org/water/wm/watersummary/uwa/index.htm#intro

Water Quality Standards for Wisconsin Surface Waters, revised February 1998:
http://www.legis.state.wi.us/rsb/code/nr/nr102.pdf

Wisconsin DNR Fisheries and Habitat Biological Database: http://infotrek.er.usgs.gov/wdnr_bio/

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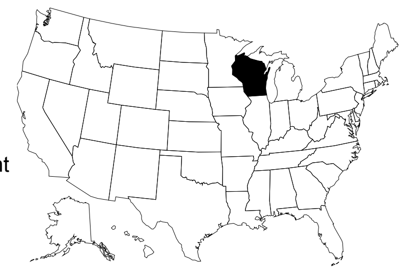


Contact Information

Mike Talbot, Chief - Monitoring Section, Bureau of Fisheries and Habitat Protection
Bob Masnado, Chief - Water Quality Standards Section, Bureau of Watershed Management
Wisconsin Department of Natural Resources (WDNR)
P.O. Box 7921 ■ Madison, Wisconsin 53707
Phone 608/266-0832 ■ Fax 608/266-2244
Phone 608/267-7662 ■ Fax 608/267-2800
email: talbom@dnr.state.wi.us and masnar@dnr.state.wi.us

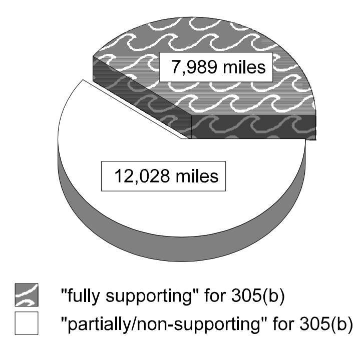
Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
	✓	monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
		promulgated into state water quality standards as biocriteria
	✓	support of antidegradation
	✓	evaluation of discharge permit conditions
	✓	TMDL assessment and monitoring
	✓	other: fishery assessments, FERC re-licensing, decisions, etc.
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(special projects only)*
	✓	fixed station (i.e., water quality monitoring stations) *(specific river basins or watersheds)*
		probabilistic by stream order/catchment area
	✓	probabilistic by ecoregion, or statewide *(comprehensive use throughout jurisdiction)*
		rotating basin
		other:

Stream Miles

Total miles*	**55,000**
Total perennial miles	32,000
Total miles assessed for biology**	**24,422**
fully supporting for 305(b)	7,989
partially/non-supporting for 305(b)	12,028
listed for 303(d)	–
number of sites sampled *(on an annual basis)*	600
number of miles assessed per site**	5

24,422 Miles Assessed for Biology



*Surface water resources for Wisconsin have been quantified using GIS. A 1:24,000 scale hydrography GIS database was developed by digitizing surface waters shown on USGS 7.5 minute quadrangle maps.

**The miles assessed for biology include fish consumption and aquatic life use. Of the 12,394 miles fully supporting for 305(b), 4,405 miles are threatened. Each site sampled represents 5 miles of stream for baseline surveys, based on research conducted by WDNR.

Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Fishery Based Uses and Warm Water vs. Coldwater	
ALU designations in state water quality standards	Five designations: 1) Coldwater – Salmonids & some sculpin species, 2) Warm Water Fish & Aquatic Life – game fish and some important forage species, 3) Warm Water Forage Fish – forage fish communities intolerant to low dissolved oxygen, 4) Limited Forage Fish – forage fish communities tolerant of low dissolved oxygen, 5) Limited Aquatic Life – communities with non-fish species (invertebrates, etc.) that are tolerant of low dissolved oxygen.	
Narrative Biocriteria in WQS	Wisconsin does not have narrative biocriteria per se. It does have narrative criteria that are applied to protect against harm to human, wildlife and fish and aquatic life communities. Please see below.*	
Numeric Biocriteria in WQS	none	
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
	✓	cause and effect determinations
	✓	permitted discharges
	✓	monitoring (e.g., improvements after mitigation)
	✓	watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	Wisconsin's bioassessment program is still evolving, but has been used regularly to make water quality management decisions that range from fishery management issues (bag limits, habitat restoration projects) to FERC license operating conditions to assessing potential vs. actual fish & aquatic life uses of surface waters.	

*__Acute Narrative Criterion__: NR 102.04(1)(d) (d) Substances in concentrations or combinations which are toxic or harmful to humans shall not be present in amounts found to be of public health significance, nor shall substances be present in amounts which are acutely harmful to animal, plant or aquatic life.
Chronic Narrative Criterion: NR 102.04(4)(d) (d) Other substances. Unauthorized concentrations of substances are not permitted that alone or in combination with other materials present are toxic to fish or other aquatic life. Surface waters shall meet the acute and chronic criteria as set forth in or developed pursuant to ss. NR 105.05 and 105.06. Surface waters shall meet the criteria which correspond to the appropriate fish and aquatic life subcategory for the surface water, except as provided in s. NR 104.02(3).

Reference Site/Condition Development

Number of reference sites	**100 total**	
Reference site determinations	✓	site-specific
		paired watershed
	✓	regional (aggregate of sites)
		professional judgment
		other:
Reference site criteria	Reference sites are defined by 1) BPJ using biota, 2) Upper quartile of biota index scores within two years, and 3) will eventually be supplemented with *a priori* land use. Also, a fish IBI is currently used, and habitat, water chemistry and macroinvertebrates will be incorporated within two years.	
Characterization of reference sites within a regional context		historical conditions
	✓	least disturbed sites
		gradient response
	✓	professional judgment
	✓	other: will eventually use *a priori* GIS land use data
Stream stratification within regional reference conditions	✓	ecoregions (or some aggregate)
		elevation
	✓	stream type *(temperature, gradient, stream order)*
		multivariate grouping
		jurisdictional (i.e., statewide)
	✓	other: will assess strata with multivariate analysis
Additional information		reference sites linked to ALU
		reference sites/condition referenced in water quality standards
	✓	some reference sites represent acceptable human-induced conditions

Field and Lab Methods

Assemblages assessed	✓	benthos *(>500 samples/year; single season, multiple sites - broad coverage)*
	✓	fish *(>500 samples/year; single season, multiple sites - broad coverage)*
	✓	periphyton *(<100 samples/year; single observation, limited sampling)*
		other:

Benthos	
sampling gear	Surber, Hess, D-frame (all limited use); 500 - 600 micron mesh
habitat selection	riffle/run (cobble)
subsample size	minimum of 125, but typically 200 - 300 organisms
taxonomy	lowest taxa-level possible - usually genus, sometimes combination
Fish	
sampling gear	backpack and boat electrofisher, pram unit (tote barge); 1/4" mesh
habitat selection	multihabitat
sample processing	length measurement, biomass- individual (gamefish), biomass- batch (non-game), anomalies
subsample	selected species
taxonomy	species
Periphyton	
sampling gear	**natural substrate**: brushing/scraping device (razor, toothbrush, etc.) **artificial substrate**: rock, rip-rap, bridge concrete
habitat selection	richest habitat
sample processing	chlorophyll *a*/ phaeophytin and taxonomic identification
taxonomy	diatoms only
Habitat assessments	quantitative measurements; performed with bioassessments
Quality assurance program elements	standard operating procedures, quality assurance plan, periodic meetings, training for biologists, sorting and taxonomic proficiency checks, specimen archival

Data Analysis and Interpretation

Data analysis tools and methods	✓	summary tables, illustrative graphs
	✓	parametric ANOVAs
	✓	multivariate analysis
	✓	biological metrics *(aggregate metrics into an index)**
	✓	disturbance gradients
		other:

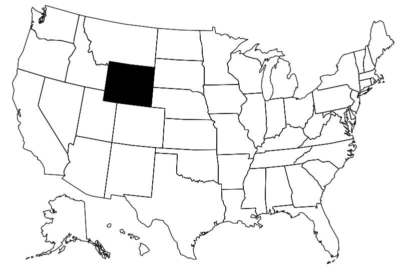
Multimetric thresholds	
transforming metrics into unitless scores	25th percentile of reference population
defining impairment in a multimetric index	25th percentile of reference population

Evaluation of performance characteristics	✓	repeat sampling
	✓	precision *(repeat sampling of assessment sites is conducted)*
	✓	sensitivity *(multiple streams along various stressor gradients have been assessed to document metric sensitivity to the stressor of concern)*
	✓	bias *(Stream habitat assessment crews assess the same site to document crew experience bias. Least-impacted streams of differing size/stream order are sampled to document macroinvertebrate metric bias among streams of varying order)*
	✓	accuracy *(multiple least-impacted streams are sampled to document metric accuracy)*

Biological data	
Storage	A database has been developed in concert with USGS. It is not currently compatible with STORET. The database can be viewed at: http://www.infotrek.er.usgs.gov/wdnr_bio/
Retrieval and analysis	SAS, Systat, and Statistica. Also, an ORACLE-based data management system is being developed to store data and provide routine report summaries and metric calculations.

*Multimetric indexes for habitat and fish have been developed, and a multimetric index for macroinvertebrates is being developed.

WYOMING



Contact Information

Jeremy ZumBerge, Monitoring Program Supervisor
Wyoming Department of Environmental Quality (WYDEQ)
1043 Coffeen Avenue, Suite D ■ Sheridan, WY 82801
Phone 307/672-6457 ■ Fax 307/674-6050
email: jzumbe@state.wy.us
WYDEQ Water Quality Division website: http://deq.state.wy.us/wqd/index.asp?pageid=5

Program Description

The primary objective of bioassessments conducted by the Wyoming Department of Environmental Quality (WYDEQ) is to assess the support of aquatic life for 303(d) listing and 305(b) reporting, using macroinvertebrates as the primary indicator. The program has been in existence since 1993, when it was initiated in the form of the Reference Stream Project (RSP). The primary goal of the RSP was to collect baseline biological data at least-impacted (reference) streams in each ecoregion of Wyoming as a benchmark for assessing biological and water quality conditions of other streams across the State. In 1998, the focus shifted from collecting reference stream data to using RSP data as a benchmark to assess biological conditions of other Wyoming streams as part of the Beneficial Use Reconnaissance Program (BURP). BURP uses a comprehensive approach (chemical, physical, and biological components) to assess water quality conditions of Wyoming streams. Today, the RSP is still ongoing, but at a much smaller scale.

Several other organizations have been or will be important sources of bioassessment data in Wyoming. The Wyoming Association of Conservation Districts (WACD) has been very involved in collecting biological data at streams across Wyoming. With proper guidance, local Conservation Districts (CDs) can elect to assume some of WYDEQ's bioassessment responsibilities, with the data being used for 303(d) and 305(b). Many CDs have welcomed the opportunity to collect bioassessment data.

The USGS also has been a very important source of biological data. Wyoming has contracted the USGS-Wyoming District to carry out the Environmental Monitoring and Assessment Program (EMAP) monitoring in Wyoming. Approximately 50 randomly selected sites will be assessed over the four year contract, with the end goal being an unbiased estimate of water quality conditions in the State. The USGS also conducted an assessment of the Yellowstone River Basin of Wyoming and Montana as part of the National Water-Quality Assessment Program (NAWQA). The considerable amount of biological data generated from these studies is being evaluated for comparability with WYDEQ data to explore the usefulness of these data for 305(b) purposes. In addition, joint-funding agreements are in place with the USGS that allow for enhanced biological monitoring of streams in areas affected by coal bed methane development.

The Wyoming Game and Fish Department (WGFD) is an important source of fish data. WYDEQ has chosen not to sample fish communities as part of bioassessments, but uses WGFD data for determining support of fisheries uses, as well as in classifying streams for assignment of uses and designating appropriate water quality standards associated with those uses.

Wyoming has made significant strides in recent years in the development of multimetric biocriteria. Work will continue toward refining the existing numeric criteria and narrative aquatic life standard, and toward the eventual implementation of numeric aquatic life standards. Implementation of numeric standards is sure to be a challenging effort. The physical heterogeneity of Wyoming (e.g., climate, landscape, land use, and geology) poses significant scientific challenges. Political considerations are also likely to pose challenges.

Currently, WY is exploring the use of predictive models for assessing biological conditions of streams, as well as the addition of periphyton as an additional biological indicator to supplement macroinvertebrate data and WGFD fish data used in bioassessments. Periphyton samples have been collected at a limited number of long-term reference stations in the past, and the use of periphyton data will expand in coming years.

Documentation and Further Information

Wyoming's 2000 305(b) State Water Quality Assessment Report and *2000 303(d) Report*: http://deq.state.wy.us/wqd/watershed/01452-doc.pdf

Wyoming Surface Water Quality Standards: http://deq.state.wy.us/wqd/index.asp?pageid=52#Stand

Manual of SOPs for Sample Collection and Analysis: http://deq.state.wy.us/wqd/watershed/10574-doc.pdf

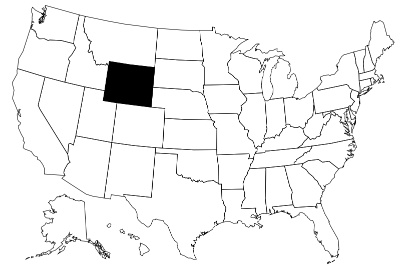
WYDEQ Water Quality Division Five-Year Comprehensive Monitoring Plan, 2001 Update, October 2001: http://deq.state.wy.us/wqd/watershed/12806-doc.pdf

Jessup, B.K. and J.B. Stribling. 2000. *Testing the Wyoming stream integrity index*. Prepared by Tetra Tech, Inc., Owings Mills, Maryland, for USEPA Region 8, Denver, CO.

Gerritsen, J; Jessup, B.K.; King, K.; Smith, J. and Stribling, J.B. 2000. *Development of Biological Criteria for Wyoming Streams and their Use in the TMDL Process.* Prepared by Tetra Tech, Inc., Owings Mills, Maryland, for USEPA Region 8, Denver, CO.

Data can be found online at http://wy.water.usgs.gov/ and http://www.wrds.uwyo.edu/

WYOMING



Contact Information

Jeremy ZumBerge, Monitoring Program Supervisor
Wyoming Department of Environmental Quality (WYDEQ)
1043 Coffeen Avenue, Suite D ■ Sheridan, WY 82801
Phone 307/672-6457 ■ Fax 307/674-6050
email: jzumbe@state.wy.us

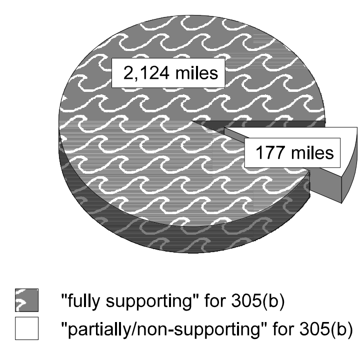
Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
	✓	monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
		promulgated into state water quality standards as biocriteria
	✓	support of antidegradation
	✓	evaluation of discharge permit conditions
	✓	TMDL assessment and monitoring
	✓	other: UAAs and site-specific standards
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(specific river basins or watersheds)*
	✓	fixed station (i.e., water quality monitoring stations) *(specific river basins or watersheds)*
		probabilistic by stream order/catchment area
		probabilistic by ecoregion, or statewide
	✓	rotating basin *(specific river basins or watersheds)*
		other:

Stream Miles

Total miles *(determined using RF3, 2000 and National Hydrography Datatbase, 2001)*	**113,422**
Total perennial miles	32,520
Total miles assessed for biology*	**2,639**
fully supporting for 305(b)	2,124
partially/non-supporting for 305(b)	177
listed for 303(d)	177
extent fully supporting, but threatened	388
number of sites sampled	700+
number of miles assessed per site	3.25

2,639 Miles Assessed for Biology



*Since a Weight-of-Evidence approach is used in use support decisions, the numbers provided reflect waterbody reach extent where some type of biological data were used in the assessment.

Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Class System (A,B,C), Fishery Based Uses and Warm Water vs. Cold Water
ALU designations in state water quality standards	Game Fish (Warm Water and Cold Water Game Fish), Non-game Fish and Aquatic Life Other than Fish
Narrative Biocriteria in WQS	Formal/informal numeric procedures exist to support ALU decisions.
Numeric Biocriteria in WQS	under development (Numeric biocriteria are in use but are still being refined and are not yet incorporated in WY's water quality standards.)

Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
	✓	cause and effect determinations
		permitted discharges
	✓	monitoring (e.g., improvements after mitigation)
	✓	watershed based management

Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	Trend analysis in watershed improvement projects and following degradation resulting from construction projects and spills.

Reference Site/Condition Development

Number of reference sites	**140** based on field investigation checklist **90** based on quantitative physical and chemical filters

Reference site determinations		site-specific
		paired watersheds
	✓	regional (aggregate of sites)
	✓	professional judgment *(Best Professional Judgment based on landscape and field investigation coupled with select water chemical and physical filters)*
		other:

Reference site criteria	Site is identified by the field investigation to be "reference quality" based on analysis of a 27 item checklist of reach and watershed characteristics plus select ecoregion specific quantitative physical and chemical filters.

Characterization of reference sites within a regional context		historical conditions
	✓	least disturbed sites
		gradient response
	✓	professional judgment
		other:
Stream stratification within regional reference conditions	✓	ecoregions (or some aggregate)
		elevation
		stream type
		multivariate grouping
		jurisdictional (i.e., statewide)
		other:
Additional information		reference sites linked to ALU
		reference sites/condition referenced in water quality standards
	✓	some reference sites represent acceptable human-induced conditions

Field and Lab Methods

Assemblages assessed	✓	benthos *(100-500 samples/year; single season, multiple sites – not at watershed level)*
		fish
	UD	periphyton
		other:
Benthos		
sampling gear		Surber, dipnet; 500-600 micron mesh
habitat selection		riffle/run (cobble)
subsample size		500 count
taxonomy		combination--genus, species
Periphyton		
sampling gear		**natural substrate:** brushing/scraping device (razor, toothbrush, etc.)
habitat selection		riffle/run (cobble)
sample processing		WYDEQ's periphyton program is under development. Samples have been collected, but analysis protocols are yet to be developed.
taxonomy		under development
Habitat assessments		visual based, quantitative measurements, hydrogeomorphology, pebble counts (Wolman), streambank stability (Bauer and Burton - EPA910/R-93-017), pool quality (Bauer and Burton); performed with bioassessments
Quality assurance program elements		standard operating procedures, quality assurance plan, periodic meetings and training for biologists, taxonomic proficiency checks, specimen archival

Data Analysis and Interpretation

Data analysis tools and methods	✓	summary tables, illustrative graphs
		parametric ANOVAs
	UD	multivariate analysis
	✓	biological metrics *(aggregate metrics into an index)*
		disturbance gradients
		other:
Multimetric thresholds		
transforming metrics into unitless scores		95th percentile of reference population
defining impairment in a multimetric index		25th percentile of reference population
Evaluation of performance characteristics	✓	repeat sampling *(select sites are sampled annually to document annual variability)*
	✓	precision *(side-by-side sampling at 10% of stations; Data Quality Objectives for density and number of taxa)*
		sensitivity
		bias
		accuracy
Biological data		
Storage		STORET, EDAS, and internal spreadsheets
Retrieval and analysis		EDAS

AMERICAN SAMOA

Contact Information

Edna Buchan, Water Program Manager
American Samoa Environmental Protection Agency (ASEPA)
Executive Office Building ■ Pago Pago, American Samoa 96799
Phone 684/633-2304 ■ Fax 684/633-5801
email: ednabuchan@hotmail.com
website: http://www.asg-gov.com/agencies/epa.asg.htm

Program Description

American (Amerika) Samoa is a group of six Polynesian islands in the South Pacific. Located fourteen degrees below the equator, it is the United States' southern-most territory.

The American Samoa Environmental Protection Agency (ASEPA) develops and implements programs that protect environmental and public health from harmful impacts on air and water quality. USEPA works in partnership with ASEPA and provides funding and technical assistance to carry out environmental programs. ASEPA activities include water quality monitoring, inspecting facilities and new developments for compliance with environmental regulations, preparing responses to hazardous material releases, advocating practices that decrease and prevent pollution, and educating the public on environmental issues and practices.

American Samoa does not have a biological assessment program in place, and has no immediate plans for implementing a bioassessment program. The American Samoa Water Quality Standards contain no numeric biocriteria. Wording in standards that states that Fresh Surface Water and Wetlands "shall be protected to support the propagation of indigenous aquatic and terrestrial life" may be considered narrative criteria.

Documentation and Further Information

Personal communication (email), Edna Buchan, 11/26/2001.

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Commonwealth of Northern Mariana Islands (CNMI)

Contact Information

Peter C. Houk, Marine Biologist
CNMI Division of Environmental Quality (DEQ)
P.O. Box 501304 ■ Saipan, MP 96950
Phone 670/664-8505 ■ Fax 670/664-8540
email: peter.houk@saipan.com
website: http://www.deq.gov.mp/

Program Description

NOTE: Since few freshwater sources exist on the islands, all information in this program summary refers to CNMI's marine environments (CNMI has only two or three, very small, perennial streams. CNMI's dynamic tropical marine system requires different approaches and techniques than are used by the states to develop biocriteria.)

The objective of CNMI's Marine Monitoring Program is to monitor CNMI's reefs, lagoon, and reef flats with regards to benthic communities, macroinvertebrate and fish abundances, and water quality. In addition, CNMI has a biodiversity list of all organisms encountered in CNMI and a reference collection. CNMI Water Quality Standards clearly state that benthic communities can not be altered due to a discharge (Section 7.12 (d)). Any significant changes would be changes from 1) previous conditions at the same site or 2) changes from a similar reference site. The goal is to gather as much baseline data in as many different areas as possible to use for comparisons. Last year, a "State of the Reef Report" was completed which comprises all of the results from monitoring efforts.

In 2001, the focus was on assessments of nearshore coral reef systems surrounding Saipan and Rota. The 2000/2001 *State of the Reef Reports* were produced summarizing past and present coral reef data for Saipan and Rota. Though it would be impossible to survey the entire coral reef system around CNMI with current resources, there are approximately 20 sites established for intensive data collection on a yearly basis. The goal is to continue to enhance CNMI's interagency marine monitoring group composed of Coastal Resources Management, Division of Fish and Wildlife, and Division of Environmental Quality. Assessments of existing and additional sites on Rota, Saipan, Tinian, and other Northern Islands will be conducted and included in the next Reef Report (2002). Data will be used for future assessments of natural disasters, potential anthropogenic disturbances/development, and overall biological health.

In 2002, the entire Saipan Lagoon, covering several watersheds, will also be surveyed to assess and understand how upland runoff (nonpoint source pollution) may be affecting this valuable resource. The entire lagoon will be divided into habitats and quantitative and qualitative data from each habitat will be gathered. Once completed, existing aerial photographs will be scanned and remote sensing techniques will delineate the habitats found. The end result will be used to examine correlations between water quality, drainage areas, other areas of concern, and the lagoon habitat. This project is also required by the Army Corps of Engineers in order to proceed with a master drainage plan for areas associated with Saipan's Lagoon. Lagoon survey work is currently a joint project between NOAA's Coastal Resource Management Program and DEQ. Hopefully, the Division of Fish and Wildlife will be involved in this project in 2002 as well.

CNMI's reef monitoring program is based on site selection. Sites that have "concerns" or "disturbances" are selected, as well as several reference sites. There are many more habitats in the nearshore coral reef communities around CNMI than are found in the Saipan Lagoon, hence the difference in methods. Also, weather conditions prohibit surveys on windward sides of the islands most of the year. All of this data is very useful for understanding baseline water quality conditions, and these data are used for assessment when and if projects are proposed that involve a discharge.

CNMI's program can not follow the same type of biocriteria monitoring program implemented in any of the U.S. states. There is a very dynamic tropical marine system surrounding CNMI which warrants the use of techniques different than those used by our State counterparts.

Documentation and Further Information

Commonwealth of Northern Mariana Islands Water Quality Assessment Report 305(b), April 2000

Commonwealth of Northern Mariana Islands Water Quality Assessment Report 305(b), 2002
(Interested parties can contact Peter Houk, CNMI DEQ, or EPA Region 9 for a copy of either report)

CNMI *State of the Reef Report*, 2000

CNMI *Nonpoint Source and Marine Monitoring Program* information: http://www.deq.gov.mp/NPS/default.htm

Commonwealth of Northern Mariana Islands

Contact Information

Peter C. Houk, Marine Biologist
CNMI Division of Environmental Quality (DEQ)
P.O. Box 501304 ■ Saipan, MP 96950
Phone 670/664-8505 ■ Fax 670/664-8540
email: peter.houk@saipan.com

Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
	✓	monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
	✓	promulgated into state water quality standards as biocriteria
	✓	support of antidegradation
	✓	evaluation of discharge permit conditions
		TMDL assessment and monitoring
	✓	other: public information and awareness
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(special projects only)*
	✓	fixed station (i.e., water quality monitoring stations) *(comprehensive use throughout jurisdiction)*
		probabilistic by stream order/catchment area
		probabilistic by ecoregion, or statewide
		rotating basin
		other:

Stream Miles* (pertains to coral reef monitoring)

Total miles	**–**
Total perennial miles	–
Total miles assessed for biology	**n/a**
fully supporting for 305(b)	n/a
partially/non-supporting for 305(b)	n/a
listed for 303(d)	n/a
number of sites sampled on the reef *(on an annual basis)*	20
number of miles assessed per site	site specific

*The above section is not applicable to CNMI's monitoring program since no stream monitoring is conducted. For lagoon surveys, CNMI plans to intensively survey and create habitat maps for the entire Saipan Lagoon system. This covers several watersheds. CNMI's outer reef monitoring program is based on site selection - sites that have "concerns" or "disturbances," as well as several reference sites. There are many more habitats in the nearshore coral reef communities around CNMI than are found in the Saipan Lagoon, hence the difference in methods. Also, weather conditions prohibit surveys on windward sides of the islands most of the year. All of these data are very useful for understanding baseline water quality conditions, and these data are used for assessment when and if projects are proposed that involve a discharge.

Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis		Class System (A,B,C)
ALU designations in state water quality standards		AA - top quality marine, A - marine non-recreational 1 - surface water (runoff mainly, no rivers) highest quality, 2 - surface water non-recreational
Narrative Biocriteria in WQS		Formal/informal numeric procedures used to support narrative biocriteria are determined by the best available data.
Numeric Biocriteria in WQS		none (Numeric biocriteria are located in yearly reports on monitoring activities. Each site differs with respect to benthic communities and CNMI's WQS uses the term "shall not differ substantially from those where similar conditions exist.")
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
		cause and effect determinations
		permitted discharges
		monitoring (e.g., improvements after mitigation)
		watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU		A ponding basin was established on Rota Island in response to CNMI DEQ's monitoring results. There are also other small projects similar to this. DEQ is collecting baseline data with the intention of using it to assess BMPs and aid future decision-making.

Reference Site/Condition Development

Number of reference sites		**5 total**
Reference site determinations	✓	site-specific
		paired watersheds
		regional (aggregate of sites)
	✓	professional judgment
	✓	other: based on benthic community composition
Reference site criteria		Reference sites are chosen based on similar geological/physical features (slope, substrate, etc.). They are sites similar in community composition that are not subjected to the discharge in question. There are usually several on each island in CNMI.
Characterization of reference sites within a regional context *Not applicable**		historical conditions
		least disturbed sites
		gradient response
		professional judgment
		other:
Stream stratification within regional reference conditions *Not applicable*		ecoregions (or some aggregate)
		elevation
		stream type
		multivariate grouping
		jurisdictional (i.e., statewide)
		other:
Additional information	✓	reference sites linked to ALU *(in some cases)*
		reference sites/condition referenced in water quality standards
	✓	some reference sites represent acceptable human-induced conditions *(in some cases)*

*Characterization of reference sites does not apply because CNMI uses a degree of community change based on reference versus test sites.

Field and Lab Methods*

Assemblages assessed	✓	benthos *(<100 samples/year; single season, multiple sites - broad coverage)*
	✓	fish *(<100 samples/year; single season, multiple sites - broad coverage)*
		periphyton
	✓	other: waterfowl *(100-500 samples/year; multiple seasons, multiple sites - broad coverage for watershed level)*
Benthos*		
sampling gear		Transect lines, underwater photo equipment, hammer, measuring tapes, diving gear, underwater slates/pencils
taxonomy		genus and species
Fish*		
sampling gear		speargun, reference books
taxonomy		species
Habitat assessments		quantitative measurements, benthic coverage estimates of major benthos, basic water quality parameter measurements, abundances of fish and macroinvertebrates, and biodiversity of all organisms present; performed with bioassessments
Quality assurance program elements		standard operating procedures, quality assurance plan, periodic meetings and training for biologists, and specimen archival

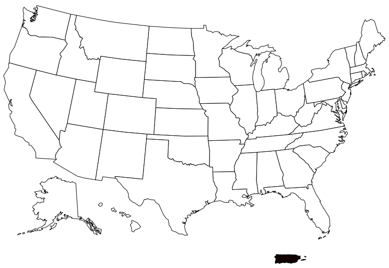
*Following is a summary of biological sampling methods used in the reef – see CNMI's *State of the Reef Report* for details

- Three 50 meter transect lines are secured parallel to the shoreline (laid end-to-end, 150m total length), and marked with a sediment trap holder and re-bar driven securely into the reef.
- For benthics, an underwater camera is used to take still photographs of .5-m quadrats placed at all even numbers along the transect line. For each photo the bottom right corner of the quadrat is aligned with the corresponding transect line distance.
- Coral communities are examined using the point-quarter method described by Randall et al., (1988). A dive knife is haphazardly tossed 16 times along the three transects. For each toss the distance to the nearest living coral colony is noted for each of four quadrants, as well as the diameter and taxonomic name.
- Fish abundance is determined by a single observer swimming along the transect lines recording data. Counts of all fishes within 5 meters of each side of the transect line are recorded. Fishes are identified to the family level.
- All macroinvertebrates within 2 meters of each side of the transect line are counted. These data were presented as abundances per (100-m^2) of reef on each of three transects. Macroinvertebrates are either identified to genus or grouped by life form, depending on abundances.
- Sediment traps provide sedimentation rate data from sites where sedimentation is a concern.
- Water samples are taken for chemistry.

Data Analysis and Interpretation

Data analysis tools and methods	✓	summary tables, illustrative graphs
	✓	parametric ANOVAs
	✓	multivariate analysis
		biological metrics
		disturbance gradients
	✓	other: distribution analysis and cluster analysis
Multivariate thresholds		
defining impairment in a multivariate index		5th percentile of reference population (Pvalue of .05 is cut off)
Evaluation of performance characteristics	✓	repeat sampling
		precision
		sensitivity
		bias
		accuracy
Biological data		
Storage		MS Access, Excel, Word, Arcview GIS and Photo documentation
Retrieval and analysis		Excel

PUERTO RICO and the U.S. VIRGIN ISLANDS



Contact Information

James Kurtenbach, Aquatic Biologist
USEPA - Region II, Division of Environmental Monitoring and Assessment
2890 Woodbridge Avenue, Bldg. 209 ■ Edison, NJ 08837
Phone 732/321-6695 ■ Fax 732/321-6616
email: kurtenbach.james@epa.gov

Program Description

Puerto Rico is presently evaluating Rapid Bioassessment Protocols (RBPs) for mountain streams. According to the Water Monitoring Plan for fiscal year 2002, the Puerto Rico Environmental Quality Board (PREQB), in coordination with EPA Region II, will continue to work on the development of biological indicators for stream monitoring. PREQB is responsible for current monitoring activities which include ambient water quality monitoring, intensive water quality studies, and 305(b) reporting. The 2000 Cycle 305(b) Report doesn't include any biological information (aside from limited wetland loss data). The EPA (ORD Coastal 2000 Program) conducted an EMAP study on the estuaries of Puerto Rico, which included benthic macroinvertebrate sampling.

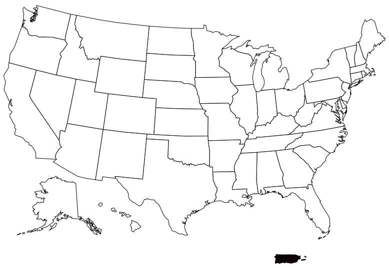
The *U.S. Virgin Islands 2000 Water Quality Assessment* reported that there are "no perennial streams on any of the islands; intermittent streams can only be seen after heavy rainfall. The absence of large freshwater resources and perennial streams means that *guts* (watercourses) form the basis for watershed management in the territory." Also, the Virgin Islands primarily assess coastal waters and estuaries, but "no monitoring for biological effects is conducted for lack of baseline standards for Virgin Islands conditions. According to the Virgin Islands multi-year monitoring strategy, the Department of Planning and Natural Resources (DPNR) will explore options for implementing a biological component of the Ambient Monitoring Program. This may include developing a partnership with NOAA or another agency with similar monitoring objectives."

Documentation and Further Information

Goals and Progress of Statewide Water Quality Management Planning: Puerto Rico 1998-1999, 2000 Cycle 305(b) Report. Puerto Rico Environmental Quality Board. November 2000.

2000 Water Quality Assessment for the United States Virgin Islands, 2000 305(b) Report. Department of Planning and Natural Resources, Division of Environmental Protection (DPNR/DEP). April 2001.

PUERTO RICO and the
U.S. VIRGIN ISLANDS



Contact Information

James Kurtenbach, Aquatic Biologist
USEPA - Region II, Division of Environmental Monitoring and Assessment
2890 Woodbridge Avenue, Bldg. 209 ■ Edison, NJ 08837
Phone 732/321-6695 ■ Fax 732/321-6616
email: kurtenbach.james@epa.gov

Programmatic Elements

Uses of bioassessment within overall water quality program *Not currently used*		problem identification (screening)
		nonpoint source assessments
		monitoring the effectiveness of BMPs
		ALU determinations/ambient monitoring
		promulgated into state water quality standards as biocriteria
		support of antidegradation
		evaluation of discharge permit conditions
		TMDL assessment and monitoring
		other:
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(special projects only)*
	✓	fixed station (i.e., water quality monitoring stations) *(special projects only)*
		probabilistic by stream order/catchment area
		probabilistic by ecoregion, or statewide
		rotating basin
		other:

Stream Miles

***NOTE:** These stream and river miles apply only to Puerto Rico. The U.S. Virgin Islands reports no stream miles.*

Total miles *(determined using RF3)*	**5,394.2**
Total perennial miles	–
Total miles assessed for biology*	**0**
fully supporting for 305(b)	n/a
partially/non-supporting for 305(b)	n/a
listed for 303(d)	n/a
number of sites sampled	n/a
number of miles assessed per site	n/a

*Specific biological studies have been conducted, but there are no ongoing projects. However, Puerto Rico does conduct other regular chemical and physical monitoring. According to PR's 2000 305(b) report, during the 1998 - 1999 monitoring cycle there were 5,394 total assessed miles; 4,297 evaluated segments; and 1,096 monitored segments. Of the 1,096.7 river miles monitored for Aquatic Life Use, 222.4 miles were determined to be fully supporting, 16.8 miles were partially supporting, and 857.5 miles were non-supporting.

Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Class System (A,B,C)	
ALU designations in state water quality standards	Standards list definitions for the following: pelagic and planktonic species, propagation and preservation of desirable species.	
Narrative Biocriteria in WQS	none (Puerto Rico and the U.S. Virgin Islands have no biocriteria. According to Puerto Rico's 2000 305(b) report, there were expectations of achieving/developing some, but no monitoring strategy has been submitted as of yet.)	
Numeric Biocriteria in WQS	none	
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria) *Not currently used*	☐	assessment of aquatic resources
	☐	cause and effect determinations
	☐	permitted discharges
	☐	monitoring (e.g., improvements after mitigation)
	☐	watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	none	

Reference Site/Condition Development*

Number of reference sites	**none**	
Reference site determinations	☐	site-specific
	☐	paired watersheds
	☐	regional (aggregate of sites)
	☐	professional judgment
	☐	other:
Reference site criteria		
Characterization of reference sites within a regional context	☐	historical conditions
	☐	least disturbed sites
	☐	gradient response
	☐	professional judgment
	☐	other:
Stream stratification within regional reference conditions	☐	ecoregions (or some aggregate)
	☐	elevation
	☐	stream type
	☐	multivariate grouping
	☐	jurisdictional (i.e., statewide)
	☐	other:
Additional information	☐	reference sites linked to ALU
	☐	reference sites/condition referenced in water quality standards
	☐	some reference sites represent acceptable human-induced conditions

*This section is not applicable – no biological monitoring is conducted in Puerto Rico or the U.S. Virgin Islands, thus neither territory has reference sites.

Field and Lab Methods*

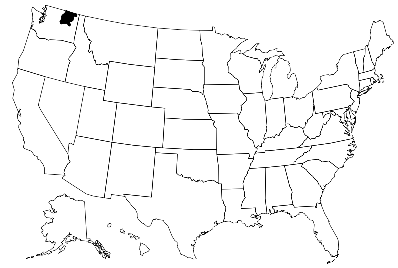
Assemblages assessed	☐ benthos ☐ fish ☐ periphyton ☐ other:
Habitat assessments	not applicable
Quality assurance program elements	not applicable

Data Analysis and Interpretation*

Data analysis tools and methods	☐ summary tables, illustrative graphs ☐ parametric ANOVAs ☐ multivariate analysis ☐ biological metrics ☐ disturbance gradients ☐ other:
Evaluation of performance characteristics	☐ repeat sampling ☐ precision ☐ sensitivity ☐ bias ☐ accuracy
Biological data	
Storage	not applicable
Retrieval and analysis	not applicable

*These sections are not applicable since no biological monitoring is conducted in Puerto Rico or the U.S. Virgin Islands.

CONFEDERATED TRIBES OF THE COLVILLE RESERVATION



Contact Information

Gary Passmore, Office of Environmental Trust
Confederated Tribes of the Colville Reservation
P.O. Box 150 ■ Nespelem, WA 99155
Phone 509/634-2200 ■ Fax 509/634-4116
email: gary.passmore@colvilletribes.com
website: http://www.colvilletribes.com/

Program Description

The Colville Indian Reservation land base covers 1.4 million acres or 2,100 square acres located in North Central Washington, primarily in Okanogan and Ferry counties. The Reservation consists of tribally owned lands held in federal trust status for the Confederated Tribes, land owned by individual Colville tribal members (most of which is held in federal trust status), and land owned by others (described as fee property and taxable by counties). Colville Reservation lands are diverse with natural resources including standing timber, streams, rivers, lakes, minerals, varied terrain, native plants and wildlife.

Although the Confederated Tribes of the Colville Reservation do have federally approved water quality standards, the Tribes' Office of Environmental Trust doesn't use biological assessment methods as a means to assess water quality. In 2001, the Tribes gave permission to the State of Washington Department of Ecology to conduct some biological assessments on the reservation, but the results of those surveys are not yet complete. The primary obstacle to conducting bioassessment has been cost. The water quality monitoring program is reevaluated every year, and it is possible the Tribes may implement biological monitoring in the future.

Documentation and Further Information

Personal Communication (email), Gary Passmore, 11/28/2001.

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NEZ PERCE TRIBE

Contact Information

Ann Storrar, Water Planner
Nez Perce Tribe Department of Natural Resources
P.O. Box 365 ■ Lapwai, Idaho 83540
Phone 208/843-7368 ■ Fax 208/843-7371
email: anns@nezperce.org
website: http://www.nezperce.org/

Program Description

The Nez Perce Reservation is located in North Central Idaho. The Tribal Department of Natural Resources consists of the Land Services, Cultural Resources, Wildlife Resources, Forest Resources, Water Resources, and Environmental Restoration and Waste Management Programs. These programs focus on delivering resource management services on the Reservation and participating in the planning and decisions of land management activities affecting the Nez Perce Treaty area. The programs provide protection of reserved treaty-rights in all areas to their best abilities. Department administration is structured to facilitate an interdisciplinary approach in meeting these needs.

Currently the Tribe is collecting baseline chemical and physical habitat data on Reservation waterbodies and will, eventually, be establishing its own water quality standards for the reservation area. The Nez Perce Tribe may soon promulgate the standards USEPA is developing for Indian country, with the idea of refining them from narrative standards to both chemical and biological criteria. The Tribe has used the State of Idaho Beneficial Use Assessment Procedure (BURP) for reservation water bodies in 1997, 1998 and 1999 and would like to adopt its own protocols for beneficial use assessment.

The Tribe recently obtained funds to begin the EMAP bioassessment procedure for the reservation. This will be accomplished through participation in the EMAP Western Pilot and methods will be developed based on EMAP protocols.

Documentation and Further Information

Personal Communication (email), Ann Storrar, 10/01/2001.

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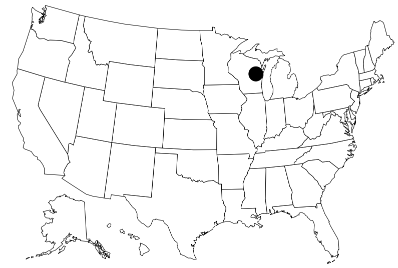
ONEIDA NATION OF WISCONSIN



Contact Information

James L. Snitgen, Water Resources Team Leader
Oneida Nation of Wisconsin, Environmental, Health and Safety Department
P.O. Box 365, 3759 W. Mason Street ■ Oneida, WI 54155
Phone 920/497-5812 ■ Fax 920/496-7883
email: jsnitgen@oneidanation.org
website: http://www.oneidanation.org

Program Description

Objectives

The Oneida Tribe's current and future uses of information gathered using bioassessment include protection, restoration, assessing impacts, monitoring changes, as well as driving policy and promoting knowledge and appreciation of aquatic resources.

Background

Although there had been some invertebrate and fish surveys performed on the Reservation over the last twenty years or so, the development of a formal biological monitoring program was initiated in 2000. Tri-annual fishery surveys at established monitoring sites have been performed since 1997. In 1999, the Tribe began sampling invertebrate communities and immediately began using the findings as tools. An onsite aquatic invertebrate taxonomy laboratory was also established in 1999 and equipped with scopes, literature, drying oven, hood, etc. In 2000, qualitative sampling of invertebrates was performed at five stream sites and a quantitative study of one lake was initiated to determine the effectiveness of BMPs in the surrounding basin. In the meantime, SOPs were developed for qualitative and quantitative methods for lakes and wadeable streams and metrics were researched and tested. Contracts were set up for the picking and sorting of invertebrate samples (UW-Superior) and for toxicity testing (Environmental Consulting and Testing) of certain waterbodies. In 2001, quantitative samples were collected at three stream sites and the lake, as well as three more sites being sampled qualitatively. Stream types have not been formalized, but four reference sites have been established:

1. **Thornberry Creek** (at forest Drive), a first order cold water system, exhibiting "pristine" conditions during 1999 and 2000.
2. **Trout Creek** (at County FF), a 3rd order cold water system, exhibiting "good" to "very good" conditions.
3. **Oneida Creek** (at VanBoxtel Road), a 3rd order cool water system, exhibiting "good" conditions in 2000. A very rare fingernet caddisfly, *Wormaldia moesta*, known to occur only in "small, cold, rapid streams" has been collected at this site.
4. **Duck Creek** (at Seminary Road), a 4th order warm water system, the largest stream on the Reservation. The water quality and invertebrate community represent "good" conditions. The same stream is in "poor" condition before entering the Reservation from the south near the Town of Freedom.

The streams at these sites represent the reference conditions for all stream types on the Reservation. In 2002, qualitative or quantitative sampling will be conducted at approximately 30 invertebrate sites and mid-summer fish IBIs will be conducted at eleven sites.

Setting/Land Use

The entire Reservation, covering approximately 64,500 acres, is in the Southeastern Wisconsin Till Plains ecoregion (Omernick 1987). At this time, the main sources of impairment are sedimentation (construction and agriculture) and nutrients (agriculture, suburban lawns, golf courses). The Reservation straddles the boundary of Brown and Outagamie Counties and includes all or portions of the City of Green Bay, Villages of Ashwaubenon and Howard, and the Towns of Hobart, Oneida and Pittsfield. Eleven additional municipalities rest within the watersheds flowing through the Reservation. All surface waters within the Oneida Reservation drain to the Great Lakes Basin (Lake Michigan). There are four separate surface water drainages, bearing numerous tributaries:
1) Duck Creek River – Fish Creek, Oneida Creek, Trout Creek, Lancaster Brook, Beaver Dam Creek, Silver Creek (*Lower Green Bay Basin*); 2) South Branch of the Suamico River (*Upper Green Bay Basin*); 3) Ashwaubenon Creek – North Branch, South Branch, Hemlock Creeks (*Fox River Basin*); and 4) Dutchman Creek (*Fox River Basin*)

Land use percentages surrounding the sites will be mapped this summer (2002), and the first formal biomonitoring report is being produced.

Metrics and Biocriteria Development

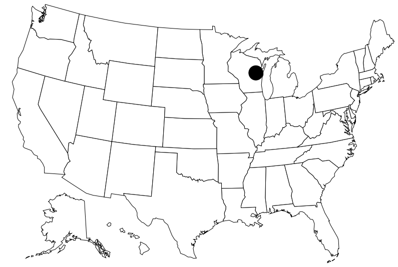
While the Oneida Nation does not have federally approved water quality standards, the Tribe is implementing a water quality program with bioassessment surveys under tribal law. The inclusion of biocriteria into the Tribe's WQS has been delayed due to urgent water resource issues that have come up, rather than lack of information. The appropriate metrics to accurately predict responses in benthic invertebrate communities for the area are fairly well proven at this time. The metrics currently being used (for streams) are the Hilsenhoff Biotic Index (HBI), Taxa Richness, dominance, percent clingers and in some cases Ephemeroptera, Plecoptera and Trichoptera (EPT) and E, P and T taken separately. The most common impacts are due to sedimentation and organic loading. Because of the limited number and type of streams within the Reservation, it is believed that the appropriate reference sites to represent all of the stream types have been selected. A final designation of these has not been made, nor are biocriteria being submitted for inclusion in the WQS until there is a chance to conduct more sampling of test sites to compare with the reference sites.

Documentation and Further Information

Personal communication (letter), James L. Snitgen, 1/2002.

Hard copies of documents including the Oneida Nation's WQS; SOPs for the Qualitative Sampling (#BI002) and Quantitative Sampling (#BI003) of Streams for Benthic Invertebrates; Annual Water Resources Report (future reports will contain fish and macroinvertebrate data)

ONEIDA NATION OF WISCONSIN



Contact Information

James Snitgen, Water Resources Team Leader
Oneida Nation of Wisconsin, Environmental, Health and Safety Department
P.O. Box 365, 3759 W. Mason Street ■ Oneida, WI 54155
Phone 920/497-5812 ■ Fax 920/496-7883
email: jsnitgen@oneidanation.org

Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
	✓	monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
		promulgated into state water quality standards as biocriteria
	✓	support of antidegradation
		evaluation of discharge permit conditions
		TMDL assessment and monitoring
		other:
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose)
	✓	fixed station (i.e., water quality monitoring stations)
		probabilistic by stream order/catchment area
		probabilistic by ecoregion, or statewide
		rotating basin
		other:

Stream Miles

Total miles	**233**
Total perennial miles	–
Total miles assessed for biology	–
fully supporting for 305(b)	n/a
partially/non-supporting for 305(b)	n/a
listed for 303(d)	n/a
number of sites sampled *(in summer 2002)*	41
number of miles assessed per site	~0.02 miles (25 meters)

Aquatic Life Use (ALU) Designations and Decision-Making*

ALU designation basis		Warm Water vs. Cold Water
ALU designations in state water quality standards		Two designations: cold water ecosystems, warm water ecosystems
Narrative Biocriteria in WQS		Inclusion of narrative and numeric biocriteria into the Tribe's WQS is under development, as is nutrient criteria. Tribal WQS include biological and water quality language but this does not constitute formal biocriteria.
Numeric Biocriteria in WQS		see above
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
	✓	cause and effect determinations
		permitted discharges
	✓	monitoring (e.g., improvements after mitigation)
	✓	watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU		Macroinvertebrate community data were used to designate one stream as a cold water resource. RBPs were conducted following a stormwater spill.

*Water quality standards were federally approved in 1996 and then rescinded following a lawsuit.

Reference Site/Condition Development

Number of reference sites		**4 total**
Reference site determinations		site-specific
		paired watershed
		regional (aggregate of sites)
	✓	professional judgment *(Qualitative data gathered initially on candidate reference sites. Most "pristine" of each stream type used as reference--still in early stages of determining all necessary reference sites)*
		other:
Reference site criteria		water quality, benthic invertebrate community (Hilsenhoff Biotic Index), land use, physical habitat, geomorphology, qualitative benthos investigations
Characterization of reference sites within a regional context		historical conditions
	✓	least disturbed sites
		gradient response
		professional judgment
		other:
Stream stratification within regional reference conditions		ecoregions (or some aggregate)
		elevation
	✓	stream type *(all within Reservation/all in same ecoregion)*
		multivariate grouping
		jurisdictional (i.e., statewide)
		other:
Additional information	UD	reference sites linked to ALU
	UD	reference sites/condition referenced in water quality standards
	✓	some reference sites represent acceptable human-induced conditions

Field and Lab Methods*

Assemblages assessed	✓	benthos *(<100 samples per year; single season, multiple sites - broad coverage)*
	✓	fish *(<100 samples per year; multiple seasons, multiple sites - broad coverage for watershed level)*
		periphyton
		other:
Benthos		
sampling gear		Surber, D-frame, collect by hand; 500 micron mesh
habitat selection		riffle/run (cobble)
subsample size		300 count
taxonomy		species
Fish		
sampling gear		backpack electrofisher; 1/4" mesh
habitat selection		previously established monitoring sites and/or sites suitable for long term monitoring
sample processing		biomass - individual (identify and count)
subsample		none
taxonomy		species
Habitat assessments		visual based, quantitative measurements; performed with bioassessments
Quality assurance program elements		standard operating procedures, periodic meetings and training for biologists, sorting and taxonomic proficiency checks, specimen archival

*The Oneida Nation has sampled fish for four years and began a macroinvertebrate program in 2001 using the RBP habitat rating score sheet. The Tribe's first herpetile survey is planned for summer 2002 to collect baseline data on two riverways and three wetlands. Oneida also plans to begin using macrophytes as indicators in wetlands.

Data Analysis and Interpretation

Data analysis tools and methods	✓	summary tables, illustrative graphs
	✓	parametric ANOVAs
		multivariate analysis
	✓	biological metrics *(aggregate metrics into an index and return single metrics)*
		disturbance gradients
		other:
Multimetric thresholds		
transforming metrics into unitless scores		information not provided
defining impairment in a multimetric index		information not provided
Evaluation of performance characteristics	✓	repeat sampling
	✓	precision (replicates)
		sensitivity
		bias
		accuracy
Biological data		
Storage		Macroinvertebrate data in Corel Quattro Pro; fish data in MS Access
Retrieval and analysis		information not provided

PASSAMAQUODDY TRIBE, PLEASANT POINT RESERVATION

Contact Information

Deirdre Whitehead
Passamaquoddy Tribe at Pleasant Point
P.O. Box 343 ■ Perry, Maine 04667
Phone 207/853-2600
email: deirdre@wabanaki.com
website: http://www.wabanaki.com

Program Description

The Passamaquoddy Tribe at Pleasant Point is located in coastal Maine, near the border of New Brunswick. The Tribe's Environmental Department is responsible for the health of the natural resources under Tribal Management. This responsibility begins by assessing and mapping these resources and related risks, then developing programs to insure that these natural resources are protected. While the Passamaquoddy Tribe does not have federally approved water quality standards, it is implementing a water quality program with limited bioassessment surveys under tribal law. Current water quality work includes testing salt water for fecal coliform and phytoplankton in a cooperative arrangement with the Maine Department of Marine Resources (DMR) and the Cobscook Bay Resource Center. This work provides the DMR with information to manage closure of clam flats.

Documentation and Further Information

Personal communication (email), Deirdre Whitehead, 11/30/2001.

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PYRAMID LAKE PAIUTE TRIBE

Contact Information

Dan Mosley, Environmental Specialist
Pyramid Lake Paiute Tribe, Environmental Department
P.O. Box 256 ■ Nixon, NV 89424
Phone 775/574-0101 ■ Fax 775/574-1025
email: dmosley@powernet.net
website: http://plpt.nsn.us/

Program Description

The Pyramid Lake Paiute Tribe's Reservation is located thirty five miles northeast of Reno, Nevada in a remote desert area situated in the counties of Washoe, Lyon, and Storey. The area of the reservation contains 475,000 acres or 742.2 square miles.

The Environmental Department of the Pyramid Lake Paiute Tribe (PLPT) has been conducting bioassessments on waterbodies within the reservation border since 1975. An ecological study on Pyramid Lake was conducted from 1975 through 1977. A comprehensive bioassessment study was conducted on the lower Truckee River during the summer of 1981. In 1989, a regular Rapid Bioassessment (RBA) program was established for the Truckee River, following the first EPA bioassessment training in Reno, Nevada.

PLPT is in the process of establishing standardized protocols for assessing the biological and physical conditions of wadeable streams within the exterior boundaries of the Pyramid Lake Paiute Indian Reservation. The Tribe will use protocols outlined in EPA's Rapid Bioassessment Protocols (USEPA 1989). There are plans to incorporate the bench sheets and protocols as outlined by the California Department of Fish and Game (CA DFG) Water Pollution Control Laboratory in their *California Stream Bioassessment Procedure* (May 1999). These technical documents describe RBA in more detail. Updating and developing aquatic/riparian RBA techniques is an ongoing process.

The PLPT RBA program will ensure that the information generated can be compatible with the National or State EPA bioassessment program, to produce high quality and reliable assessments of stream habitat and water quality. A professional aquatic biologist/entomologist will act as the project team leader, backed by an interdisciplinary team of two to four biologists and/or technicians.

Fish and benthic macroinvertebrates (BMIs) will be identified to the lowest taxonomic level possible (genus/species). The presence or absence of fish and BMIs are proven indicators of an impaired or healthy aquatic system. Bioassessments can be used to detect impairments to aquatic communities from point and nonpoint sources of pollution and for assessing ambient biological condition. The upper third of riffles will be targeted for collecting biological samples because they are the richest habitat for BMIs in wadeable streams. The Tribe's goal is to protect an endangered lake sucker called a "Cui-ui" (*Chasmistes cujus*), and the threatened Lahontan Cutthroat Trout.

In summer 2001, the Tribe initiated a RBA program for springs and wetlands. A wetland specialist will act as team leader, looking at amphibians, wildlife, BMIs, birds, plants, and water chemistry for each waterbody as indicators of an impaired or healthy aquatic system.

In the future, PLPT plans to explore numeric biocriteria for BMIs on the Truckee River. The Tribe will also begin gathering baseline data on the five streams that surround Pyramid Lake. The Tribe's water quality standards are currently undergoing review by EPA.

Documentation and Further Information

Personal communication (letter), Dan Mosely, 2001.

The following PLPT department homepages are under development (July 2002):
Environmental Department: http://plpt.nsn.us/modules.php?name=Sections&sop=listarticles&secid=21
Water Resources Department: http://plpt.nsn.us/modules.php?name=Sections&sop=listarticles&secid=20

PYRAMID LAKE PAIUTE TRIBE

Contact Information

Dan Mosley, Environmental Specialist
Pyramid Lake Paiute Tribe, Environmental Department
P.O. Box 256 ■ Nixon, NV 89424
Phone 775/574-0101 ■ Fax 775/574-1025
email: dmosley@powernet.net

Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
	UD	monitoring the effectiveness of BMPs
	UD	ALU determinations/ambient monitoring *(to be developed)*
	UD	promulgated into tribal water quality standards as narrative biocriteria
	UD	support of antidegradation
		evaluation of discharge permit conditions
	UD	TMDL assessment and monitoring
		other:
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(specific river basins or watersheds)*
	✓	fixed station (i.e., water quality monitoring stations)
		probabilistic by stream order/catchment area
		probabilistic by ecoregion, or statewide
		rotating basin
		other:

Stream Miles

Total miles	–
Total perennial miles	–
Total miles assessed for biology	**31+**
fully supporting for 305(b)	–
partially/non-supporting for 305(b)	–
listed for 303(d)	–
number of sites sampled*	13 to 15
number of miles assessed per site	–

*Eight to ten sites are sampled on the Truckee River, covering 31 miles. Five sites on five streams surrounding Pyramid Lake are also sampled.

Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	Fishery Based Uses	
ALU designations in state water quality standards	under development	
Narrative Biocriteria in WQS	under development (Narrative biocriteria are incorporated into Pyramid Lake's water quality standards, but are currently awaiting approval by EPA Region 9. No formal/informal numeric procedures are used to support narrative biocriteria.)	
Numeric Biocriteria in WQS	under development (The Pyramid Lake Paiute Tribe will be developing "scientifically defensible" numeric biocriteria for the Lower Truckee River over the next several years.)	
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
	UD	cause and effect determinations
	UD	permitted discharges
	UD	monitoring (e.g., improvements after mitigation)
	UD	watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	presently none - to be developed	

Reference Site/Condition Development*

Number of reference sites	**under development**	
Reference site determinations		site-specific
		paired watersheds
		regional (aggregate of sites)
	✓	professional judgment
		other:
Reference site criteria	Based on historical data, what the best conditions should be for that site. On Truckee River, the Tribe has been using reference "conditions" based on bioassessment data from 1981 to present.	
Characterization of reference sites within a regional context	✓	historical conditions
		least disturbed sites
		gradient response
	✓	professional judgment
		other:
Stream stratification within regional reference conditions	✓	ecoregions (or some aggregate)
	✓	elevation
	✓	stream type
		multivariate grouping
	✓	jurisdictional *(within Tribe's boundaries)*
		other:
Additional information	UD	reference sites linked to ALU
		reference sites/condition referenced in water quality standards
		some reference sites represent acceptable human-induced conditions

*Reference site use is currently under development.

Field and Lab Methods

Assemblages assessed*	✓	benthos *(<100 samples/year [3 replicates per riffle site]; single season, multiple sites - not at watershed level*)
	✓	fish
	✓	periphyton
		other:
Benthos		
sampling gear		surber (used 1981 through 2000), kicknet (started in 2001) - 9" x 18" rectangle 500 micron mesh
habitat selection		richest habitat - upper third of riffle
subsample size		entire sample
taxonomy		genus and species
Fish		
sampling gear		seine (multiple gill nets), backpack and boat electrofisher
habitat selection		pool/glide
sample processing		length measurement, biomass - individual, anomalies
subsample		study specific
taxonomy		species
Periphyton		
sampling gear		**natural substrate**: brushing/scraping device (razor, toothbrush, etc.) **artificial substrate**: collect by hand
habitat selection		multihabitat
sample processing		chlorophyll *a*/ phaeophytin, biomass, taxonomic identification
taxonomy		all algae; species level; genus level for soft-bodied algae when possible; diatoms are not cleared
Habitat assessments		visual based and quantitative measurements; performed with bioassessments
Quality assurance program elements		standard operating procedures, quality assurance plan, periodic meetings and training for biologist, sorting and taxonomic proficiency checks, specimen archival

*Tribal Fisheries conducts fish bioassessments and a Tribal Wetlands staff member conducts amphibian biostudies. Periphyton sampling is conducted on tribal land by the Desert Research Institute.

Data Analysis and Interpretation**

Data analysis tools and methods	☐	summary tables, illustrative graphs
	☐	parametric ANOVAs
	☐	multivariate analysis
	☐	biological metrics
	☐	disturbance gradients
	☐	other:
Evaluation of performance characteristics	☐	repeat sampling
	☐	precision
	☐	sensitivity
	☐	bias
	☐	accuracy
Biological data		
Storage		Quattro Pro and paper files
Retrieval and analysis		EDAS (under development)

**Data have not yet been analyzed or evaluated. Pyramid Lake Paiute Tribe is just beginning to sort/identify the 2001 benthic macroinvertebrate collections.

SEMINOLE TRIBE of FLORIDA

Contact Information

Bill Dunson, Environmental Scientist
The Seminole Tribe of Florida, Water Resource Management Department
6300 Stirling Road ■ Hollywood, Florida 33024
Phone 863/902-3200
email: Bdunson@semtribe.com
website: http://www.seminoletribe.com/

Program Description

The reservations that comprise the Seminole Tribe of Florida begin around Tampa and extend into the southern tip of the state. The Tribe's Water Resource Management Department is responsible for protecting the land and water systems within the Reservation while ensuring a sustainable economic and cultural future for the Tribe. USEPA has delegated to the Tribe the authority to implement the Clean Water Act within the Tribe's jurisdiction. As part of that program, the Tribe implemented a sophisticated monitoring program, adopted federally approved water quality standards for the Big Cypress reservation, and is developing standards for the other reservations.

The Tribe has developed other programs, as well, including spill prevention plans for above ground storage tanks and removal programs for underground storage tank facilities. The Tribe actively participates in a number of task forces, working groups, and commissions regarding the restoration of the South Florida ecosystem. The Tribe spends considerable resources supporting the overall design and implementation of South Florida's environmental restoration.

Currently the Tribe does not use biocriteria in any of its water quality monitoring programs. However, the Tribe is involved in a research project conducted by Florida Atlantic University that includes development of biocriteria (primarily for variations in hydroperiod and the effects of restoration), using vegetation and fish as bioindicators.

Documentation and Further Information

Personal communication (email), Bill Dunson, 12/4/2001.

Working Drafts – Bioindicators for wetland change; Presentation on use of data in conducting rapid wetland assessments

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Delaware River Basin Commission (DRBC)

Interstate compact: PA, NJ, NY, DE

Contact Information

Robert L. Limbeck, Watershed Scientist
Edward Santoro, Monitoring Coordinator
Delaware River Basin Commission (DRBC)
P.O. Box 7360 ■ West Trenton, NJ 08628
Phone 609/883-9500 ■ Fax 609/883-9522
email: rlimbeck@drbc.state.nj.us
website: http://www.state.nj.us/drbc/

Program Description

The objectives of the Commission's biological monitoring program are presently focused upon the 200-mile long non-tidal Delaware River corridor:

1. Protection of high quality aquatic life uses in Water Quality Zones 1A through 1E of the Delaware River, from Hancock, New York to Trenton, New Jersey
2. Development of anti-degradation biological criteria based upon existing water quality
3. Definition of longitudinal changes in benthic community structure along the Delaware River corridor, to support decisions to maintain or improve water quality where necessary

DRBC and the National Park Service (NPS) have operated the Scenic Rivers Monitoring Program since the early 1980s. The Commission has never used biological criteria for 305(b) assessments or determinations of impairment, other than reports arising from fish-tissue toxics analysis and inference of aquatic life use attainment based upon water chemistry. Macroinvertebrate biocriteria were developed for DRBC's Special Protection Waters rules issued in 1990, but the criteria were later found to be based upon inconsistent and non-representative methods, and have not been used as envisioned during development of the Commission's anti-degradation policies.

With the launch of DRBC's Lower Delaware Monitoring Program in 1999, declaration of most of the non-tidal Delaware River as Wild and Scenic in 2000, and major efforts to update DRBC's comprehensive plan and water quality standards (applicable to most of the Delaware River), interest in DRBC's biomonitoring program was renewed. Meetings with state and local partners resulted in the decision that the Commission would bear the primary responsibility for biological monitoring of the Delaware River, while each state would regulate and monitor tributaries. With technical support and advice from NJDEP, PADEP, USGS, USEPA Region 3, NPS, and the Academy of Natural Sciences, DRBC set out to define goals, objectives, and methods for improving its biological assessment program for the river.

DRBC investigated large-river bioassessment methods and decided to wait for issuance of EPA's large-rivers guidance before launching large-scale monitoring in difficult habitats such as pools, rapids, and upper-estuarine reaches. In 2001, DRBC initiated an annual benthic survey in 2001 of wadeable riffle, run, and island margin habitats, to develop a benthic index of biological integrity for the non-tidal river. The annual August/September low-flow survey is narrowly defined to eliminate spatial and temporal variability, enabling site-to-site, reach-to-reach, and year-to-year comparison of results. By 2005, DRBC hopes to have enough data to create a low-flow benthic IBI (B-IBI) for wadeable portions of the Delaware River, and to apply the B-IBI to future 305(b) assessments and protection of existing water quality.

The Commission would like to monitor other assemblages in order to gain a more complete picture of the ecological integrity of the Delaware River, and to measure progress toward objectives defined by the Commission's comprehensive plan. DRBC is investigating methods to assess submerged aquatic vegetation, periphyton, fish, mussels, plankton, invasive exotic species, and ecological characterization of over 50 unique microhabitats observed in the river. These investigations have been scheduled on a rotating basis as special studies, though they are not used in use support and/or impairment determinations.

Within the next year, DRBC and the NPS will begin planning for tributary Boundary Control Point biomonitoring. DRBC will establish locations and methods to define existing water quality and create biological targets at each location for antidegradation purposes. With the river survey in progress, this is an appropriate next step in improving biomonitoring coverage and implementing antidegradation policies. DRBC is also moving away from doing taxonomy in-house due to a lack of both time and work space. The identification work from the annual river survey will likely be contracted out sometime in the near future.

Documentation and Further Information

Delaware River & Bay Water Quality Assessment, 2000 305(b) report: http://www.state.nj.us/drbc/2K305b_text.PDF

DRBC Annual Report 2000: http://www.state.nj.us/drbc/ar2000.htm

DRBC Quality Assurance Project Plan 2001 Update: http://www.state.nj.us/drbc/QAplanLDEL01.PDF

DRBC Publications homepage: http://www.state.nj.us/drbc/public.htm

2001 Biomonitoring Work Plan (contains numerous citations, including three reports on DRBC's 3-year bioassessment study, issued by the Academy of Natural Sciences, Patrick Environmental Research Center with recommendations on how best to proceed with update of biocriteria and implementation of antidegradation as mandated in DRBC's Water Quality Standards)

Delaware River Basin Commission (DRBC)

Interstate compact: PA, NJ, NY, DE

Contact Information

Robert L. Limbeck, Watershed Scientist
Edward Santoro, Monitoring Coordinator
Delaware River Basin Commission (DRBC)
PO Box 7360 ■ West Trenton, NJ 08628
Phone 609/883-9500 ■ Fax 609/883-9522
email: rlimbeck@drbc.state.nj.us

Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
		monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
	✓	promulgated into state water quality standards as biocriteria
	✓	support of antidegradation
		evaluation of discharge permit conditions
		TMDL assessment and monitoring
		other:
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(special projects and specific river basins or watersheds)*
	✓	fixed station (i.e., water quality monitoring stations) *(specific river basins or watersheds)*
		probabilistic by stream order/catchment area
		probabilistic by ecoregion, or statewide
		rotating basin
		other:

Stream Miles

Total miles* *(total miles of mainstem segment only, not including tributaries; determined using RF3 - Interstate river corridor is well-defined by river reaches, not watershed based)*	**200**
Total perennial miles	unknown
Total miles assessed for biology	**200**
fully supporting for 305(b)**	n/a
partially/non-supporting for 305(b)**	n/a
listed for 303(d)**	n/a
number of sites sampled *(on an annual basis)*	23
number of miles assessed per site***	~8.7

*DRBC is an Interstate Compact encompassing river miles in four states: Pennsylvania, New Jersey, New York and Delaware, and has not determined the number of total stream miles in the Basin. The Delaware River Basin watershed encompasses 13,539 square miles. Bioassessment and biocriteria activities are concentrated on a 200-mile non-tidal segment of the Delaware River and tributary boundary control points.

**Biocriteria are not currently used for the 305(b) report. Biocriteria were developed years ago, but the extent of their application is unknown.

***The number of miles assessed per site (~8.7) is very rough. DRBC's goal is to sample approximately 10 additional sites, thus reducing this number.

Aquatic Life Use (ALU) Designations and Decision-Making*

ALU designation basis	Single Aquatic Life Use and Fishery Based Uses	
ALU designations in state water quality standards	Two designations: The fishery-based designation is general, narrative, and defined by river zone. The single aquatic life use designation is macroinvertebrate criteria within DRBC's Special Protection Waters areas, and is defined for antidegradation purposes.	
Narrative Biocriteria in WQS	See definition of Existing Water Quality in Special Protection Waters (found in the 2001 workplan) for procedures used to support narrative biocriteria.*	
Numeric Biocriteria in WQS	See DRBC's *Administraive Manual – Part III, Water Quality Regulations*, Section 3.10.3 Stream Quality Objectives, Section A. Antidegradation of Waters, Table 1.*	
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
	✓	cause and effect determinations
		permitted discharges
		monitoring (e.g., improvements after mitigation)
	✓	watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	DRBC/NPS attempted to use existing criteria to define perceived problem areas. The existing criteria, as defined, could not distinguish anthropogenic versus natural measurable change. Program redesign is necessary.	

*Application of the existing system has been unsuccessful thus far due to the low priority given to biomonitoring. Program redesign recommendations were recently made to improve effectiveness and applicability of the criteria. Criteria for the entire non-tidal river are currently being updated, and a best-habitat based benthic IBI that might eventually be applied to future 305(b) assessments and the protection of existing water quality is under development. Additional data will be required, as well as a clear definition of how the criteria will be applied to the 305(b) process. Separate criteria will be required for the river, the tributaries, and for different levels of application and interpretation.

Reference Site/Condition Development

Number of reference sites	**23 total**	
Reference site determinations		site-specific
		paired watersheds
	✓	regional (aggregate of sites)
		professional judgment
	✓	other: aggregate sites in each river reach were used to define existing water quality for antidegradation purposes.**
Reference site criteria	In known high-quality waters numeric definition of Existing Water Quality provides a reference for comparison. Measurable Change determines departure from the reference condition.	
Characterization of reference sites within a regional context	✓	historical conditions
	✓	least disturbed sites
		gradient response
		professional judgment
		other:
Stream stratification within regional reference conditions *UD - tributaries are assessed according to methods used by states to facilitate comparability and data sharing*		ecoregions (or some aggregate)
		elevation
		stream type
		multivariate grouping
		jurisdictional (i.e., statewide)
		other:
Additional information	✓	reference sites linked to ALU *(not well linked)*
	✓	reference sites/condition referenced in water quality standards *(found in water quality standards)*
	✓	some reference sites represent acceptable human-induced conditions *(exceptional water quality was defined under 1980's New York City reservoir operations & dischargers)*

**The program's purpose is to protect the high quality of the river; therefore all sites sampled could be theoretically considered reference sites (the same sites are continually sampled each year and findings are compared to the original samples' data to determine if the quality has changed).

Field and Lab Methods

Assemblages assessed	✓	benthos *(<100 samples/year; single season, multiple sites)*
	✓	fish* *(<100 samples/year; single season, multiple sites)*
		periphyton
	✓	other: macrophytes *(<100 samples/year; single season, multiple sites)*

Benthos	
sampling gear	Surber, Hess, D-frame (500 - 600 micron mesh), BFN = Big-River Frame Net (custom rectangular net, bottom frame area .37 square meters, for Delaware River to 3ft deep, 4 fps, 500 micron mesh)
habitat selection	richest habitat, riffle/run (cobble), multihabitat
subsample size	tributaries - entire sample; river - 200 count
taxonomy	tributaries - family; river - genus
Habitat assessments	visual based, hydrogeomorphology, pebble counts, Pfankuch Flow characterization, Simon Channel Evolution Status; mostly performed with bioassessments, some performed independent of bioassessments
Quality assurance program elements	standard operating procedures, quality assurance plan, periodic meetings and training for biologists, sorting and taxonomic proficiency checks, specimen archival

*Some fish tissue data are collected as part of DRBC's monitoring program, but the work is contracted out to NJDEP and the Academy of Natural Sciences in Philadelphia. DRBC also makes use of PADEP, PA Fish and Boat Commission, and USGS NAWQA study data in water quality assessments.

The Delaware Estuary Program recently assembled an interstate committee to standardize fish advisories in interstate waters. DRBC has had trouble in the past with making use attainment calls based upon state fish advisories. Each state sampled different areas, species, and used different criteria. Conflicts among the different states' data arose when DRBC tried to pull everything together for the Delaware River assessment. DRBC's focus upon interstate coordination and cooperation to improve the process has subsequently increased.

Data Analysis and Interpretation

Data analysis tools and methods	✓	summary tables, illustrative graphs
		parametric ANOVAs
		multivariate analysis
	✓	biological metrics *(return single metrics - use endpoint for each single metric)*
		disturbance gradients
		other:

Multimetric thresholds	
transforming metrics into unitless scores	95^{th} percentile of all sites

Evaluation of performance characteristics**	✓	repeat sampling
	✓	precision
	✓	sensitivity
	✓	bias
	✓	accuracy

Biological data	
Storage	STORET, SAS, MS Access and Excel
Retrieval and analysis	SAS

**See reports issued by the Academy of Natural Sciences (ANS) for an evaluation. ANS identified problems with performance characteristics depending on the level of data interpretation. A redesign of the program is necessary, including refinement of the biocriteria, and field and laboratory practices.

Interstate Commission on the Potomac River Basin (ICPRB)

Interstate compact: VA, WV, MD, PA, DC

Contact Information

James D. Cummins, Associate Director for the Living Resources Section
Interstate Commission on the Potomac River Basin (ICPRB)
6110 Executive Boulevard, Suite 300 ■ Rockville, MD 20852
Phone 301/984-1908 ■ Fax 301/984-5841
email: jcummins@potomac-commission.org
website: http://www.potomacriver.org/

Program Description

ICPRB has no water/land ownership, management or regulatory authority, and therefore has set no water quality standards. However, since the Commission's creation in 1940, ICPRB often assists the basin states (Virginia, Maryland, West Virginia and Pennsylvania), the District of Columbia, and the federal government on such formulations. As part of this assistance, ICPRB conducts stream bioassessments, both fish and benthic, consults with the jurisdictions regarding current and proposed biocriteria and water quality standards, and works with the jurisdictions' data to better understand and characterize the environmental conditions of the Potomac River watershed and associated land usages.

ICPRB is currently working to integrate data from many sources (Virginia, Maryland, West Virginia, Pennsylvania, the District of Columbia, various federal and local governments, and nongovernmental sources) into a single reference watershed analysis. In addition to benthic and fish monitoring in streams and wadeable rivers, ICPRB is doing shad and herring restoration work in non-wadeable rivers. The stream data collected downstream of reservoirs, influences reservoir management decisions. The Commission also analyzes estuary data collected by other entities and works on Chesapeake Bay water quality issues.

Documentation and Further Information

Potomac Basin Water Quality Assessment home (with links to District of Columbia, Maryland, Pennsylvania, Virginia and West Virginia 305(b) and 303(d) information): http://www.potomacriver.org/wqassess.htm

Map of 303(d)-Listed Waters in the Potomac Basin: http://www.potomacriver.org/wq303d.htm

Virginia DEQ Water Quality Assessment Guidance Manual for 2002, 305(b) Water Quality Report and 303(d) Impaired Waters List, amended July 2002: http://www.deq.state.va.us/pdf/water/wqassessguide.pdf

2000 Maryland Section 305(b) Water Quality Report, with *Appendix E, Assessment Methodology*, August 2000: http://dnrweb.dnr.state.md.us/download/bays/MD2000_305b.pdf

Commonwealth of Pennsylvania 2000 Water Quality Assessment 305(b) Report: http://www.dep.state.pa.us/dep/deputate/watermgt/Wqp/WQStandards/305_wq2000_narr.htm

For a link to *West Virginia Water Quality Status Assessment 2000 305(b) Report for the period 1997-1999,* go to: http://www.dep.state.wv.us/item.cfm?ssid=11&ss1id=192

For a list of ICPRB publications and ordering information, go to: http://www.potomacriver.org/publications.htm

Interstate Commission on the Potomac River Basin (ICPRB)

Interstate compact: VA, WV, MD, PA, DC

Contact Information

James D. Cummins, Associate Director for the Living Resources Section
Interstate Commission on the Potomac River Basin (ICPRB)
6110 Executive Boulevard, Suite 300 ■ Rockville, MD 20852
Phone 301/984-1908 ■ Fax 301/984-5841
email: jcummins@potomac-commission.org

Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
	✓	monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
		promulgated into state water quality standards as biocriteria
		support of antidegradation
		evaluation of discharge permit conditions
	✓	TMDL assessment and monitoring
		other:
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(special projects and specific river basins or watersheds)*
		fixed station (i.e., water quality monitoring stations)
		probabilistic by stream order/catchment area
		probabilistic by ecoregion, or statewide
	✓	rotating basin *(special projects and specific river basins or watersheds)*
		other:

Stream Miles

Total miles* *(total miles of Potomac River mainstem, not including tributaries)*	**383**
Total perennial miles	–
Total miles assessed for biology**	**n/a**
fully supporting for 305(b)	n/a
partially/non-supporting for 305(b)	n/a
listed for 303(d)	n/a
number of sites sampled*	~1,300
number of miles assessed per site	–

*The Potomac River drainage area includes 14,670 square miles in the following jurisdictions: Maryland, Virginia, West Virginia, Pennsylvania and the District of Columbia.

**ICPRB is not a regulatory authority, but assists the states in the Potomac River Basin (ICPRB doesn't develop own criteria, etc.). The Commission looks at the basin as a whole, across state lines, and thus has no way of producing an accurate estimate of miles assessed. Although ICPRB works with the data from roughly 1,300 sampling stations, sampling is only conducted at several hundred of those stations – these include the samples collected and provided to Pennsylvania's Potomac Watershed Program. The rest of the stations are sampled by various state agencies who supply ICPRB with data to analyze and use for management decisions.

Aquatic Life Use (ALU) Designations and Decision-Making*

ALU designation basis	n/a	
ALU designations in state water quality standards	n/a	
Narrative Biocriteria in WQS	n/a	
Numeric Biocriteria in WQS	n/a	
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
	n/a	cause and effect determinations
	n/a	permitted discharges
	✓	monitoring (e.g., improvements after mitigation)
	✓	watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	Not applicable for ICPRB, but member jurisdictions in the Potomac basin use data in various ways.	

*ICPRB does not define aquatic life uses, but uses those designated by member jurisdictions: Virginia, Maryland, West Virginia, Pennsylvania, and the District of Columbia.

Reference Site/Condition Development**

Number of reference sites	**under development**	
Reference site determinations		site-specific
		paired watersheds
	✓	regional (aggregate of sites)
		professional judgment
		other:
Reference site criteria	Under development. Each member jurisdiction has its own reference site criteria. ICPRB is working to establish regional reference sites using the "common elements" of the various jurisdictions' habitat evaluations and water quality information. The criteria will be based on water quality data and habitat parameters, and possibly macroinvertebrate data as well. The reference sites will be the least disturbed sites based on these parameters.	
Characterization of reference sites within a regional context		historical conditions
	✓	least disturbed sites
	✓	gradient response
		professional judgment
		other:
Stream stratification within regional reference conditions	✓	ecoregions (or some aggregate)
		elevation
		stream type
		multivariate grouping
	✓	jurisdictional (i.e., statewide)
		other:
Additional information	n/a	reference sites linked to ALU
	n/a	reference sites/condition referenced in water quality standards
		some reference sites represent acceptable human-induced conditions

**Reference sites are presently defined by statistical category (example: 95th percentile), but ICPRB would prefer to establish hypothetical reference conditions.

Field and Lab Methods

Assemblages assessed	✓	benthos *(<100 samples/year; multiple seasons, multiple sites – broad coverage for watershed level)*
	✓	fish *(<100 samples/year; multiple seasons, multiple sites – broad coverage for watershed level)*
		periphyton
	✓	other: phytoplankton and zooplankton *(<100 samples/year; multiple seasons, multiple sites – broad coverage for watershed level)*
Benthos		
sampling gear		kick net (1 meter); 200-400 micron mesh
habitat selection		riffle/run (cobble)
subsample size		entire sample
taxonomy		family
Fish		
sampling gear		backpack electrofisher, seine; 1/4" mesh
habitat selection		multihabitat
sample processing		length measurement and anomalies
subsample		selected species, batch
taxonomy		species
Habitat assessments		visual based; performed with bioassessments
Quality assurance program elements		ICPRB follows QA protocols according to each state's requirements. Elements include periodic meetings and training for biologists, taxonomic proficiency checks, and a certification program for bioassessment.

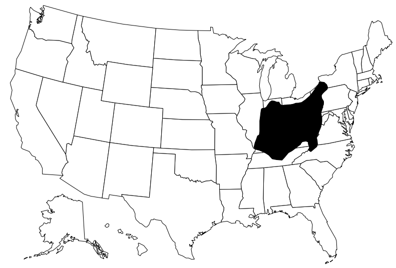
Data Analysis and Interpretation*

Data analysis tools and methods	✓	summary tables, illustrative graphs
	✓	parametric ANOVAs
	✓	multivariate analysis
	✓	biological metrics *(aggregate metrics into an index)*
		disturbance gradients
		other:
Multimetric thresholds		
transforming metrics into unitless scores		Current emphasis is on the 95th percentile of all sites (reference and stressed) and a quadrisection of the range. Presently testing various published methods of establishing scoring thresholds in each jurisdiction.
defining impairment in a multimetric index		Consistent thresholds are currently being assembled from impairment criteria applied by member states.
Evaluation of performance characteristics		repeat sampling
		precision
Not currently evaluated		sensitivity
		bias
		accuracy
Biological data		
Storage		Raw data and documentation are obtained from state and federal agencies in varying formats (hardcopy, disc, downloadable ftp files). Data are stored and analyzed using a custom-developed MS Access database similar to EDAS.
Retrieval and analysis		Various statistical software applications are being evaluated; i.e. S-PLUS, Total Access Statistics, et al.

*The objective of the *Basinwide Assessments* program is to integrate and analyze monitoring data from member states' nontidal rivers and streams. While states' data cannot be compared directly, most apply a similar data analysis approach. ICPRB is adapting this analysis framework by selecting and normalizing consistent criteria from the various approaches to define reference and stressed conditions. Invertebrate communities at these sites will be measured and compared. Candidate metrics are also being screened for assessment accuracy and redundancy to select core metrics.

Ohio River Valley Water Sanitation Commission (ORSANCO)

Interstate compact: NY, VA, PA, WV, OH, KY, IN, IL



Contact Information

Erich Emery, Senior Biologist
Ohio River Valley Water Sanitation Commission (ORSANCO)
5735 Kellogg Avenue ■ Cincinnati, OH 45228
Phone 513/231-7719 ■ Fax 513/231-7761
email: emery@orsanco.org
website: http://www.orsanco.org/

Program Description

The strategic objective of ORSANCO's Biological Program is to conduct biological monitoring of the Ohio River in order to determine the extent to which the objective of Article 1 of the Compact "..that the Ohio River be capable of maintaining fish and other aquatic life" is met. Tasks conducted in support of this strategic objective include: 1) Developing techniques for biological monitoring of large rivers in general, and the Ohio River in particular, and 2) Utilizing biological monitoring, assessment, and criteria to characterize the condition of the river. ORSANCO is currently developing numeric biological criteria and plans to integrate biological methods into overall monitoring and assessment efforts.

ORSANCO has been collecting biological data from the Ohio River since 1957 with the initiation of a lockchamber rotenone sampling program, which continues to this day. This method has provided the Commission with a 45-year look at fish community changes within the Ohio River.

ORSANCO is collecting biological data from the Ohio River on behalf of the eight states of the Commission (NY, VA, PA, WV, OH, KY, IN, and IL). These states rely on the Commission to develop appropriate methods, conduct sampling, develop assessment indices and eventually incorporate biological information into all assessment strategies. The states are also relying on ORSANCO to assist them in conducting similar programs on the large Ohio River tributaries within each state.

The Commission uses biological data in a report to each of the states which the states then use for their 305(b) report and 303(d) listings. The Commission is currently in the process of developing numeric biological criteria. Discussions are underway to determine whether the Commission should proceed with referencing biological criteria in Pollution Control Standards for the Ohio River, or incorporating said criteria as 'hard numbers' or codified criteria. ORSANCO will proceed at the recommendation of the states.

ORSANCO is also expanding its programs, including biological efforts, into the tributaries and reaches of the basin. In the very near future, ORSANCO will be working with the states to conduct biological sampling on larger, navigable, tributaries to test methods, develop indices, and eventually expand the coverage of biocriteria. The tributary work will be important in determining how to transition from great rivers to large rivers, in terms of monitoring and assessment, and will enable researchers to make that transition seamlessly.

Documentation and Further Information

ORSANCO 1998 305(b) Fact Sheet for the Ohio River

ORSANCO Water Quality Protection, *Biological Program* homepage: http://www.orsanco.org/watqual/aquatic/biological.htm

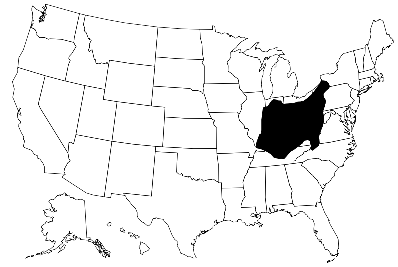
2000 Kentucky Report to Congress on Water Quality, 305(b) report, November 2000: http://water.nr.state.ky.us/wq/305b/2000/2000_305b.htm

1998 Kentucky Report to Congress on Water Quality, 305(b) report, January 1999 (sites sampled by ORSANCO found in *Table 2*): http://water.nr.state.ky.us/305b/

For a list of publications (including QA/QC documents, monitoring and assessment strategies, data summaries, etc.), go to: http://www.orsanco.org/rivinfo/pubs/pubs.htm

Ohio River Valley Water Sanitation Commission (ORSANCO)

Interstate compact: NY, VA, PA, WV, OH, KY, IN, IL



Contact Information

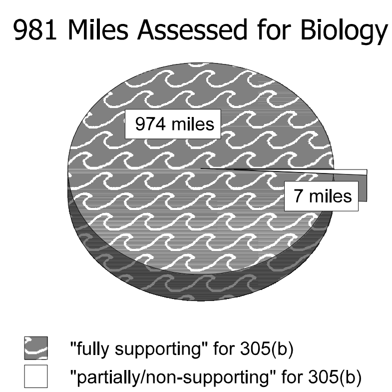
Erich Emery, Senior Biologist
Ohio River Valley Water Sanitation Commission (ORSANCO)
5735 Kellogg Avenue ■ Cincinnati, OH 45228
Phone 513/231-7719 ■ Fax 513/231-7761
email: emery@orsanco.org

Programmatic Elements

Uses of bioassessment within overall water quality program*	✓	problem identification (screening)
	UD	nonpoint source assessments
	UD	monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
	✓	promulgated into state water quality standards as biocriteria
	UD	support of antidegradation
	UD	evaluation of discharge permit conditions
	UD	TMDL assessment and monitoring
		other:
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(special projects only)*
	✓	fixed station (i.e., water quality monitoring stations) *(special projects only)*
	UD	probabilistic by stream order/catchment area
	UD	probabilistic by ecoregion, or statewide
		rotating basin
		other:

Stream Miles

Total miles *(total miles of mainstem only, not including tributaries)*	**981**
Total perennial miles	–
Total miles assessed for biology*	**981**
fully supporting for 305(b)*	974
partially/non-supporting for 305(b)*	7
listed for 303(d)*	55
number of sites sampled *(on an annual basis)*	>1,000
number of miles assessed per site	0.5



*The Ohio River flows through or borders six states: Illinois, Indiana, Kentucky, Ohio, Pennsylvania, and West Virginia. It encompasses 203,940 square miles, but ORSANCO only conducts biological monitoring on the mainstem of the Ohio River, which is 981 miles long. ORSANCO produces a 305(b) report exclusively for the Ohio River, and this document is referenced by different states for use in their own 305(b) reports. Fifty-five Ohio River miles are listed on Kentucky's 303(d) list, but this number is based on a past report and the Kentucky Division of Water feels that there is not enough biological data to delist those miles quite yet.

Aquatic Life Use (ALU) Designations and Decision-Making*

ALU designation basis	Single Aquatic Life Use	
ALU designations in state water quality standards	One designation: Warmwater Aquatic Life – other categories are under development	
Narrative Biocriteria in WQS*	Formal/informal numeric procedures used to support narrative biocriteria are under development.	
Numeric Biocriteria in WQS*	under development (to be included or referenced by standards)	
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)	✓	assessment of aquatic resources
	✓	cause and effect determinations
		permitted discharges
	✓	monitoring (e.g., improvements after mitigation)
	✓	watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	This is currently unknown because numeric biocriteria are just being proposed for the water quality standards.	

*ORSANCO's water quality standards are the adopted standards that serve as recommendations to states for incorporation into their own standards. ORSANCO is entering review this year (starting with a fish biocriteria proposal); ALU designations and numeric biocriteria are expected to be completed sometime before 2004.

Reference Site/Condition Development

Number of reference sites	**400 total**	
Reference site determinations	✓	site-specific
		paired watersheds
	✓	regional (aggregate of sites)
	✓	professional judgment
		other:
Reference site criteria	Least impacted sites are sites out of the immediate influence of human impact. Specifically, one kilometer below discharges or major tributaries as well as free from other obvious disturbance. Least impacted sites are used as a surrogate for reference sites.	
Characterization of reference sites within a regional context		historical conditions
	✓	least disturbed sites
		gradient response
		professional judgment
		other:
Stream stratification within regional reference conditions	✓	ecoregions (or some aggregate)**
		elevation
		stream type
		multivariate grouping
		jurisdictional (i.e., statewide)
		other:
Additional information	✓	reference sites linked to ALU
		reference sites/condition referenced in water quality standards
	✓	some reference sites represent acceptable human-induced conditions

**Plans are underway to develop a tiered aquatic life use approach with expectations based on river reach (ecoregion surrogate) and habitat type.

Field and Lab Methods

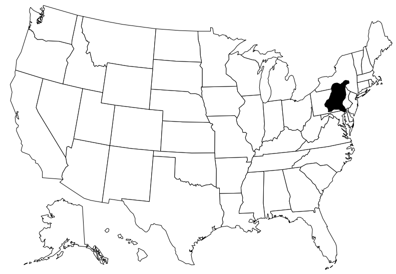
Assemblages assessed	✓	benthos *(100-500 samples/year; multiple seasons, multiple sites – broad coverage for watershed level)*
	✓	fish *(100-500 samples/year; multiple seasons, multiple sites – broad coverage for watershed level)*
		periphyton
		other:
Benthos		
sampling gear		multiplate; standard #30 sieve
habitat selection		multihabitat
subsample size		entire sample
taxonomy		lowest possible level
Fish		
sampling gear		boat electrofisher; 1/4" mesh
habitat selection		multihabitat
sample processing		length measurement, biomass - individual, anomalies
subsample		none
taxonomy		species and subspecies
Habitat assessments		ORSANCO has developed a habitat assessment approach and habitat index for the Ohio River. The index is based on substrate composition (broad categories), depth and cover estimates; these are performed with bioassessments.
Quality assurance program elements		standard operating procedures, periodic meetings and training for biologists, sorting and taxonomic proficiency checks, specimen archival. There are plans to develop a certification program for bioassessment.

Data Analysis and Interpretation

Data analysis tools and methods	✓	summary tables, illustrative graphs
	✓	parametric ANOVAs
	✓	multivariate analysis
	✓	biological metrics *(aggregate metrics into an index)*
	✓	disturbance gradients
		other:
Multimetric thresholds		
transforming metrics into unitless scores		25th percentile of reference population
defining impairment in a multimetric index		25th percentile of reference population
Evaluation of performance characteristics	✓	repeat sampling *(look at site variability)*
		precision
	✓	sensitivity *(look at metrics and index performance)*
		bias
		accuracy
Biological data		
Storage		MS Access
Retrieval and analysis		Statistica

Susquehanna River Basin Commission (SRBC)

Interstate compact: NY, PA, MD



Contact Information

Jennifer L. R. Hoffman, Aquatic Ecologist
Susquehanna River Basin Commission (SRBC)
1721 North Front Street ■ Harrisburg, PA 17102
Phone 717/238-0426 ■ Fax 717/238-2436
email: jhoffman@srbc.net
website: http://www.srbc.net/

Program Description

The Susquehanna River Basin Commission (SRBC) is the governing agency established to protect and wisely manage the water resources of the Susquehanna River Basin. The Susquehanna River starts in Cooperstown, NY and flows 444 miles to Havre de Grace, MD, where the river meets the Chesapeake Bay. The watershed encompasses parts of New York, Pennsylvania, and Maryland. Currently, SRBC implements several programs assessing the biological condition of streams and rivers, including the Subbasin Survey and Interstate Water Quality Monitoring Network (ISWQN) Programs.

Six subbasins exist in the Susquehanna River Basin: the Chemung, Upper Susquehanna, Middle Susquehanna, West Branch Susquehanna, Juniata, and Lower Susquehanna. SRBC samples each subbasin on a rotating schedule, assessing each approximately every ten years. The assessment evaluates the chemical, biological, and habitat conditions of streams, identifies major sources of pollution, documents changes in stream quality over time, and identifies areas for more intensive study. This program was initiated in 1982 and was refined in 1998 to include a more intensive second year of sampling to address specific local concerns, such as restoration and protection. Year 1 includes collection of macroinvertebrate samples and physical habitat information using Rapid Bioassessment Protocol (RBP) III, water quality collection, and flow measurement in a single-sampling event during baseflow conditions. Year 2 of the program can include a variety of projects, such as more intensive bimonthly water quality sampling to provide information to watershed groups for protection and restoration efforts. All data collected during SRBC's subbasin surveys are used in reporting to the USEPA under Section 305(b) of the Clean Water Act.

The ISWQN program, initiated in 1986, includes periodic collection of water quality and biological samples, as well as physical habitat assessments of interstate streams. Water quality data are collected quarterly and are used to assess compliance with water quality standards, characterize stream quality and seasonal variations, build a database for assessing water quality trends, and identify areas for restoration and protection. SRBC staff collect macroinvertebrate and physical habitat information annually from 51 sites on interstate streams along the New York-Pennsylvania and Pennsylvania-Maryland borders using RBP III methods. Water samples and flow information are collected at 19 sites quarterly and 30 sites yearly. Water quality data also are used to determine the existence and magnitude of trends for selected parameters. All data collected during SRBC's interstate streams surveys are used in 305(b) reporting to USEPA.

Currently, SRBC is initiating a pilot project to determine proper methods of assessing the biological conditions, using benthic macroinvertebrate populations, of the large rivers in the Susquehanna River Basin. The pilot project will take place on the Susquehanna River between Windsor, NY and Sayre, PA, during late summer 2002. Three separate methodologies will be tested: RBP III, artificial substrate samplers, and a diver operated dome (suction) sampler. A habitat assessment will be performed and water quality samples will also be taken at each site. Data will be used to select and calculate metrics for a benthic Index of Biotic Integrity to assess the biological conditions of the large rivers in the Susquehanna River Basin and will be included in 305(b) reporting.

Documentation and Further Information

2000 Susquehanna River Basin Commission 305(b) Narrative

The 1998 Susquehanna River Basin Water Quality Assessment 305(b) Report: http://www.srbc.net/docs/305bReport_201.pdf

Report Announcement - *2002 Susquehanna River Basin Water Quality Assessment 305(b) Report*, Publication No. 220: http://www.srbc.net/docs/summary_may02.PDF

Report Announcement - *Water Quality of Interstate Streams in the Susquehanna River Basin*, Publication No. 211: http://www.srbc.net/pub211summary.pdf

Assessment of Interstate Streams in the Susquehanna River Basin: 1997-1998, Monitoring Report #12, June 1999: http://www.srbc.net/docs/iswq97-98.pdf

Upper Susquehanna Subbasin: A Water Quality and Biological Assessment, 1999: http://www.srbc.net/docs/pub203.pdf

Susquehanna River Basin Commission (SRBC)

Interstate compact: NY, PA, MD

Contact Information

Jennifer L. R. Hoffman, Aquatic Ecologist
Susquehanna River Basin Commission (SRBC)
1721 North Front Street ■ Harrisburg, PA 17102
Phone 717/238-0426 ■ Fax 717/238-2436
email: jhoffman@srbc.net

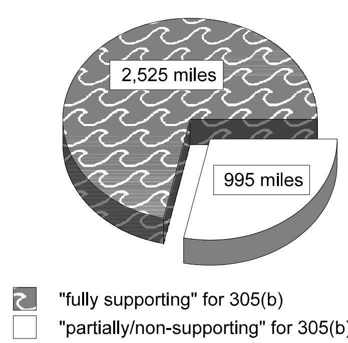
Programmatic Elements

Uses of bioassessment within overall water quality program	✓	problem identification (screening)
	✓	nonpoint source assessments
		monitoring the effectiveness of BMPs
	✓	ALU determinations/ambient monitoring
		promulgated into state water quality standards as biocriteria
		support of antidegradation
		evaluation of discharge permit conditions
	✓	TMDL assessment and monitoring
		other:
Applicable monitoring designs	✓	targeted (i.e., sites selected for specific purpose) *(special projects only)*
	✓	fixed station (i.e., water quality monitoring stations) *(specific river basins or watersheds)*
		probabilistic by stream order/catchment area
		probabilistic by ecoregion, or statewide
	✓	rotating basin *(comprehensive use throughout jurisdiction)*
		other:

Stream Miles

Total miles*	**31,193**
Total perennial miles	–
Total miles assessed for biology	**3,520**
fully supporting for 305(b)**	2,525
partially/non-supporting for 305(b)**	995
listed for 303(d)	n/a
number of sites sampled *(on an annual basis)*	317
number of miles assessed per site	11

3,520 Miles Assessed for Biology



*Stream mile estimate is based on the 1993 EPA document, *Total Waters Estimates for United States Streams and Lakes: Total Waters Database and Reporting Program*. Monitoring Branch Assessment and Watershed Protection Division, Office of Wetlands, Oceans, and Watersheds, Office of Water, Washington, D.C.

**305(b) reporting is for SRBC benefit, USEPA requirements (contracts), and to provide more samples for states to use in their official 305(b) and 303(d) listings.

Aquatic Life Use (ALU) Designations and Decision-Making*

ALU designation basis		
ALU designations in state water quality standards		
Narrative Biocriteria in WQS		
Numeric Biocriteria in WQS		
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria)		assessment of aquatic resources
		cause and effect determinations
		permitted discharges
		monitoring (e.g., improvements after mitigation)
		watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU		

*This section is not applicable to SRBC's biological monitoring program. SRBC does not define aquatic life uses, but utilizes those designated by member jurisdictions: Maryland, New York, and Pennsylvania.

Reference Site/Condition Development

Number of reference sites	**total number varies according to project**	
Reference site determinations		site-specific
		paired watersheds
	✓	regional (aggregate of sites)
	✓	professional judgment
		other:
Reference site criteria	Habitat disturbance, best available conditions of the biological and chemical components	
Characterization of reference sites within a regional context		historical conditions
	✓	least disturbed sites
		gradient response
		professional judgment
		other:
Stream stratification within regional reference conditions	✓	ecoregions (or some aggregate)
		elevation
		stream type
		multivariate grouping
		jurisdictional (i.e., statewide)
		other:
Additional information		reference sites linked to ALU
		reference sites/condition referenced in water quality standards
	✓	some reference sites represent acceptable human-induced conditions

Field and Lab Methods

Assemblages assessed	✓	benthos *(100-500 samples/year; single season, multiple sites - broad coverage)*
	☐	fish
	☐	periphyton
	☐	other:
Benthos		
sampling gear		D-frame, kick net (1 meter); 500-600 micron mesh
habitat selection		riffle/run (cobble)
subsample size		100 count
taxonomy		genus
Habitat assessments		visual based; performed with bioassessments
Quality assurance program elements		standard operating procedures, quality assurance plan, periodic meetings and training for biologists, sorting and taxonomic proficiency checks, specimen archival

Data Analysis and Interpretation

Data analysis tools and methods	✓	summary tables, illustrative graphs
	☐	parametric ANOVAs
	☐	multivariate analysis
	✓	biological metrics *(aggregate metrics into an index)*
	☐	disturbance gradients
	☐	other:
Multimetric thresholds		
transforming metrics into unitless scores		varies according to metric used: RBP 1989 methods. Always try to use 6 metrics for each project, but the metrics chosen vary depending on the project
defining impairment in a multimetric index		varies according to metric used: >81% non impaired, though this could vary slightly depending on the project
Evaluation of performance characteristics	☐	repeat sampling
	☐	precision
Not currently evaluated	☐	sensitivity
	☐	bias
	☐	accuracy
Biological data		
Storage		Excel spreadsheets for internal projects; SRBC is currently working on entering data into STORET.
Retrieval and analysis		Excel spreadsheets for internal projects; working on finding a good statistical package that fits needs

4. RELEVANT EXCERPTS FROM WATER QUALITY STANDARDS AND BIOCRITERIA LANGUAGE

This section of the report contains excerpts from the approved water quality standards of states, tribes, territories, and interstate commissions. These excerpts may contain any or all of the following: designated uses as related to aquatic life uses, narrative and/or numeric biocriteria, and any other specific sections that are relevant to the entity's protection and propagation of aquatic life. It is important to note that this chapter is not intended to be a compendium of the entire water quality standard for each state, tribe and territory, but rather to highlight specific language within the standard that describes the use of biology and biological assessments to develop relevant criteria that assess water quality and protect aquatic life.

STATES

Alabama

SOURCE: Alabama Department of Environmental Management, Water Division - Water Quality Program, Chapter 335, Division 6, Volume 1, Chapter 10, Water Quality Criteria: September 7, 2000.
http://www.adem.state.al.us/Regulations/Regulations/regulations.htm

335-6-10-.03 Water Use Classifications.

1. Outstanding Alabama Water
3. Swimming and Other Whole Body Water-Contact Sports
5. Fish and Wildlife
6. Limited Warmwater Fishery
7. Agricultural and Industrial Water Supply

335-6-10-.04 Antidegradation Policy.

(1) The purpose and intent of the water quality standards is to conserve the waters of the State of Alabama and to protect, maintain and improve the quality thereof for public water supplies, for the propagation of wildlife, fish and aquatic life, and for domestic, agricultural, industrial, recreational and other legitimate beneficial uses; and to provide for the prevention, abatement and control of new or existing water pollution.

(4) Where high quality waters constitute an outstanding National resource, such as waters of national and state parks and wildlife refuges and waters of exceptional recreational or ecological significance, that water quality shall be maintained and protected.

(5) Developments constituting a new or increased source of thermal pollution shall assure that such release will not impair the propagation of a balanced indigenous population of fish and aquatic life.

335-6-10-.06 Minimum Conditions Applicable to All State Waters. The following minimum conditions are applicable to all State waters, at all places and at all times, regardless of their uses:

(c) State waters shall be free from substances attributable to sewage, industrial wastes or other wastes in concentrations or combinations which are toxic or harmful to human, animal or aquatic life to the extent commensurate with the designated usage of such waters.

335-6-10-.09 Specific Water Quality Criteria.

(1) OUTSTANDING ALABAMA WATER

(a) Best usage of waters: activities consistent with the natural characteristics of the waters.

(b) Conditions related to best usage:

1. High quality waters that constitute an outstanding Alabama resource, such as waters of state parks and wildlife refuges and waters of exceptional recreational or ecological significance, may be considered for classification as an Outstanding Alabama Water (OAW).

(3) SWIMMING AND OTHER WHOLE BODY WATER-CONTACT SPORTS

(b) Conditions related to best usage: ... The quality of waters will also be suitable for the propagation of fish, wildlife and aquatic life. The quality of salt waters and estuarine waters to which this classification is assigned will be suitable for the propagation and harvesting of shrimp and crabs.

(5) FISH AND WILDLIFE

(a) Best usage of waters: fishing, propagation of fish, aquatic life, and wildlife...

(b) Conditions related to best usage: the waters will be suitable for fish, aquatic life and wildlife propagation. The quality of salt and estuarine waters to which this classification is assigned will also be suitable for the propagation of shrimp and crabs.

(e) Specific criteria:

3. Temperature:

(ii) The maximum temperature in streams, lakes, and reservoirs in the Tennessee and Cahaba River Basins, and for that portion of the Tallapoosa River Basin from the tailrace of Thurlow Dam at Tallassee downstream to the junction of the Coosa and Tallapoosa Rivers which has been designated by the Alabama Department of Conservation and Natural Resources as supporting smallmouth bass, sauger, or walleye, shall not exceed 86° F.

(vi) In all waters the normal daily and seasonal temperature variations that were present before the addition of artificial heat shall be maintained, and there shall be no thermal block to the migration of aquatic organisms.

(vii) Thermal permit limitations in NPDES permits may be less stringent than those required by subparagraphs (i)-(iv) hereof when a showing by the discharger has been made pursuant to Section 316 of the Federal Water Pollution Control Act (FWPCA), 33 U.S.C. §1251 et seq. or pursuant to a study of an equal or more stringent nature required by the State of Alabama authorized by Title 22, Section 22-22-9(c), Code of Alabama, 1975, that such limitations will assure the protection and propagation of a balanced, indigenous population of shellfish, fish and wildlife, in and on the body of water to which the discharge is made. Any such demonstration shall take into account the interaction of the thermal discharge component with other pollutants discharged.

4. Dissolved oxygen:

(i) For a diversified warm water biota, including game fish, daily dissolved oxygen concentrations shall not be less than 5 mg/l at all times; except under extreme conditions due to natural causes, it may range between 5 mg/l and 4 mg/l, provided that the water quality is favorable in all other parameters. The normal seasonal and daily fluctuations shall be maintained above these levels. In no event shall the dissolved oxygen level be less than 4 mg/l due to discharges from existing hydroelectric generation impoundments. All new hydroelectric generation impoundments, including addition of new hydroelectric generation units to existing impoundments, shall be designed so that the discharge will contain at least 5 mg/l dissolved oxygen where practicable and technologically possible. The Environmental Protection Agency, in cooperation with the State of Alabama and parties responsible for impoundments, shall develop a program to improve the design of existing facilities.

(iv) In the application of dissolved oxygen criteria referred to above, dissolved oxygen shall be measured at a depth of 5 feet in waters 10 feet or greater in depth; and for those waters less than 10 feet in depth, dissolved oxygen criteria will be applied at mid-depth.

5. Toxic substances attributable to sewage, industrial wastes, or other wastes: only such amounts, whether alone or in combination with other substances, as will not exhibit acute toxicity or chronic toxicity, as demonstrated by effluent toxicity testing or by application of numeric criteria given in Rule 335-6-10-.07, to fish and aquatic life, including shrimp and crabs in estuarine or salt waters or the propagation thereof.

6. Taste, odor, and color-producing substances attributable to sewage, industrial wastes, or other wastes: only such amounts, whether alone or in combination with other substances, as will not exhibit acute toxicity or chronic toxicity, as demonstrated by effluent toxicity testing or by application of numeric criteria given in Rule 335-6-10-.07, to fish and aquatic life, including shrimp and crabs in estuarine and salt waters or adversely affect the propagation thereof; impair the palatability or marketability of fish and wildlife or shrimp and crabs in estuarine and salt waters; or unreasonably affect the aesthetic value of waters for any use under this classification.

(6) LIMITED WARMWATER FISHERY

(a) The (a) The provisions of the Fish and Wildlife water use classification at Rule 335-6-10-.09(5) shall apply to the Limited Warmwater Fishery water use classification, except as noted below. Unless alternative criteria for a given parameter are provided in paragraph (e) below, the applicable Fish and Wildlife criteria at paragraph 10-.09(5)(e) shall apply year-round. At the time the Department proposes to assign the Limited Warmwater Fishery classification to a specific waterbody, the Department may apply criteria from other classifications within this chapter if necessary to protect a documented, legitimate existing use.

(7) AGRICULTURAL AND INDUSTRIAL WATER SUPPLY

(b) Conditions related to best usage:

(i) The waters, except for natural impurities which may be present therein, will be suitable for ... fish survival...

335-6-10-.10 Special Designations.

(1) OUTSTANDING NATIONAL RESOURCE WATER

(a) Designation:

1. High quality waters that constitute an outstanding National resource, such as waters of national and state parks and wildlife refuges and waters of exceptional recreational or ecological significance, may be considered for designation as an Outstanding National Resource Water (ONRW). For waters designated as ONRW, existing water quality shall be maintained and protected.

Alaska

SOURCE: Alaska Administrative Code: Chapter 70, Title 18, amended as of May 27, 1999: http://www.state.ak.us/local/akpages/ENV.CONSERV/title18/70wqs.pdf

18 AAC 70.020. PROTECTED WATER USE CLASSES AND SUBCLASSES; WATER QUALITY CRITERIA; WATER QUALITY STANDARDS TABLE.

(a) Classes and subclasses of use of the state's water protected by criteria set out under (b) of this section are:

(1) fresh water

(A) aquaculture

(C) growth and propagation of fish, shellfish, other aquatic life, and wildlife; and

(2) marine water

(C) growth and propagation of fish, shellfish, other aquatic life, and wildlife; and

(D) harvesting for consumption of raw mollusks or other raw aquatic life.

Arizona

SOURCE: Arizona Administrative Code, Title 18, Environmental Quality, Chapter 11. Department of Environmental Quality, Article 1. Water Quality Standards for Surface Waters, amended effective March 8, 2002: http://www.sosaz.com/public_services/Title_18/18-11.htm

R18-11-101. Definitions

The terms of this Article shall have the following meanings:

7. “Aquatic and wildlife (cold water)” means the use of a surface water by animals, plants, or other cold-water organisms, generally occurring at elevations greater than 5000 feet, for habitation, growth, or propagation.

8. "Aquatic and wildlife (effluent dependent water)" means the use of an effluent dependent water by animals, plants, or other organisms for habitation, growth, or propagation.

9. "Aquatic and wildlife (ephemeral)" means the use of an ephemeral water by animals, plants, or other organisms, excluding fish, for habitation, growth, or propagation.

10. “Aquatic and wildlife (warm water)” means the use of a surface water by animals, plants, or other warm-water organisms, generally occurring at elevations less than 5000 feet, for habitation, growth, or propagation.

22. “Ephemeral water” means a surface water that has a channel that is at all times above the water table and that flows only in direct response to precipitation.

26. "Fish consumption" means the use of a surface water by humans for harvesting aquatic organisms for consumption. Harvestable aquatic organisms include, but are not limited to, fish, clams, turtles, crayfish, and frogs.

44. "Unique water" means a surface water which has been classified as an outstanding state resource water by the Director under R18-11-112.

R18-11-108. Narrative Water Quality Standards

A. A surface water shall be free from pollutants in amounts or combinations that:
   1. Settle to form bottom deposits that inhibit or prohibit the habitation, growth, or propagation of aquatic life or that impair recreational uses;
   5. Are toxic to humans, animals, plants, or other organisms;
   6. Cause the growth of algae or aquatic plants that inhibit or prohibit the habitation, growth, or propagation of other aquatic life or that impair recreational uses;

R18-11-112. Unique Waters

D. The Director may classify a surface water as a unique water upon finding that the surface water is an outstanding state resource water based upon the following criteria:
   a. The surface water is a perennial water;
   b. The surface water is in a free-flowing condition. For purposes of this subsection, “in a free-flowing condition” means that a surface water does not have an impoundment, diversion, channelization, rip-rapping or other bank armor, or another hydrological modification within the reach nominated for unique water classification;
   c. The surface water has good water quality. For purposes of this subsection, “good water quality” means that the surface water has water quality that meets or exceeds applicable surface water quality standards. A surface water that is listed as impaired under § 303(d) of the Clean Water Act [33 U.S.C. § 1313] is ineligible for unique waters classification; and
   d. The surface water meets one or both of the following conditions:
   e. The surface water is of exceptional recreational or ecological significance because of its unique attributes, including but not limited to, attributes related to the geology, flora, fauna, water quality, aesthetic values, or the wilderness characteristics of the surface water.
   f. Threatened or endangered species are known to be associated with the surface water and the existing water quality is essential to the maintenance and propagation of a threatened or endangered species or the surface water provides critical habitat for a threatened or endangered species. Endangered or threatened species are identified in “Endangered and Threatened Wildlife and Plants,” 50 CFR § 17.11 and § 17.12 (revised as of October 1, 2000) which is incorporated by reference and on file with the Department and the Office of the Secretary of State. This incorporation by reference contains no future editions or amendments.

Arkansas

SOURCE: Arkansas Pollution Control and Ecology Commission Regulation 2, Regulation Establishing Water Quality Standards for Surface Waters of the State of Arkansas, October 28, 2002, Chapter 3 Water Body Uses, http://www.adeq.state.ar.us/regs/files/reg02_final_021028.pdf

Section 2.302 Designated Uses

The designated uses are defined as follows:

A. **Extraordinary Resource Waters** - This beneficial use is a combination of the chemical, physical and biological characteristics of a waterbody and its watershed which is characterized by scenic beauty, aesthetics, scientific values, broad scope recreation potential and intangible social values.

B. **Ecologically Sensitive Waterbody** - This beneficial use identifies segments known to provide habitat within the existing range of threatened, endangered or endemic species of aquatic or semi-aquatic life forms.

C. **Natural and Scenic Waterways** - This beneficial use identifies segments which have been legislatively adopted into a state or federal system.

F. **Fisheries** - This beneficial use provides for the protection and propagation of fish, shellfish and other forms of aquatic life. It is further subdivided into the following subcategories:

(1) Trout - water which is suitable for the growth and survival of trout (Family: Salmonidae).

(2) Lakes and Reservoirs - water which is suitable for the protection and propagation of fish and other forms of aquatic life adapted to impounded waters. Generally characterized by a dominance of sunfishes such as bluegill or similar species, black basses and crappie. May include substantial populations of catfishes such as channel, blue and flathead catfish and commercial fishes including carp, buffalo and suckers. Forage fishes are normally shad or various species of minnows. Unique populations of walleye, striped bass and/or trout may also exist.

(3) Streams - water which is suitable for the protection and propagation of fish and other forms of aquatic life adapted to flowing water systems whether or not the flow is perennial.

(a) Ozark Highlands Ecoregion - Streams supporting diverse communities of indigenous or adapted species of fish and other forms of aquatic life. Fish communities are characterized by a preponderance of sensitive species and normally dominated by a diverse minnow community followed by sunfishes and darters. The community may be generally characterized by the following fishes:

Key Species	Indicator Species
Duskystripe shiner	Banded sculpin
Northern hogsucker	Ozark madtom
Slender madtom	Southern redbelly dace
"Rock" basses	Whitetail shiner
Rainbow and/or Orangethroat darters	Ozark minnow
Smallmouth bass	

(b) Boston Mountains Ecoregion - Streams supporting diverse communities of indigenous or adapted species of fish and other forms of aquatic life. Fish communities are characterized by a major proportion of sensitive species; a diverse, often darter-dominated community exists but with nearly equal proportions of minnows and sunfishes. The community may be generally characterized by the following fishes:

Key Species	Indicator Species
Bigeye shiner	Shadow bass
Black redhorse	Wedgespot shiner

Key Species	Indicator Species
Slender madtom	Longnose darter
Longear sunfish	Fantail darter
Greenside darter	
Smallmouth bass	

(c) Arkansas River Valley Ecoregion - Streams supporting diverse communities of indigenous or adapted species of fish and other forms of aquatic life. Fish communities are characterized by a substantial proportion of sensitive species; a sunfish- and minnow-dominated community exists but with substantial proportions of darters and catfishes (particularly madtoms). The community may be generally characterized by the following fishes:

Key Species	Indicator Species
Bluntnose minnow	Orangespotted sunfish
Golden redhorse	Blacksidedarter
Yellow bullhead	Madtoms
Longear sunfish	
Redfin darter	
Spotted bass	

(d) Ouachita Mountains Ecoregion - Streams supporting diverse communities of indigenous or adapted species of fish and other forms of aquatic life. The fish community is characterized by a major proportion of sensitive species; a minnow-sunfish-dominated community exists, followed by darters. The community may be generally characterized by the following fishes:

Key Species	Indicator Species
Bigeye shiner	Shadow bass
Northern hogsucker	Gravel chub
Freckled madtom	Northern studfish
Longear sunfish	Striped shiner
Orangebelly darter	
Smallmouth bass	

(e) Typical Gulf Coastal Ecoregion - Streams supporting diverse communities of indigenous or adapted species of fish and other forms of aquatic life. Fish communities are characterized by a limited proportion of sensitive species; sunfishes are distinctly dominant followed by darters and minnows. The community may be generally characterized by the following fishes:

Key Species	Indicator Species
Redfin shiner	Pirate perch
Spotted sucker	Warmouth
Yellow bullhead	Spotted sunfish
Flier	Dusky darter

Key Species	Indicator Species
Slough darter	Creek chubsucker
Grass pickerel	Banded pygmy sunfish

(f) Springwater-influenced Gulf Coastal Ecoregion -Streams supporting diverse communities of indigenous or adapted species of fish and other forms of aquatic life. Fish communities are characterized by a substantial proportion of sensitive species; sunfishes normally dominate the community and are followed by darters and minnows. The community may be generally characterized by the following fishes:

Key Species	Indicator Species
Redfin shiner	Pirate perch
Blacktail redhorse	Golden redhorse
Freckled madtom	Spotted bass
Longear sunfish	Scaly sand darter
Creole darter	Striped shiner
Grass pickerel	Banded pygmy sunfish

(g) Least-altered Delta Ecoregion - Streams supporting diverse communities of indigenous or adapted species of fish and other forms of aquatic life. Fish communities are characterized by an insignificant proportion of sensitive species; sunfishes are distinctly dominant followed by minnows. The community may be generally characterized by the following fishes:

Key Species	Indicator Species
Ribbon shiner	Pugnose minnow
Smallmouth buffalo	Mosquitofish
Yellow bullhead	Pirate perch
Bluegill	Tadpole madtom
Bluntnose darter	Banded pygmy sunfish
Largemouth bass	

(h) Channel-altered Delta Ecoregion- Streams supporting diverse communities of indigenous or adapted species of fish and other forms of aquatic life. Fish communities are characterized by an absence of sensitive species; sunfishes and minnows dominate the population followed by catfishes. The community may be generally characterized by the following fishes:

Key Species	Indicator Species
Blacktail shiner	Mosquitofish
Drum	Gizzard shad
Carp	Emerald shiner
Channel catfish	
Green sunfish	
Spotted gar	

California*

*This language has not been reviewed for accuracy by state/tribal agency.

SOURCE: California Ocean Plan, Water Quality Control Plan for Ocean Waters of California, State Water Resources Control Resolution No. 90-27, Approval of the Amendment to the Water Quality Control Plan For Ocean Waters of California, effective March 22, 1990.
http://www.epa.gov/ost/standards/wqslibrary

Chapter II WATER QUALITY OBJECTIVES

E. Biological Characteristics

1. Marine communities, including vertebrate, invertebrate, and plant species, shall not be degraded.

Chapter III GENERAL REQUIREMENTS FOR MANAGEMENT OF WASTE* DISCHARGE TO THE OCEAN*

A. Waste management systems that discharge to the ocean must be designed and operated in a manner that will maintain the indigenous marine life and a healthy and diverse marine community.

B. Waste discharged to the ocean must be essentially free of:

2. Settleable material or substances that may form sediments which will degrade benthic communities or other aquatic life.
3. Substances which will accumulate to toxic levels in marine waters, sediments or biota.
4. Substances that significantly decrease the natural light to benthic communities and other marine life.

D. Location of waste discharges must be determined after a detailed assessment of the oceanographic characteristics and current patterns to assure that:

2. Natural water quality conditions are not altered in areas designated as being of special biological significance or areas that existing marine laboratories use as a source of seawater.

Chapter V DISCHARGE PROHIBITIONS

B. Areas of Special Biological Significance--Waste shall not be discharged to areas designated as being of special biological significance. Discharges shall be located a sufficient distance from such designated areas to assure maintenance or natural water quality conditions in these areas.

Region I (North Coast)

Source: Water Quality Control Plan for the North Coast Region, North Coast Regional Water Quality Control Board, Section 6 - Surveillance and Monitoring, Section 6-1.00, amended May 23, 1996. http://www.epa.gov/ost/standards/wqslibrary/ca/ca_9_north_coast.pdf

STATEWIDE MONITORING PROGRAMS

State Mussel Watch Program

The California State Mussel Watch (SMW) Program is a long-term monitoring program administered by the State Water Board. Actual sampling and analysis are performed by the Department of Fish and Game. SMW provides the State Water Board and the six coastal regional water boards with an indication of geographical and temporal (year-to-year) trends in toxic pollutants along the California coast. Mussels (the common bay mussel, Myilus edulis, and the California mussel, M. californianus) have been shown to be efficient bioaccumulators of many toxic substances in their water environment. Further, the sedentary nature of mussels, whether native or transplanted, permits a time integrated sampling of toxic pollutants at one location. The merits of employing mussels as water quality indicators are well established in the scientific literature, previous SMW reports, and other scientific publications. The North Coast Region will continue to participate in existing SMW monitoring and the development of freshwater applications. The North Coast Region has been involved in developing freshwater applications of SMW methodology, using freshwater clams, Corbicula sp. The North Coast Region has required that some discharges be monitored using these techniques. There are current plans to expand the use of these organisms as indicators in sensitive areas. In the North Coast Region sampling under the SMW program has led to the detection and mitigation of controllable releases of toxic substances. Sampling priorities are directed toward areas of immediate concern.

Region II (San Francisco Bay Basin)

Source: Chapter 2, Beneficial Uses, Water Quality Control Plan, Region 2, California Regional Water Quality Control Board, San Francisco Bay Region, June 21, 1995:

http://www.epa.gov/ost/standards/wqslibrary/ca/ca_9_san_francisco.pdf

Definitions of Beneficial Uses
(ASBS) Areas of Special Biological Significance
Areas designated by the State Water Resources Control Board.
These include marine life refuges, ecological reserves, and designated areas where the preservation and enhancement of natural resources requires special protection, in these areas, alteration of natural water quality is undesirable. The areas that have been designated as ASBS in this region are depicted in Figure 2-1. The State Ocean Plan (see Chapter 5) requires wastes to be discharged at a suffitionfor cient distance from these areas to assure maintenance of natural water quality conditions

(COLD) COLD FRESHWATER HABITAT
Uses of water that support cold water ecosysterns,including, but not limited to preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates.

Cold freshwater habitats generally support trout and may support the anadromous salmon and steelhead fisheries as well. Cold water habitats are commonly well-oxygenated. Life within these waters is relatively intolerant to environmental stresses. Often, soft waters feed cold water habitat These waters render fish more susceptible to toxic metals, such as copper, because of their lower buffering capacity.

(EST) ESTUARINE HABITAT
Uses of water that support estuarine ecosysterns, including, but not limited to, preservation or enhancement of estuarine habitats, vegetation, fish, shellfish, or wildlife (e.g., estuarine mammals, waterfowl, shorebirds), and the propagation, sustenance, and migration of estuarine organisms.

Estuarine habitat provides an essential and unique habitat that serves to acclimate anadromous fishes (salmon, striped bass) migrating into fresh or marine water conditions. The protection of estuarine habitat is contingent upon (1) the maintenance of adequate Delta outflow to provide mixing and salinity control; and (2) provisions to protect wildlife habitat associated with marshlands and essential to the Bay periphery (i.e., prevention of fill activities). Estuarine habitat is generally associated with moderate seasonal fluctuations in dissolved oxygen, pH, and temperature and with a wide range in turbidity.

(MAR) MARINE HABITAT
Uses of water that support marine ecosysterns, including, but not limited to, preservation or enhancement of marine habitats, vegetation such as kelp, fish, shellfish, or wildlife (e.g., marine mammals, shorebirds).

In many cases, the protection of marine habitat will be accomplished by measures that protect wildlife habitat generally, but more stringent criteria may be necessary for waterfowl marshes and other habitat, such as those for shellfish and marine fishes. Some marine habitats, such as important intertidal zones and kelp beds, may require special protection.

(MIGR) FISH MIGRATION
Uses of water that support habitats necessary for migration, acclimatization between fresh water and salt water, and protection of aquatic organisms that are temporary inhabitants of waters within the region.

The water quality provisions acceptable to cold water fish generally protect anadromous fis*h* as well. However, particular attention must be paid to maintaining zones of passage. Any barrier to migration or free movement of migratory fish is harmful. Natural tidal movement in estuaries and unimpeded river flows are necessary to sustain migratory fish and their offspring. A water quality barrier, whether thermal, physical, or chemical, can destroy the integrity of the migration mute and lead to the rapid decline of dependent fisheries. Water quality may vary through a zone of passage as a result of natural or human-induced activities. Fresh water entering estuaries may float on the surface of the denser salt water or hug one shore as a result of density differences related to water temperature, salinity, or suspended matter.

(RARE) PRESERVATION OF RARE AND ENDANGERED SPECIES
Uses of waters that support habitats necessary for the survival and successful maintenance of plant or animal species established under state and/or federal law as rare, threatened, or endangered.

The water quality criteria to be achieved that would encourage development and protection of rare and endangered species should be the same as those for protection of fish and wildlife habitats generally. However, where rare or endangered species exist, special control requirements may be necessary to assure attainment and maintenance of particular quality criteria, which may vary slightly with the environmental needs of each particular species. Criteria for species using areas of special biological significance should likewise be derived from the general criteria for the habitat types involved, with special management diligence given where required.

(SPWN) FISH SPAWNING
Uses of water that support high quality aquatic habitats suitable for reproduction and early deteiopment of fish.

Dissolved oxygen levels in spawning areas should ideally approach saturation levels. Free movement of water is essential to maintain well-oxygenated conditions around eggs deposited in sediments. Water temperature, size distribution and organic content of sediments, water depth, and current velocity are also important determinants of spawning area adequacy.

(WARM) WARM FRESHWATER HABITAT
Uses of water that support warm water ecosystems including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates.

The warm freshwater habitats supporting bass, bluegill, perch, and other panfish are generally lakes and reservoirs, although some minor streams will serve this purpose where stream flow is sufficient to sustain the fishery. The habitat is also important to a variety of nonfish species, such as flogs, crayfish, and insects, which provide food for fish and small mammals. This habitat is less sensitive to environmental changes, but more diverse than the cold freshwater habitat and natural fluctuations in temperature, dissolved oxygen, pH, and turbidity are usually greater.

WII.D) WILDLIFE HABITAT
Uses of waters that support wildllife habitats, including, but not limited to, the preservation and enhancement of vegetation and prey species used by wildlife, such as waterfowl.

The two most important types of wildlife habitat are riparian and wetland habitats. These habitats can be threatened by development, erosion, and sedimentation, as well as by poor water quality. The water quality requirements of wildlife pertain to the water directly ingested, the aquatic habitat itself, and the effect of water quality on the production of food materials. Waterfowl habitat is particularly sensitive to changes in water quality. Dissolved oxygen, pH, alkalinity, salinity, turbidity, settleable matter, oil, toxicants, and specific disease organisms are water quality characteristics particularly important to waterfowl habitat. Dissolved oxygen is needed in waterfowl habitats to suppress development of botulism organisms; botulism has killed millions of waterfowl. It is particularly important to mainrain adequate circulation and aerobic conditions in shallow fringe areas of ponds or reservoirs where botulism has caused problems.

Region III (Central Coast)
Source: Water Quality Control Plan -Regional Water Quality Control Board 3 (Central Coast), California Regional Water Quality Control Board, Chapter 6: Surveillance And Monitoring, pg. VI-2, September 8, 1991: http://www.epa.gov/ost/standards/wqslibrary/ca/ca_9_wqcp.pdf

III.A.1. TOXIC SUBSTANCE MONITORING
The Toxic Substances Monitoring (TSM) portion of the Primary Network has been integrated with other Primary Network Monitoring. Streams and lakes were ranked according to various criteria established to indicate their importance to the State in terms of water quality. From this process, the water bodies ranked Priority 1, or highest priority, were included in the Primary Network; routine chemical and biological water monitoring is performed by DWR and/or the USGS; and toxic substances monitoring of resident organisms is performed by the Department of Fish and Game. The objectives of the Primary Network TSM program are:

1. To develop statewide baseline data and to demonstrate trends in the occurrence of toxic elements and organic substances in the aquatic biota,

Region IV (Los Angeles)
Source: Water Quality Control Plan Los Angeles - Region Basin Plan for the Coastal Watersheds of Los

Angeles and Ventura Counties, Chapter 6: Surveillance And Monitoring**,** approved February 23, 1995: http://www.epa.gov/ost/standards/wqslibrary/ca/ca_9_los_angeles.pdf

Biological Criteria
Biological criteria are narrative (and sometimes numeric) expressions that describe the biological integrity of aquatic communities (EPA, 1991). Biological criteria supplement other water quality objectives (physical, chemical, toxicity) by providing a direct measure of aquatic communities at risk from human activities. These criteria can also provide evidence of streams with exceptional water quality. Baseline data must be collected from both reference and impacted streams in the Region. Regular monitoring of these areas can then provide a continual assessment of instream impacts. Over 30 of the 50 states have developed, or are developing, biological criteria programs. Although there is not a current biological criteria program in the Region, Regional Board staff are planning to begin conducting baseline surveys in the coming years. Although **there is not a current** biological criteria program in the Region, Regional Board staff are planning to begin conducting baseline surveys in the coming years.

Colorado

SOURCE: Colorado Department of Public Health and Environment, Department Regulations, Water Quality Control Commission, Surface Water Quality Classifications & Standards, Regulation 31- Basic Standards & Methodologies for Surface Water, amended effective October 30, 2001:
http://www.cdphe.state.co.us/op/regs/100231.pdf and http://www.cdphe.state.co.us/wq/wqhom.html

31.5 DEFINITIONS

(8) "COLD WATER BIOTA" means aquatic life, including trout, normally found in waters where the summer temperature does not often exceed 20° C.

(32) "WARM WATER BIOTA" means aquatic life normally found in waters where the summer temperature frequently exceeds 20° C.

31.11 BASIC STANDARDS APPLICABLE TO SURFACE WATERS OF THE STATE
All surface waters of the state are subject to the following basic standards; however, discharge of substances regulated by permits which are within those permit limitations shall not be a basis for enforcement proceedings under these basic standards:

(1) Except where authorized by permits, BMP's, 401 certifications, or plans of operation approved by the Division or other applicable agencies, state surface waters shall be free from substances attributable to human-caused point source or nonpoint source discharge in amounts, concentrations or combinations which:

(a) for all surface waters of the state except wetlands;
(v) are harmful to the beneficial uses or toxic to humans, animals, plants, or aquatic life; or
(vi) produce a predominance of undesirable aquatic life;

(b) for surface waters in wetlands;
(ii) are toxic to humans, animals, plants, or aquatic life of the wetland.

31.13 STATE USE CLASSIFICATIONS

(c) Aquatic Life
These surface waters presently support aquatic life uses as described below, or such uses may reasonably be expected in the future due to the suitability of present conditions, or the waters are intended to become suitable for such uses as a goal:
(i) Class I - Cold Water Aquatic Life
These are waters that (1) currently are capable of sustaining a wide variety of cold water biota, including sensitive species, or (2) could sustain such biota but for correctable water quality conditions. Waters shall be considered capable of sustaining such biota where physical habitat, water flows or levels, and water quality conditions result in no substantial impairment of the

abundance and diversity of species.

(ii) Class 1 - Warm Water Aquatic Life
These are waters that (1) currently are capable of sustaining a wide variety of warm water biota, including sensitive species, or (2) could sustain such biota but for correctable water quality conditions. Waters shall be considered capable of sustaining such biota where physical habitat, water flows or levels, and water quality conditions result in no substantial impairment of the abundance and diversity of species.

(iii) Class 2- Cold and Warm Water Aquatic Life
These are waters that are not capable of sustaining a wide variety of cold or warm water biota, including sensitive species, due to physical habitat, water flows or levels, or uncorrectable water quality conditions that result in substantial impairment of the abundance and diversity of species.

(e) Wetlands

(v) The Commission may adopt a "wetlands" classification based on the functions of the wetlands in question. Wetland functions that may warrant site-specific protection include ground water recharge or discharge, flood flow alteration, sediment stabilization, sediment or other pollutant retention, nutrient removal or transformation, biological diversity or uniqueness, wildlife diversity or abundance, aquatic life diversity or abundance, and recreation.

Connecticut

SOURCE: Connecticut Water Quality Standards Sections II and III, effective April 9, 1997: http://dep.state.ct.us/wtr/wqsinfo.htm and http://dep.state.ct.us/wtr/wqs.pdf

NARRATIVE BIOCRITERIA

Surface waters and sediments shall be free from chemical constituents in concentrations or combinations which will or can reasonably be expected to result in acute or chronic toxicity to aquatic organisms or impair the biological integrity of aquatic or marine ecosystems outside of any allocated zone of influence or which will or can reasonably be expected to bioconcentrate or bioaccumulate in tissues of fish, shellfish and other aquatic organisms to levels which will impair the health of aquatic organisms or wildlife or result in unacceptable tastes, odors or health risks to human consumers of aquatic life. In determining consistency with this Standard, the Commissioner shall at a minimum consider the specific number criteria listed in Appendix D and any other information she or he deems relevant.

Benthic invertebrate criteria may be utilized where appropriate for assessment of biological integrity of surface waters. The criteria apply to the fauna of erosional or riffle habitats in flowing waters which are not subject to tidal influences.

III. SURFACE WATER CLASSIFICATIONS
INLAND SURFACE WATERS
CLASS AA

Designated Use - Existing or proposed drinking water supply; fish and wildlife habitat; recreational use; agricultural, industrial supply and other purposes, (recreational uses may be restricted).

CRITERIA

Parameter	Standard
13. Benthic Invertebrates which inhabit lotic waters	A wide variety of macroinvertebrate taxa should normally be present and all functional feeding groups should normally be well represented. Presence and productivity of aquatic species is not limited except by natural conditions, permitted flow regulation or irreversible cultural impacts. Water quality shall be sufficient to sustain a diverse macroinvertebrate community of indigenous species. Taxa within the Orders Plecoptera (stoneflies), Ephemeroptera (mayflies), Coleoptera (beetles) and Trichoptera (caddisflies) should be well represented.

INLAND SURFACE WATERS
CLASS A
Designated Uses - Potential drinking water supply; fish and wildlife habitat; recreational use; agricultural, industrial supply and other legitimate uses, including navigation.

CRITERIA

Parameter	Standard
13. Benthic Invertebrates which inhabit lotic waters	A wide variety of macroinvertebrate taxa should normally be present and all functional feeding groups should normally be well represented. Presence and productivity of aquatic species is not limited except by natural conditions, permitted flow regulation or irreversible cultural impacts. Water quality shall be sufficient to sustain a diverse macroinvertebrate community of indigenous species. Taxa within the Orders Plecoptera (stoneflies), Ephemeroptera (mayflies), Coleoptera (beetles) and Trichoptera (caddisflies) should be well represented.

INLAND SURFACE WATERS
CLASS B
Designated Use - Recreational use; fish and wildlife habitat; agricultural and industrial supply and other legitimate uses including navigation.

CRITERIA

Parameter	Standard
13. Benthic Invertebrates which inhabit lotic waters	Water quality shall be sufficient to sustain a diverse macroinvertebrate community of indigenous species. All functional feeding groups and a wide variety of macroinvertebrate taxa shall be present, however one or more may be disproportionate in abundance. Waters which currently support a high quality aquatic community shall be maintained at that high quality. Presence and productivity of taxa within the Orders Plecoptera (stoneflies), Ephemeroptera (mayflies); and pollution intolerant Coleoptera (beetles) and Trichoptera (caddis-flies) may be limited due to cultural activities. Macroinvertebrate communities in waters impaired by cultural activities shall be restored to the extent practical through implementation of the department's procedures for control of pollutant discharges to surface waters and through Best Management Practices for non-point sources of pollution.

INLAND SURFACE WATERS
CLASS C
Present water quality conditions preclude the full attainment of one or more designated uses for Class B waters some or all of the time. One or more Water Quality Criteria for Class B waters are not being consistently achieved. Class C waters may be suitable for certain fish and wildlife habitat, certain recreational activities, industrial use and other legitimate uses, including navigation.

INLAND SURFACE WATERS
CLASS D
Present water quality conditions persistently preclude the attainment of one or more designated uses for Class B waters. One or more Water Quality Criteria for Class B waters are not being achieved most or all of the time. Class D waters may be suitable for bathing or other recreational purposes, certain fish and wildlife habitat, industrial or other legitimate uses, including navigation.

Delaware

SOURCE: State of Delaware Surface Water Quality Standards as amended, August 11, 1999, Department of Natural Resources and Environmental Control: http://www.dnrec.state.de.us/water/wqs1999.pdf

Section 1: Intent

1.1. It is the policy of the Department to maintain within its jurisdiction surface waters of the State of satisfactory quality consistent with public health and public recreation purposes, the propagation and protection of fish and aquatic life, and other beneficial uses of the water.

Section 2: Definitions

Cold water fish use: Protection of fish species (such as from the family Salmonidae) and other flora and fauna indigenous to a cold water habitat.

Fish, aquatic life and wildlife: All animal and plant life found in Delaware, either indigenous or migratory, regardless of life stage or economic importance.

Section 3: Antidegradation Policy

3.1. Existing instream water uses and the level of water quality necessary to protect the existing uses shall be maintained and protected. Degradation of water quality in such a manner that results in reduced number, quality, or river or stream mileage of existing uses shall be prohibited. Degradation shall be defined for the purposes of this section as a statistically significant reduction, accounting for natural variations, in biological, chemical, or habitat quality as measured or predicted using appropriate assessment protocols.

3.2. Where the quality of the waters exceeds levels necessary to support propagation of fish, shellfish, and wildlife and recreation in and on the water, that quality shall be maintained and protected. In the case of waters of exceptional recreational or ecological significance, existing quality shall be maintained or enhanced...

3.3. Where high quality waters constitute an outstanding National resource, such as waters of National parks and wildlife refuges, existing quality shall be maintained and protected.

Section 4: General Stream Criteria

4.1. All surface waters of the State (except as detailed in Sections 8 and 12) shall meet the following minimum criteria:

(a) Waters shall be free from substances that are attributable to wastes of industrial, municipal, agricultural or other human-induced origin. Examples include but are not limited to the following:

(iii) Any pollutants, including those of a thermal, toxic, corrosive, bacteriological, radiological, or other nature, that may interfere with attainment and maintenance of designated uses of the water, may impart undesirable odors, tastes, or colors to the water or to aquatic life found therein, may endanger public health, or may result in dominance of nuisance species.

District of Columbia*

*This language has not been reviewed for accuracy by state/tribal agency.

SOURCE: Chapter 11, Water Quality Standards of Title 21 of the District of Columbia Municipal Regulations (Notice of Final Rulemaking, January 21, 2000): http://dchealth.dc.gov/services/administration_offices/environmental/services2/water_division/pdf/WaterQualityStandards.shtm

1101.1 For the purposes of water quality standards, the surface waters of the District shall be classified on the basis of their (i) current uses, and (ii) future uses to which the waters will be restored. The categories of beneficial uses for the surface waters of the District shall be as follows:

Categories of Uses Which Determine Water Quality Standards	Classes of Water
Protection & propagation of fish, shellfish and wildlife	...C...

1102.3 TIER III: Where High Quality Waters constitute an outstanding National resource, such as waters of the National and District parks and wildlife refuges and waters of exceptional recreational or ecological significance, those waters shall be designated Outstanding National Resource Waters (ONRW) and the water quality in the ONRW shall be maintained, protected and designated as below:
(a) New point and nonpoint source discharges, treated or otherwise, shall be prohibited in these segments;
(b) Increases in loadings or new pollutants from existing point and nonpoint source discharges shall be prohibited in these segments;
(c) Short-term degradation of the water quality shall be allowed after opportunity for public participation and addressing their comments, if any. However, all practical means of minimizing such degradation shall be implemented; and
(d) Designation of ONRWs shall be adopted after full satisfaction of the intergovernmental coordination of the District's agencies and public participation.

1102.4 SPECIAL WATERS OF THE DISTRICT OF COLUMBIA (SWDC): Any segment or segments of the surface waters of the District which are of water quality better than needed for the current use or have scenic or aesthetic importance shall be designated as Special Waters of the District of Columbia (SWDC)...

1103 WETLANDS

1103.1 In a wetland, the numerical and the narrative criteria shall be applied to the column of water above the wetland in accordance with the designated use.

1103.2 Wetlands with rooted vascular aquatic vegetation, except those specifically constructed or created as waste water treatment devices and except as provided in D. C. Code subsection 6-923(d) and subsection 6-926(a)(3), shall be protected from significant adverse hydrologic modifications, excessive sedimentation, deposition of toxic substances in toxic amounts, nutrient imbalances, and other adverse anthropogenic impacts.

1104 STANDARDS

1104.1 The surface waters of the District shall be free from substances in amounts or combinations that do any of one the following:

(d) cause injury to, are toxic to, or produce adverse physiological or behavioral changes in humans, plants or animals
(e) Produce undesirable or nuisance aquatic life or result in the dominance of nuisance species; or
(f) Impair the biological community that naturally occurs in the waters or depends on the waters for its survival and propagation

1104.5 Class C streams shall be maintained to support aquatic life and shall not be placed in pipes.

Florida

SOURCE: Florida Administrative Code, Chapter 62-302 Surface Water Quality Standards, effective December 26, 1996: http://www.dep.state.fl.us/water/surfacewater/rules.htm and http://www8.myflorida.com/environment/learn/science/laboratories/index.html

62-302.200 Definitions.
(10)"Exceptional Ecological Significance" shall mean that a water body is a part of an ecosystem of unusual value. The exceptional significance may be in unusual species, productivity, diversity, ecological

relationships, ambient water quality, scientific or educational interest, or in other aspects of the ecosystem's setting or processes.

(15)"Nuisance Species" shall mean species of flora or fauna whose noxious characteristics or presence in sufficient number, biomass, or areal extent may reasonably be expected to prevent, or unreasonably interfere with, a designated use of those waters.

(16)"Nursery Area of Indigenous Aquatic Life" shall mean any bed of the following aquatic plants, either in monoculture or mixed: Halodule wrightii, Halophila spp., Potamogeton spp. (pondweed), Ruppia maritima (widgeon-grass), Sagittaria spp. (arrowhead), Syringodium filiforme (manatee-grass), Thalassia testudinum (turtle grass), or Vallisneria spp. (eel-grass), or any area used by the early-life stages, larvae and post-larvae, of aquatic life during the period of rapid growth and development into the juvenile states.

(17)"Outstanding Florida Waters" shall mean waters designated by the Environmental Regulation Commission as worthy of special protection because of their natural attributes.

(18)"Outstanding National Resource Waters" shall mean waters designated by the Environmental Regulation Commission that are of such exceptional recreational or ecological significance that water quality should be maintained and protected under all circumstances, other than temporary lowering and the lowering allowed under Section 316 of the Federal Clean Water Act.

(22)"Propagation" shall mean reproduction sufficient to maintain the species' role in its respective ecological community.

(24)"Shannon-Weaver Diversity Index" shall mean: negative summation (from i=1 to s) of (n i /N) log 2 (n i /N) where s is the number of species in a sample, N is the total number of individuals in a sample, and n i is the total number of individuals in species i.

(25)"Special Waters" shall mean water bodies designated in accordance with Section 62-302.700, F.A.C., by the Environmental Regulation Commission for inclusion in the Special Waters Category of Outstanding Florida Waters, as contained in Section 62-302.700, F.A.C. A Special Water may include all or part of any water body.

62-302.400 Classification of Surface Waters, Usage, Reclassification, Classified Waters.

(1) All surface waters of the State have been classified according to designated uses as follows:
CLASS III Recreation, Propagation and Maintenance of a Healthy, Well-Balanced Population of Fish and Wildlife

(4) Water quality classifications are arranged in order of the degree of protection required, with Class I water having generally the most stringent water quality criteria and Class V the least. However, Class I, II, and III surface waters share water quality criteria established to protect recreation and the propagation and maintenance of a healthy, well-balanced population of fish and wildlife.

Excerpt from 62-302.530, Criteria for Surface Water Quality Classifications

Parameter	Units	Class I: Potable Water Supply	Class II: Shellfish Propagation or Harvesting	Class III: Recreation, Propagation and Maintenance of a Health, Well-balanced Population of Fish and Wildlife		Class IV: Agricultural Water Supplies	Class V: Navigation, Utility, and Industrial Use
				Predominantly Fresh Waters	Predominantly Marine Waters		
11) Biological Integrity	Percent reduction of Shannon-Weaver Diversity Index	The Index for benthic macro-invertebrates shall not be reduced less than 75% of background levels measured using organisms retained by a U. S. Standard No. 30 sieve and collected and composited from a minimum of three Hester-Dendy type artificial substrate samplers of 0.10 to 0.15 m2 area each, incubated for a period of four weeks.	The Index for benthic macro-invertebrates shall not be reduced to less than 75% of established background levels as measured using organisms retained by a U. S. Standard No. 30 sieve and collected and composited from a minimum of three natural substrate samples, taken with Ponar type samplers with minimum sampling area of 225 cm2.	The Index for benthic macro-invertebrates shall not be reduced to less than 75% of established background levels as measured using organisms retained by a U. S. Standard No. 30 sieve and collected and composited from a minimum of three Hester-Dendy type artificial substrate samplers of 0.10 to 0.15 m2 area each, incubated for a period of four weeks.	The Index for benthic macro-invertebrates shall not be reduced to less than 75% of established background levels as measured using organisms retained by a U. S. Standard No. 30 sieve and collected and composited from a minimum of three natural substrate samples, taken with Ponar type samplers with minimum sampling area of 225 cm2.		

62-302.800 Site Specific Alternative Criteria.

(2) The affirmative demonstration required by this section shall mean a documented showing that the proposed alternative criteria would exist due to natural background conditions or man-induced conditions which cannot be controlled or abated. Such demonstration shall be based upon relevant factors which include:

(c) A description of the historical and existing biology, including variations, which may be affected by the parameter of concern. Conditions in similar water bodies may be used for comparison.

Georgia

SOURCE: Rules of Georgia Department of Natural Resources, Environmental Protection Division, Chapter 391-3-6, Water Quality Control, revised October 2001: http://www.dnr.state.ga.us/dnr/environ/rules_files/exist_files/391-3-6.pdf and http://www.dnr.state.ga.us/dnr/environ

(2) Water Quality Enhancement:

(a) The purposes and intent of the State in establishing Water Quality Standards are to provide enhancement of water quality and prevention of pollution; to protect the public health or welfare in accordance with the public interest for drinking water supplies, conservation of fish, wildlife and other beneficial aquatic life, and agricultural, industrial, recreational, and other reasonable and necessary uses and to maintain and improve the biological integrity of the waters of the State.

391-3-6.03 Water Use Classifications and Water Quality Standards

(3) Definitions:

(b) "Biological integrity" is functionally defined as the condition of the aquatic community inhabiting least impaired waterbodies of a specified habitat measured by community structure and function.

(4) Water Use Classifications. Water use classifications for which the criteria of this Paragraph are applicable are as follows:
   (c) Fishing, Propagation of Fish, Shellfish, Game and Other Aquatic Life
   (d) Wild River
   (e) Scenic River
   (f) Coastal Fishing

(6) Specific Criteria for Classified Water Usage. In addition to the general criteria, the following criteria are deemed necessary and shall be required for the specific water usage as shown:
   (a) Drinking Water Supplies: Those waters approved as a source for public drinking water systems permitted or to be permitted by the Environmental Protection Division. Waters classified for drinking water supplies will also support the fishing use and any other use requiring water of a lower quality.
   (c) Fishing: Propagation of Fish, Shellfish, Game and Other Aquatic Life; secondary contact recreation in and on the water; or for any other use requiring water of a lower quality.
   (d) Wild River: For all waters designated in 391-3-6-.03(13) as "Wild River," there shall be no alteration of natural water quality from any source.
   (e) Scenic River: For all waters designated in 391-3-6-.03(13) as "Scenic River," there shall be no alteration of natural water quality from any source.
   (f) Coastal Fishing: This classification will be applicable to specific sites when so designated by the Environmental Protection Division. For waters designated as "Coastal Fishing", site specific criteria for dissolved oxygen will be assigned and detailed by footnote in Section 391-3-6.03(13), "Specific Water Use Classifications." All other criteria and uses for the fishing use classification will apply for coastal fishing.

(15) Trout Streams. Streams designated as Primary Trout Waters are waters supporting a self-sustaining population of Rainbow, Brown or Brook Trout. Streams designated as Secondary Trout Streams are those with no evidence of natural trout reproduction, but are capable of supporting trout throughout the year...

Hawai`i

SOURCE: Source: Hawai`i Administrative Rules Title 11, Department of Health Chapter 54, Water Quality Standards, April 17, 2000:
http://www.hawaii.gov/health/rules/11-54.pdf and
http://www.epa.gov/waterscience/standards/wqslibrary/hi/hawaii_9_wqs.pdf

§11-54-01 Definitions. As used in this chapter:

- "Amphidromous" means aquatic life that migrate to and from the sea, but not specifically for reproductive purposes. Amphidromous aquatic life in Hawaiʻian streams are confined to fresh waters as adults, but their larval stages are partially or entirely spent in the ocean as part of the zooplankton.
- "Anchialine pools" means coastal bodies of standing waters that have no surface connections to the ocean but display both tidal fluctuations and salinity ranges characteristic of fresh and brackish waters, indicating the presence of subsurface connections to the watertable and ocean. Anchialine pools are located in porous substrata (recent lava or limestone) and often contain a distinctive assemblage of native aquatic life. Deeper anchialine pools may display salinity stratification, and some shallow pools may contain standing water only on the highest tides.
- "Aquatic life" means "any type or species of mammal, fish, amphibian, reptile, mollusk, crustacean, arthropod, invertebrate, coral, or other animal that inhabits the freshwater or marine environment and includes any part, product, egg, or offspring thereof; or freshwater or marine plants, including, seeds, roots, products, and other parts thereof".
- "Estuaries" means characteristically brackish coastal waters in well-defined basins with a continuous or seasonal surface connection to the ocean that allows entry of marine fauna. Estuaries may be either natural or developed.
- "Introduced aquatic life" means those species of aquatic organisms that are not native to a given area or water body and whose populations were established (deliberately or accidentally) by human activity. "Introduced" organisms are also referred to as "alien" or "exotic".

- "Low wetlands" means freshwater wetlands located below 100 m (330 ft) elevation that may be natural or artificial in origin and are usually found near coasts or in valley termini. Low wetlands are maintained by either stream, well, or ditch influent water, or by exposure of the natural water table. Low wetlands include, but are not limited to, natural lowland marshes, riparian wetlands, littoral zones of standing waters (including lakes, reservoirs, ponds and fishponds) and agricultural wetlands such as taro lo'i.
- "Native aquatic life" means those species or higher taxa of aquatic organisms that occur naturally in a given area or water body and whose populations were not established as a result of human activity.
- "Natural estuaries" means volumes of brackish coastal waters in well-defined basins of natural origin, found mainly at the mouths of streams or rivers. Natural estuaries can be either stream-fed (drowned stream mouths fed by perennial stream runoff) or spring-fed (nearshore basins with subterranean fresh water sources). Stream-fed estuaries serve as important migratory pathways for larval and juvenile amphidromous stream fauna.
- "Natural freshwater lakes" means standing water that is always fresh, in well-defined natural basins, with a surface area usually greater than 0.1 ha (0.25 acres), and in which rooted emergent hydrophytes, if present, occupy no more than 30% of the surface area. Natural freshwater lakes in Hawai‘i occur at high, intermediate, and low elevations. Lowland freshwater lakes characteristically lack a natural oceanic connection (surface or subsurface) of a magnitude sufficient to cause demonstrable tidal fluctuations.

§11-54-03 Classification of water uses.

(a) The following use categories classify inland and marine waters for purposes of applying the standards set forth in this chapter, and for the selection or definition of appropriate quality parameters and uses to be protected in these waters. Storm water discharge into State waters shall be allowed provided it meets the requirements specified in this section and the basic water quality criteria specified in section 11-54-04.

(b) Inland waters.

(1) Class 1. It is the objective of class 1 waters that these waters remain in their natural state as nearly as possible with an absolute minimum of pollution from any human-caused source. To the extent possible, the wilderness character of these areas shall be protected. Waste discharge into these waters is prohibited. Any conduct which results in a demonstrable increase in levels of point or nonpoint source contamination in class 1 waters is prohibited.

(a) Class 1.a. The uses to be protected in class 1.a waters are scientific and educational purposes, protection of native breeding stock, baseline references from which human-caused changes can be measured, compatible recreation, aesthetic enjoyment, and other nondegrading uses which are compatible with the protection of the ecosystems associated with waters of this class;

(b) Class 1.b. The uses to be protected in class 1.b waters are domestic water supplies, food processing, protection of native breeding stock, the support and propagation of aquatic life...

(2) Class 2. The objective of class 2 waters is to protect their use for recreational purposes, the support and propagation of aquatic life, agricultural and industrial water supplies, shipping, and navigation. The uses to be protected in this class of waters are all uses compatible with the protection and propagation of fish, shellfish, and wildlife, and with recreation in and on these waters. These waters shall not act as receiving waters for any discharge which has not received the best degree of treatment or control compatible with the criteria established for this class...

(c) Marine waters.

(1) Class AA. It is the objective of class AA waters that these waters remain in their natural pristine state as nearly as possible with an absolute minimum of pollution or alteration of water quality from any human-caused source or actions. To the extent practicable, the wilderness character of these areas shall be protected. No zones of mixing shall be permitted in this class:

(a) Within a defined reef area, in waters of a depth less than 18 meters (ten fathoms); or

(b) In waters up to a distance of 300 meters (one thousand feet) off shore if there is no defined reef area and if the depth is greater than 18 meters (ten fathoms). The uses to be protected in this class of waters are oceanographic research, the support and propagation of shellfish and other marine life, conservation of coral reefs and wilderness areas, compatible recreation, and aesthetic enjoyment. The classification of any water area as Class AA shall not preclude other uses of the waters compatible with these objectives and in conformance with the criteria applicable to them;

(2) Class A. It is the objective of class A waters that their use for recreational purposes and aesthetic

enjoyment be protected. Any other use shall be permitted as long as it is compatible with the protection and propagation of fish, shellfish, and wildlife, and with recreation in and on these waters. These waters shall not act as receiving waters for any discharge which has not received the best degree of treatment or control compatible with the criteria established for this class.

(d) Marine bottom ecosystems.
   (1) Class I. It is the objective of class I marine bottom ecosystems that they remain as nearly as possible in their natural pristine state with an absolute minimum of pollution from any human-induced source. Uses of marine bottom ecosystems in this class are passive human uses without intervention or alteration, allowing the perpetuation and preservation of the marine bottom in a most natural state, such as for nonconsumptive scientific research (demonstration, observation or monitoring only), nonconsumptive education, aesthetic enjoyment, passive activities, and preservation;
   (2) Class II. It is the objective of class II marine bottom ecosystems that their use for protection including propagation of fish, shellfish, and wildlife, and for recreational purposes not be limited in any way. The uses to be protected in this class of marine bottom ecosystems are all uses compatible with the protection and propagation of fish, shellfish, and wildlife, and with recreation.

§11-54-05.2 Inland water criteria.
(b) Specific criteria for streams.
   (2) Bottom criteria for streams:
      (e) The director shall prescribe the appropriate parameters, measures, and criteria for monitoring stream bottom biological communities including their habitat, which may be affected by proposed actions. Permanent benchmark stations may be required where necessary for monitoring purposes. The water quality criteria for this subsection shall be deemed to be met if time series surveys of benchmark stations indicate no relative changes in the relevant biological communities, as noted by biological community indicators or by indicator organisms which may be applicable to the specific site.

Idaho

SOURCE: Source: Rules of the Department of Environmental Quality, IDAPA 58.01.02, Water Quality Standards and Wastewater Treatment Requirements, amended April 5, 2000:
http://www2.state.id.us/adm/adminrules/rules/idapa58/0102.pdf and
http://www2.state.id.us/adm/adminrules/rules/idapa58/58index.htm

3. Definitions

04. Beneficial Use. Any of the various uses which may be made of the water of Idaho, including, but not limited to, domestic water supplies, industrial water supplies, agricultural water supplies, navigation, recreation in and on the water, wildlife habitat, and aesthetics. The beneficial use is dependent upon actual use, the ability of the water to support a non-existing use either now or in the future, and its likelihood of being used in a given manner. The use of water for the purpose of wastewater dilution or as a receiving water for a waste treatment facility effluent is not a beneficial use. (8-24-94)

05. Aquatic Species. Any plant or animal that lives at least part of its life in the water column or benthic portion of waters of the state. (8-24-94)

11. Biological Monitoring or Biomonitoring. The use of a biological entity as a detector and its response as a measure to determine environmental conditions. Toxicity tests and biological surveys, including habitat monitoring, are common biomonitoring methods.

23. Desirable Species. Species indigenous to the area or those introduced by the Idaho Department of Fish and Game.

71. Outstanding Resource Water (ORW). A high quality water, such as water of national and state parks and wildlife refuges and water of exceptional recreational or ecological significance, which has been designated by the legislature and subsequently listed in this chapter. ORW constitutes an outstanding national or state resource that requires protection from point and nonpoint source activities that may lower water quality. (3-20-97)

85. Reference Stream Or Condition. A water body which represents the minimum conditions necessary to fully support the applicable designated beneficial uses as further specified in these rules, or natural conditions with few impacts from human activities and which are representative of the highest level of support attainable in the basin. In highly mineralized areas or in the absence of such reference streams or water bodies, the Director, in consultation with the basin advisory group and the technical advisors to it, may define appropriate hypothetical reference conditions or may use monitoring data specific to the site in question to determine conditions in which the beneficial uses are fully supported.

87. Resident Species. Those species that commonly occur in a site including those that occur only seasonally or intermittently. This includes the species, genera, families, orders, classes, and phyla that: (8-24-94)

a. Are usually present at the site; (8-24-94)
b. Are present only seasonally due to migration; (8-24-94)
c. Are present intermittently because they periodically return or extend their ranges into the site; (8-24-94)
d. Were present at the site in the past but are not currently due to degraded conditions, and are expected to be present at the site when conditions improve; and (8-24-94)
e. Are present in nearby bodies of water but are not currently present at the site due to degraded conditions, and are expected to be present at the site when conditions improve. (8-24-94)

111. Unique Ecological Significance. The attribute of any stream or water body which is inhabited or supports an endangered or threatened species of plant or animal or a species of special concern identified by the Idaho Department of Fish and Game, which provides anadromous fish passage, or which provides spawning or rearing habitat for anadromous or desirable species of lake dwelling fishes.

53. BENEFICIAL USE SUPPORT STATUS.

In determining whether a water body fully supports designated and existing beneficial uses, the Department shall determine whether all of the applicable water quality standards are being achieved, including any criteria developed pursuant to these rules, and whether a healthy, balanced biological community is present. The Department shall utilize biological and aquatic habitat parameters listed below and in the current version of the "Water Body Assessment Guidance", as published by the Idaho Department of Environmental Quality, as a guide to assist in the assessment of beneficial use status. Revisions to this guidance will made after notice and an opportunity for public comment. These parameters are not to be considered or treated as individual water quality criteria or otherwise interpreted or applied as water quality standards. (4-5-00)

01. Aquatic Habitat Parameters. These parameters may include, but are not limited to, stream width, stream depth, stream shade, measurements of sediment impacts, bank stability, water flows, and other physical characteristics of the stream that affect habitat for fish, macroinvertebrates or other aquatic life; and (3-20-97)

02. Biological Parameters. These parameters may include, but are not limited to, evaluation of aquatic macroinvertebrates including Ephemeroptera, Plecoptera and Trichoptera (EPT), Hilsenhoff Biotic Index, measures of functional feeding groups, and the variety and number of fish or other aquatic life to determine biologicalcommunity diversity and functionality.

100. SURFACE WATER USE DESIGNATIONS.

01. Aquatic Life. (7-1-93)

a. Cold water (COLD): water quality appropriate for the protection and maintenance of a viable aquatic life community for cold water species. (4-5-00)
b. Salmonid spawning: waters which provide or could provide a habitat for active self-propagating populations of salmonid fishes. (7-1-93)
c. Seasonal cold water (SC): water quality appropriate for the protection and maintenance of a viable aquatic life community of cool and cold water species, where cold water aquatic life may be absent

during, or tolerant of , seasonally warm temperatures. (4-5-00)

d. Warm water (WARM): water quality appropriate for the protection and maintenance of a viable aquatic life community for warm water species. (4-5-00)

e. Modified (MOD): water quality appropriate for an aquatic life community that is limited due to one (1) or more conditions set forth in 40 CFR 131.10(g) which preclude attainment of reference streams or conditions.

04. Wildlife Habitats. Water quality appropriate for wildlife habitats. This use applies to all surface waters of the state. (4-5-00)

Illinois

SOURCE: Title 35: Environmental Protection, Subtitle C: Water Pollution, Chapter I: Pollution Control Board, Part 302 and 303 Water Quality Standards, amended August 26, 1999:
http://www.ipcb.state.il.us/Title_35/Subtitles/C/302.pdf and
http://www.ipcb.state.il.us/Title_35/Subtitles/C/303.pdf

Section 302.102 Allowed Mixing, Mixing Zones and ZIDs

(b) The portion, volume and area of any receiving waters within which mixing is allowed pursuant to subsection (a) shall be limited by the following:
  2) Mixing is not allowed in waters which include a tributary stream entrance if such mixing occludes the tributary mouth or otherwise restricts the movement of aquatic life into or out of the tributary.
  3) Mixing is not allowed in waters containing mussel beds, endangered species habitat, fish spawning areas, areas of important aquatic life habitat, or any other natural features vital to the well being of aquatic life in such a manner that the maintenance of aquatic life in the body of water as a whole would be adversely affected.
  6) Mixing must allow for a zone of passage for aquatic life in which water quality standards are met.

SUBPART E:
Section 302.501 Scope, Applicability, and Definitions

"Resident or indigenous species" means species that currently live a substantial portion of their life cycle, or reproduce, in a given body of water, or that are native species whose historical range includes a given body of water.

"Target species" is a species to be protected by the criterion.

"Target species value" is the criterion value for the target species.

"Trophic level" means a functional classification of taxa within a community that is based on feeding relationships. For example, aquatic green plants and herbivores comprise the first and second trophic levels in a food chain.

SUBPART B: Nonspecific Water Use Designations:
Section 303.204 Secondary Contact and Indigenous Aquatic Life Waters

Waters which are required to meet the secondary contact and indigenous aquatic life standards of Subpart D, Part 302, are not required to meet the general use standards or the public and food processing water supply standards of Subparts B and C, Part 302.

Indiana

SOURCE: Indiana Administrative Code, Title 327 Water Pollution Control Board, Article 2: Water Quality Standards, Updated April 1, 2002: http://www.ai.org/legislative/iac/title327.html

Indiana Water Quality Standards for the Non-Great Lakes Basin Portions of Indiana

327 IAC 2-1-3 Surface water use designations; multiple uses

Sec. 3. (a) The following water uses are designated by the water pollution control board:

(1) Surface waters of the state are designated for full-body contact recreation as provided in section 6(d) of this rule.

(2) All waters, except as described in subdivision (5), will be capable of supporting a well-balanced, warm water aquatic community and, where natural temperatures will permit, will be capable of supporting put-and-take trout fishing. All waters capable of supporting the natural reproduction of trout as of February 17, 1977, shall be so maintained.

(3) All waters which are used for public or industrial water supply must meet the standards for those uses at the points where the water is withdrawn. This use designation and its corresponding water quality standards are not to be construed as imposing a user restriction on those exercising or desiring to exercise the use.

(4) All waters which are used for agricultural purposes must, as a minimum, meet the standards established in section 6(a) of this rule.

(5) All waters in which naturally poor physical characteristics (including lack of sufficient flow), naturally poor chemical quality, or irreversible man-induced conditions, which came into existence prior to January 1, 1983, and having been established by use attainability analysis, public comment period, and hearing may qualify to be classified for limited use and must be evaluated for restoration and upgrading at teach triennial review of this rule. Specific waters of the state designated for limited use are listed in section 11(a) of this rule.

(6) All waters which provide unusual aquatic habitat, which are an integral feature of an area of exceptional natural beauty or character, or which support unique assemblages of aquatic organisms may be classified for exceptional use. Specific waters of the state designated for exceptional use are listed in section 11(b) of this rule.

(b) Where multiple uses have been designated for a body of water, the most protective of all simultaneously applicable standards will apply. *(Water Pollution Control Board; 327 IAC 2-1-3; filed Sep 24, 1987, 3:00 p.m.: 11 IR 580; filed Feb 1, 1990, 4:30 p.m.: 13 IR 1019; filed Jan 14, 1997, 12:00 p.m.: 20 IR 1348)*

327 IAC 2-1-6 Minimum surface water quality standards

Sec. 6. (a) The following are minimum water quality conditions:

(1) All waters at all times and at all places, including the mixing zone, shall meet the minimum conditions of being free from substances, materials, floating debris, oil, or scum attributable to municipal, industrial, agricultural, and other land use practices, or other discharges:

(A) that will settle to form putrescent or otherwise objectionable deposits;

(B) that are in amounts sufficient to be unsightly or deleterious;

(C) that produce color, visible oil sheen, odor, or other conditions in such degree as to create a nuisance;

(D) which are in amounts sufficient to be acutely toxic to, or to otherwise severely injure or kill aquatic life, other animals, plants, or humans:

(i) to assure protection of aquatic life, concentrations of toxic substances shall not exceed the final acute value (FAV = 2 (AAC)) in the undiluted discharge or the acute aquatic criterion (AAC) outside the zone of initial dilution or, if applicable, the zone of discharge-induced mixing:

(AA) for certain substances, the AAC are established and set forth in Table 1 (which table4 incorporates Table 2); and (BB) for substances for which an AAC is not specified in Table 1, or if a different AAC can be scientifically justified based on new toxicological data or site-specific conditions concerning water quality characteristics or species present, an AAC can be calculated by the commissioner using the procedures in section 8.2 of this rule; and

(ii) this clause shall not apply to the chemical control of plants and animals when that control is performed in compliance with approval conditions specified by the Indiana Department of Natural Resources as provided by IC 14-2-1; and

(E) which are in concentrations or combinations that will cause or contribute to the growth of aquatic plants or algae to such degree as to create a nuisance, be unsightly, or otherwise impair the designated uses.

(2) At all times, all waters outside of mixing zones shall be free of substances in concentrations which on the basis of available scientific data are believed to be sufficient to injure, be chronically toxic to, or be carcinogenic, mutagenic, or teratogenic to humans, animals, aquatic life, or plants. To assure protection against the adverse effects identified in this subdivision, the following requirements are established:

The Great Lakes Basin is covered by its own regulation which follows:
327 IAC 2-1.5-5: GLI Water Use Designations
327 IAC 2-1.5-5 Surface water use designations; multiple uses

Sec. 5. (a) The following water uses are designated by the board:

(1) All surface waters of the state within the Great Lakes system are designated for full-body contact recreation.

(2) All surface waters, except as described in subdivision (7), shall be capable of supporting a well-balanced, warm water aquatic community.

(3) Where natural temperatures will permit, surface waters shall be capable of supporting put-and-take trout fishing. All waters capable of supporting the natural reproduction of trout shall be so maintained. The following waters are designated as salmonid waters and shall be capable of supporting a salmonid fishery:
   (A) Trail Creek and its tributaries downstream to Lake Michigan.
   (B) East Branch of the Little Calumet River and its tributaries downstream to Lake Michigan via Burns Ditch.
   (C) Salt Creek above its confluence with the Little Calumet River.
   (D) Kintzele Ditch (Black Ditch) from Beverly Drive downstream to Lake Michigan.
   (E) The Galena River and its tributaries in LaPorte County.
   (F) The St. Joseph River and its tributaries in St. Joseph County from the Twin Branch Dam in Mishawaka downstream to the Indiana/Michigan state line.
   (G) The Indiana portion of the open waters of Lake Michigan.
   (H) Those waters designated by the Indiana department of natural resources for put-and-take trout fishing.

(4) All surface waters used for public water supply are designated as a public water supply. This use designation and its corresponding water quality criteria are not to be construed as imposing a user restriction on those exercising or desiring to exercise the use.

(5) All surface waters used for industrial water supply are designated as an industrial water supply. This use designation and its corresponding water quality criteria are not to be construed as imposing a user restriction on those exercising or desiring to exercise the use.

(6) All surface waters used for agricultural purposes are designated as an agricultural use water.

(7) Limited use waters are designated under section 19(a) of this rule pursuant to section 18 of this rule. All waters that are designated as a limited use water under section 19(a) of this rule must be evaluated for restoration and upgrading at each triennial review of this rule.

(8) Outstanding state resource waters are designated under section 19(b) of this rule pursuant to section 18 of this rule.

(b) Where multiple uses have been designated for a body of water, the most protective of all simultaneously applicable standards will apply. (Water Pollution Control Board; 327 IAC 2-1.5-5; filed Jan 14, 1997, 12:00 p.m.: 20 IR 1369)

327 IAC 2-1.5-8 Minimum surface water quality criteria

Sec. 8. (a) All surface water quality criteria in this section, except those provided in subsection (b)(1), will cease to be applicable when the stream flows are less than the applicable stream design flow for the particular criterion as determined under 327 IAC 5-2-11.4. (b) The following are minimum water quality conditions:

(1) All waters within the Great Lakes system at all times and at all places, including waters within the mixing zone, shall meet the minimum conditions of being free from substances, materials, floating

debris, oil, or scum attributable to municipal, industrial, agricultural, and other land use practices, or other discharges that do any of the following:
(A) Will settle to form putrescent or otherwise objectionable deposits.
(B) Are in amounts sufficient to be unsightly or deleterious.
(C) Produce color, visible oil sheen, odor, or other conditions in such degree as to create a nuisance.
(D) Are in concentrations or combinations that will cause or contribute to the growth of aquatic plants or algae to such degree as to create a nuisance, be unsightly, or otherwise impair the designated uses.
(E) Are in amounts sufficient to be acutely toxic to, or to otherwise severely injure or kill aquatic life, other animals, plants, or humans. To assure protection of aquatic life, the waters shall meet the following requirements:
(i) Concentrations of toxic substances shall not exceed the CMC outside the zone of initial dilution or the final acute value (FAV = 2 (CMC)) in the undiluted discharge unless, for a discharge to a receiving stream or Lake Michigan, an alternate mixing zone demonstration is conducted and approved in accordance with 327 IAC 5-2-11.4(b)(4), in which case, the CMC shall be met outside the discharge-induced mixing zone:

(2) At all times, all waters outside of the applicable mixing zones determined in accordance with 327 IAC 5-2-11.4(c) through 327 IAC 5-2-11.4(f) shall be free of substances in concentrations, that, on the basis of available scientific data, are believed to be sufficient to injure, be chronically toxic to, or be carcinogenic, mutagenic...

Iowa

SOURCE: Iowa Administrative Code, Environmental Protection Rule 567, Chapter 61, Water Quality Standards, October 18, 2000:
http://www.state.ia.us/government/dnr/organiza/epd/prgrmdsc/wtrqual/spqual.htm
http://www.state.ia.us/epd/prgrmdsc/wtrqual/sum.htm and
http://www.state.ia.us/dnr/organiza/epd/wtrq/wtrqbor.htm

Class "B" Waters: Waters which are designated as Class "B" are to be protected for wildlife, fish, aquatic and semi-aquatic life and secondary contact water uses. Class "B" waters are divided into the following categories:

- Class "B" (CW) (cold water aquatic life): streams or lakes that support trout and associated aquatic communities
- Class "B" (WW) (significant resource warm water): lakes or rivers which support warm water game fish and associated aquatic communities, including sensitive species
- Class "B" (LR) (limited resource warm water): streams which support limited aquatic life populations primarily composed of minnows and other nongame fish species
- Class "B" (LW) (lakes and wetlands): artificial impoundments and natural lakes with lake-like conditions that support warm water game fish and associated aquatic communities

High Quality (HQ) waters: Waters with exceptionally better quality than specified by Iowa water quality criteria and with exceptional recreational and ecological importance. Special protection is warranted to maintain the unusual, unique or outstanding physical, chemical, or biological characteristics that these waters possess.

High Quality Resource (HQR) waters: Waters of substantial recreational or ecological significance that possess unusual, outstanding or unique physical, chemical or biological characteristics that enhance the beneficial uses and warrant special protection.

Kansas

SOURCE: Kansas Register, Notice/Regulations, Administrative Regulations, Kansas Department of Health and Environment, Water Pollution Control, Chapter 28-1, Volume 20, Number 33, August 16, 2001:

http://www.kdhe.state.ks.us/water/index.html#Proposed%20Regulations%20and%20 and
http://www.kdhe.state.ks.us/environment/qmp_2000/SBMP_QAMP.pdf

Article 16. Surface Water Quality Standards

28-16-28b. Definitions.

(h) ''Bioassessment methods and procedures'' means the use of biological methods of assessing surface water quality including, but not limited to, field investigations of aquatic organisms and laboratory or field aquatic toxicity tests.

(k) ''Biota'' means the animal and plant life of a given geographical region.

(v) ''Ecological integrity'' means the natural or unimpaired structure and functioning of an aquatic or terrestrial ecosystem.

(oo) ''Outstanding natural resource water'' means any of the surface waters or surface water segments of exceptional recreational or ecological significance identified in the surface water register, as defined in K.A.R. 28-16-28b(uu), and afforded the highest level of water quality protection under the antidegradation provisions of K.A.R. 28-16-28c(a) and the mixing zone provisions of K.A.R. 28-16-28c(b).

(ddd) ''Surface waters'' means all of the following:

(1) Streams, including rivers, creeks, brooks, sloughs, draws, arroyos, canals, springs, seeps, and cavern streams, and any alluvial aquifers associated with these surface waters;

(2) lakes, including oxbow lakes and other natural lakes and man-made reservoirs, lakes, and ponds; and

(3) wetlands, including water bodies meeting the technical definition for jurisdictional wetlands given in the corps of engineers wetlands delineation manual,'' as published in January 1987, which is hereby adopted by reference.

28-16-28d. Surface water use designation and classification.

(a) Designated uses of surface waters are defined as follows.

(2) ''Aquatic life support use'' means the use of surface water for the maintenance of the ecological integrity of streams, lakes and wetlands, including the sustained growth and propagation of native aquatic life, indigenous or migratory semi-aquatic life, or terrestrial wildlife directly or indirectly dependent on surface water for survival.

(A) ''Special aquatic life use waters'' means either surface waters that contain combinations of habitat types and indigenous biota not found commonly in the state or surface waters that contain representative populations of threatened or endangered species.

(B) ''Expected aquatic life use waters'' means surface waters containing habitat types and indigenous biota commonly found or expected in the state.

(C) ''Restricted aquatic life use waters'' means surface waters containing indigenous biota limited in abundance diversity by the physical quality or availability of habitat, due to natural deficiencies or artificial modifications, compared to more suitable habitats in adjacent waters.

28-16-28e. Surface water quality criteria.

(a) Criteria development guidance. The development of surface water quality criteria for substances not listed in these standards shall be guided by water quality criteria published by the United States environmental protection agency. If the department finds that the criteria listed in this regulation are underprotective or overprotective for given surface water segment, appropriate site-specific criteria may be developed and applied by the department, in accordance with K.A.R. 28-16-28f(f), using bioassessment methods or other related scientific procedures...

(c) Criteria for designated uses of surface waters. The numeric criteria in tables 1a, 1b, 1c, 1d, and 1e shall not apply if the critical low flow is less than 0.03 cubic meters per second for waters designated as expected aquatic life use waters and restricted aquatic life use waters, unless studies conducted or approved by the department show that water present during periods of no flow, or flow below critical low flow, provides important refuges for aquatic life and permits biological recolonization of intermittently flowing segments. The numeric criteria in tables 1a, 1b, 1c, 1d, and 1e shall not apply if the critical low flow is less than 0.003 cubic meters per second for waters designated as special aquatic life use waters, unless studies conducted or approved by the department show that water present during periods of no flow, or flow below critical low flow, provides important refuges for aquatic life and permits biological recolonization of intermittently flowing segments. The following critieria shall apply to all classified surface waters for the indicated designated uses.

Kentucky

SOURCE: Title 401, Chapter 5, Kentucky Administrative Regulations (KAR), effective December 8, 1999: http://www.lrc.state.ky.us/kar/401/005/026.htm

401 KAR 5:002. Definitions for 401 KAR Chapter 5.

Section 1. Definitions.

(8) "Adversely affect" or "adversely change" means, for purposes of 401 KAR 5:026 through 5:031, to alter or change the community structure or function, to reduce the number or proportion of sensitive species, or to increase the number or proportion of pollution tolerant aquatic species so that aquatic life use support or aquatic habitat is impaired.

(54) "Cold water aquatic habitat" or "CAH" means surface waters and associated substrate that will support indigenous aquatic life or self-sustaining or reproducing trout populations on a year-round basis.

(124) "Impairment" means, for the purpose of 401 KAR 5:026 through 5:031, a detrimental impact to a surface water that prevents attainment of a designated use.

(127) "Indigenous aquatic life" means naturally occurring aquatic organisms including but not limited to bacteria, fungi, algae, aquatic insects, other aquatic invertebrates, reptiles, amphibians, and fishes. Under some natural conditions one (1) or more of the above groups may be absent from a surface water.

(233) "Productive aquatic community" means an assemblage of indigenous aquatic life capable of reproduction and growth.

(236) "Propagation" means the continuance of a species by successful spawning, hatching, and development or natural generation in the natural environment, as opposed to the maintenance of the species by artificial culture and stocking.

(250) "Representative important species" means species which are representative, in terms of their biological needs, of a balanced, indigenous community of shellfish, fish, and wildlife in the body of water into which a discharge of heat is made.

(317) "Warm water aquatic habitat" or "WAH" means any surface water and associated substrate capable of supporting indigenous warm water aquatic life.

401 KAR 5:026.Designation of uses of surface waters.

Section 1. Scope of Designation.

(2) Designated uses are:
- (a) Warm water aquatic habitat;
- (b) Cold water aquatic habitat;
- (f) Outstanding state resource water.

(4) Outstanding state resource waters may have unique water quality characteristics that shall be protected by additional criteria established in 401 KAR 5:031, Section 7.

401 KAR 5:029.General provisions.

Section 3. Documentation for Redesignations.

(3) Documentation to support the redesignation of a surface water of the Commonwealth shall be:
- (g) An assessment of the existing and potential aquatic life habitat in the surface waters under consideration and the adjacent upstream surface waters. The existing aquatic life shall be

documented and livestock and natural wildlife dependence on the surface water shall be assessed. The occurrence of individuals or populations, indices of diversity and well-being, and abundance of species of any unique native biota shall be documented;

<u>401 KAR 5:030. Antidegradation policy implementation methodology.</u>

Section 1. Implementation of Antidegradation Policy..

(1) Categorization. Surface waters shall be placed into one (1) of three (3) categories:
- (a) Outstanding national resource waters:
- (b) Exceptional waters:
  1. Surface water designated as a Kentucky Wild River, unless it is categorized as an outstanding national resource water;
  2. Outstanding state resource water that does not support a federally threatened or endangered aquatic species;
  3. Surface water that fully supports all applicable designated uses and contains:
     a. A fish community that is rated "excellent" by the use of the Index of Biotic Integrity included in "Methods for Assessing Biological Integrity of Surface Waters", incorporated by reference in Section 4 of this administration regulation; or
     b. A macroinvertebrate community that is rated "excellent" by the Macroinvertebrate Bioassessment Index included in "A Macroinvertebrate Bioassessment Index for Streams of the Interior Plateau Ecoregion in Kentucky", incorporated by reference in Section 4 of this administrative regulation; and
  4. Water in the cabinet's reference reach network.

<u>401 KAR 5:031.Surface water standards.</u>

Section 2. Minimum Criteria Applicable to All Surface Waters.

(1) The following minimum water quality criteria are applicable to all surface waters including mixing zones, with the exception that toxicity to aquatic life in mixing zones shall be subject to the provisions of 401 KAR 5:029, Section 4. Surface waters shall not be aesthetically or otherwise degraded by substances that:
- (d) Injure, are chronically or acutely toxic to or produce adverse physiological or behavioral responses in humans, animals, fish and other aquatic life;
- (e) Produce undesirable aquatic life or result in the dominance of nuisance species;

Section 4. Aquatic Life.

(1) Warm water aquatic habitat. The following parameters and associated criteria shall apply for the protection of productive warm water aquatic communities, fowl, animal wildlife, arboreous growth, agricultural, and industrial uses:
- (a) Natural alkalinity as $CaCO_3$ shall not be reduced by more than twenty-five (25) percent. If natural alkalinity is below twenty (20) mg/l $CaCO_3$, there shall not be a reduction below the natural level. Alkalinity shall not be reduced or increased to a degree which may adversely affect the aquatic community.
- (c) Flow shall not be altered to a degree which will adversely affect the aquatic community.
- (d) Temperature shall not exceed thirty-one and seven-tenths (31.7) degrees Celsius (eighty-nine (89) degrees Fahrenheit).
  2. The cabinet may determine allowable surface water temperatures on a site-specific basis utilizing available data which shall be based on the effects of temperature on the aquatic biota which utilize specific surface waters of the Commonwealth and which may be affected by person-induced temperature changes. Effects on downstream uses will also be considered in determining site-specific temperatures...
  3. A successful demonstration concerning thermal discharge limits carried out under Section 316(a) of the Clean Water Act shall constitute compliance with the temperature requirements of this subsection. A successful demonstration assures the protection and propagation of a balanced indigenous population of shellfish, fish and wildlife in or on the water into which the discharge is made.
- (f) Solids.
  1. Total dissolved solids. Total dissolved solids shall not be changed to the extent that the indigenous aquatic community is adversely affected.
  2. Total suspended solids. Total suspended solids shall not be changed to the extent that the

indigenous aquatic community is adversely affected.

3. Settleable solids. The addition of settleable solids that may alter the stream bottom so as to adversely affect productive aquatic communities is prohibited.

Louisiana

SOURCE: Louisiana Administrative Code, Title 33: Environmental Regulatory Code, Part IX, Water Quality, March 20, 2001: http://www.deq.state.la.us/planning/regs/title33/33v09.pdf

Chapter 11. Surface Water Quality Standards

§1101. Introduction

A. The purpose of this Chapter is to establish surface water quality standards which will:
   1. provide for the protection and preservation of the abundant natural resources of Louisiana's many and varied aquatic ecosystems;

§1105. Definitions

Biological and Aquatic Community Integrity—the condition of the aquatic community inhabiting a specified habitat as measured by community structure and function.

Biological Succession—the gradual and orderly process of ecosystem or community development brought about by changes in species populations that culminates in the production of a climax characteristic of a particular geographic region.

Fresh Warmwater Biota—those aquatic life species whose populations typically inhabit waters with warm temperatures (seasonal averages above 20 o C, 68 o F) and low salinities (less
than 2 parts per thousand,‰), including but not limited to, black basses and freshwater sunfish and catfish and characteristic freshwater aquatic invertebrates and wildlife.

Marine Water Biota—those aquatic life species whose populations typically inhabit waters with salinities equal to or greater than 2 parts per thousand (‰) including but not limited to characteristic fishes, invertebrates and wildlife of coastal waters and the Gulf of Mexico.

§1109. Policy

B. Water Use
   1. It is the policy of the state of Louisiana that all state waters should be protected for recreational uses and for the preservation and propagation of desirable species of aquatic biota and indigenous species of wildlife...
   2. In applying this policy, the terms "recreational uses" and "desirable species of aquatic biota" will be given common sense applications. Recreational uses will be classified as either "primary contact" or "secondary contact." "Desirable species of aquatic biota" refers to a diverse and naturally occurring range of aquatic biota and not to species that exist in the area in question in disproportionate numbers as a result of wastewater discharges. Desirable species of fish, shellfish and other invertebrates, wildlife, and other aquatic biota will be specified as "fresh warmwater" or "marine water" species. All future designations of water uses and their associated criteria must, at a minimum, adhere to these classifications, except as provided in LAC 33:IX.1109.B.3 and C. will be viewed as a problem to be solved, not as an impediment to categorizing water bodies or assigning designated uses...

§1111. Water Use Designations

C. Fish and Wildlife Propagation. Fish and wildlife propagation includes the use of water for aquatic habitat, food, resting, reproduction, cover, and/or travel corridors for any indigenous wildlife and aquatic life species associated with the aquatic environment. This use also includes the maintenance of water quality at a level that prevents damage to indigenous wildlife and aquatic life species associated with the aquatic environment and contamination of aquatic biota consumed by humans. The subcategory of "limited aquatic life and wildlife use" recognizes the natural variability of aquatic habitats, community requirements, and local environmental conditions. Limited aquatic life and wildlife use may be designated for water bodies having habitat that is uniform in structure and morphology with most of the regionally expected aquatic species absent, low species diversity and richness, and/or a severely imbalanced trophic structure. Aquatic life able to survive and/or propagate in such water bodies include species tolerant of severe or variable environmental conditions. Water bodies that might qualify for the limited aquatic life and wildlife use subcategory include intermittent streams and man-made water bodies with characteristics including, but not limited to, irreversible hydrologic modification, anthropogenically and irreversibly degraded water quality, uniform channel morphology, lack of channel structure, uniform substrate, lack of riparian structure, and similar characteristics making the available habitat for aquatic life and wildlife suboptimal. Limited aquatic life and wildlife use will be denoted in Table 3 (LAC 33:IX.1123) as an "L."

E. Oyster Propagation. Oyster propagation is the use of water to maintain biological systems that support economically important species of oysters, clams, mussels, or other mollusks so that their productivity is preserved and the health of human consumers of these species is protected.
   This use shall apply only to those water bodies named in the Numerical Criteria and Designated Uses Table and not to their tributaries or distributaries unless so specified.

G. Outstanding Natural Resource Waters. Outstanding natural resource waters include water bodies designated for preservation, protection, reclamation, or enhancement of wilderness, aesthetic qualities, and ecological regimes, such as those designated under the Louisiana Natural and Scenic Rivers System or those designated by the department as waters of ecological significance. Characteristics of outstanding natural resource waters include, but are not limited to, highly diverse or unique instream and/or riparian habitat, high species diversity, balanced trophic structure, unique species, or similar qualities. This use designation applies only to the water bodies specifically identified in Table 3 (LAC 33:IX.1123) and not to their tributaries or distributaries unless so specified.

§1113. Criteria

B. General Criteria.
   12. Biological and Aquatic Community Integrity. The biological and community structure and function in state waters shall be maintained, protected, and restored except where not attainable and feasible as defined in LAC 33:IX.1109.B.3. This is the ideal condition of the aquatic community inhabiting the unimpaired water bodies of a specified habitat and region as measured by community structure and function. The biological integrity will be guided by the fish and wildlife propagation use designated for that particular water body. Fish and wildlife propagation uses are defined in LAC 33:IX.1111.C. The condition of these aquatic communities shall be determined from the measures of physical, chemical, and biological characteristics of each surface water body type, according to its designated use (LAC 33:IX.1123). Reference site conditions will represent naturally attainable conditions. These sites should be the least impacted and most representative of water body types. Such reference sites or segments of water bodies shall be those observed to support the greatest variety and abundance of aquatic life in the region as is expected to be or has been recorded during past surveys in natural settings essentially undisturbed by human impacts, development, or discharges. This condition shall be determined by consistent sampling and reliable measures of selected, indicative communities of animals and/or invertebrates as established by the department and may be used in conjunction with acceptable chemical, physical, and microbial water quality measurements and records as deemed for this purpose.

Maine

SOURCE: Title 38, Section 464, Maine Revised Statutes, 1999:
http://janus.state.me.us/legis/statutes/38/title38sec464.html and http://www.state.me.us/dep/blwq

38 MRSA Section 464. Classification of Maine waters:

1. **Findings; objectives; purpose.**...The Legislature declares that it is the State's objective to restore and maintain the chemical, physical and biological integrity of the State's waters and to preserve certain pristine state waters. The Legislature further declares that in order to achieve this objective the State's goals are:
   C. That water quality be sufficient to provide for the protection and propagation of fish, shellfish and wildlife and provide for recreation in and on the water.

4. **General provisions.** The classification system for surface waters established by this article shall be subject to the following provisions.
   F. The antidegradation policy of the State is governed by the following provisions.
      (1) ...Determinations of what constitutes an existing in-stream water use on a particular water body must be made on a case-by-case basis by the department. In making its determination of uses to be protected and maintained, the department shall consider designated uses for that water body and:
         (a) Aquatic, estuarine and marine life present in the water body;
         (b) Wildlife that utilize the water body;
         (c) Habitat, including significant wetlands, within a water body supporting existing populations of wildlife or aquatic, estuarine or marine life, or plant life that is maintained by the water body;
         (d) Any other evidence that, for divisions (a), (b) and (c), demonstrates their ecological significance because of their role or importance in the functioning of the ecosystem or their rarity and, for division (d), demonstrates its historical or social significance.
      (1-A) The department may only issue a waste discharge license pursuant to section 414-A, or approve a water quality certification pursuant to the United States Clean Water Act, Section 401, Public Law 92-500, as amended, when the department finds that:
         (a) The existing in-stream use involves use of the water body by a population of plant life, wildlife, or aquatic, estuarine or marine life, or as aquatic, estuarine, marine, wildlife, or plant habitat, and the applicant has demonstrated that the proposed activity would not have a significant impact on the existing use. For purpose of this division, significant impact means:
            (i) Impairing the viability of the existing population, including significant impairment to growth and reproduction or an alteration of the habitat which impairs viability of the existing population; or

         The department shall determine what constitutes a population of a particular species based upon the degree of geographic and reproductive isolation from other individuals of the same species.

6. **Implementation of biological water quality criteria.** The implementation of water quality criteria pertaining to the protection of the resident biological community shall be governed by the provisions of this subsection.
   A. At any time during the term of a valid wastewater discharge license that was issued prior to the effective date of this article, the board may modify that license in accordance with section 341-D, subsection 3 if the discharger is not in compliance with the water quality criteria pertaining to the protection of the resident biological community. When a discharge license is modified under this subsection, the board shall establish a reasonable schedule to bring the discharge into compliance with the water quality criteria pertaining to the protection of the resident biological community.
   B. When a discharge license is issued after the effective date of this article and before the effective date of the rules adopted pursuant to subsection 5, the department shall establish a reasonable schedule to bring the discharge into compliance with the water quality criteria pertaining to the protection of the resident biological community.

<u>38 MRSA § 465. Standards for classification of fresh surface waters</u>

The department shall have 4 standards for the classification of fresh surface waters which are not classified as great ponds.

1. Class AA waters. Class AA shall be the highest classification and shall be applied to waters which are outstanding natural resources and which should be preserved because of their ecological, social, scenic or recreational importance.
   A. Class AA waters shall be of such quality that they are suitable... as habitat for fish and other aquatic life. The habitat shall be characterized as free flowing and natural.
   B. The aquatic life, dissolved oxygen and bacteria content of Class AA waters shall be as naturally occurs.

2. Class A waters. Class A shall be the 2nd highest classification.
   A. Class A waters shall be of such quality that they are suitable...as habitat for fish and other aquatic life.

The habitat shall be characterized as natural.

B. ...The aquatic life and bacteria content of Class A waters shall be as naturally occurs.

3. Class B waters. Class B shall be the 3rd highest classification.
   A. Class B waters shall be of such quality that they are suitable... as habitat for fish and other aquatic life. The habitat shall be characterized as unimpaired.
   B. The dissolved oxygen content of Class B waters shall be not less than 7 parts per million or 75% of saturation, whichever is higher, except that for the period from October 1st to May 14th, in order to ensure spawning and egg incubation of indigenous fish species...
   C. Discharges to Class B waters shall not cause adverse impact to aquatic life in that the receiving waters shall be of sufficient quality to support all aquatic species indigenous to the receiving water without detrimental changes in the resident biological community.

4. Class C waters. Class C shall be the 4th highest classification.
   A. Class C waters shall be of such quality that they are suitable...as a habitat for fish and other aquatic life.
   B. The dissolved oxygen content of Class C water may be not less than 5 parts per million or 60% of saturation, whichever is higher, except that in identified salmonid spawning areas where water quality is sufficient to ensure spawning, egg incubation and survival of early life stages, that water quality sufficient for these purposes must be maintained...
   C. Discharges to Class C waters may cause some changes to aquatic life, provided that the receiving waters shall be of sufficient quality to support all species of fish indigenous to the receiving waters and maintain the structure and function of the resident biological community.

38 MRSA § 466. Definitions: http://janus.state.me.us/legis/statutes/38/title38sec466.html

1. **Aquatic life.** "Aquatic life" means any plants or animals which live at least part of their life cycle in fresh water.

2. **As naturally occurs.** "As naturally occurs" means conditions with essentially the same physical, chemical and biological characteristics as found in situations with similar habitats free of measurable effects of human activity.

3. **Community function.** "Community function" means mechanisms of uptake, storage and transfer of life-sustaining materials available to a biological community which determines the efficiency of use and the amount of export of the materials from the community.

4. **Community structure.** "Community structure" means the organization of a biological community based on numbers of individuals within different taxonomic groups and the proportion each taxonomic group represents of the total community.

10. **Resident biological community.** "Resident biological community" means aquatic life expected to exist in a habitat which is free from the influence of the discharge of any pollutant. This shall be established by accepted biomonitoring techniques.

11. **Unimpaired.** "Unimpaired" means without a diminished capacity to support aquatic life.

12. **Without detrimental changes in the resident biological community.** "Without detrimental changes in the resident biological community" means no significant loss of species or excessive dominance by any species or group of species attributable to human activity.

Maryland

SOURCE: Code of Maryland Regulations, Title 26, Department of the Environment, Subtitle 08 Water Pollution, Subpart 26.0.02, November 6, 1995: COMAR 26.08.02.01, Surface Water Quality Protection and 26.08.02.02, Designated Uses: https://constmail.gov.state.md.us/comar/26/26.08.02.01.htm and https://constmail.gov.state.md.us/comar/26/26.08.02.02.htm

.01 Surface Water Quality Protection

A. Purpose. To protect surface water quality, this State shall adopt water quality standards to:
   (1) Protect public health or welfare;
   (2) Enhance the quality of water;
   (3) Protect aquatic resources; and
   (4) Serve the purposes of the Federal Act.

B. Water Quality Standards.
   (2) Water quality standards shall, wherever attainable, provide water quality for the designated uses of:
      (b) Fishing;
      (c) Propagation of fish, other aquatic life, and wildlife...

.02 Designated Uses

A. General.
   (1) Waters of this State shall, wherever attainable, be protected for the basic uses of water contact recreation, fishing, protection of aquatic life and wildlife, and agricultural and industrial water supply as identified in Use I.

B. Specific Designated Uses.
   (1) Use I: Water Contact Recreation, and Protection of Aquatic Life. This use designation includes waters which are suitable for:
      (c) Fishing;
      (d) The growth and propagation of fish (other than trout), other aquatic life, and wildlife;

   (2) Use I-P: Water Contact Recreation, Protection of Aquatic Life, and Public Water Supply. This use designation includes:
      (a) All uses identified for Use I....

   (3) Use II: Shellfish Harvesting Waters. This use designation includes waters where:
      (a) Shellfish are propagated, stored, or gathered for marketing purposes; and
      (b) There are actual or potential areas for the harvesting of oysters, softshell clams, hardshell clams, and brackish water clams.

   (4) Use III: Natural Trout Waters. This use designation includes waters which have the potential for or are:
      (a) Suitable for the growth and propagation of trout; and
      (b) Capable of supporting self-sustaining trout populations and their associated food organisms.

   (5) Use III-P: Natural Trout Waters and Public Water Supply. This use designation includes:
      (a) All uses identified for Use III waters; and...

   (6) Use IV: Recreational Trout Waters. This use designation includes cold or warm waters which have the potential for or are:
      (a) Capable of holding or supporting adult trout for put-and-take fishing; and
      (b) Managed as a special fishery by periodic stocking and seasonal catching.

   (7) Use IV-P: Recreational Trout Waters and Public Water Supply. This use designation includes:
      (a) All uses identified for Use IV waters; and...

Massachusetts

SOURCE: 314 CMR 4.00: Massachusetts Surface Water Quality Standards, effective May 12, 2000: http://www.state.ma.us/dep/bwp/iww/files/314cmr4.htm

4.02: Definitions

Aquatic Life - A native, naturally diverse, community of aquatic flora and fauna.

Cold Water Fishery - Waters in which the maximum mean monthly temperature generally does not exceed 68°F (20°C) and, when other ecological factors are favorable (such as habitat), are capable of supporting a year-round population of cold water stenothermal aquatic life such as trout (*salmonidae*).

Vernal Pool - A waterbody that has been certified by the Massachusetts Division of Fisheries and Wildlife as a vernal pool.

Warm Water Fishery - Waters in which the maximum mean monthly temperature generally exceeds 68°F (20°C) during the summer months and are not capable of sustaining a year-round population of cold water stenothermal aquatic life.

4.05 Classes and Criteria

(3) Inland Water Classes:

(a) Class A - These waters are designated as a source of public water supply. To the extent compatible with this use they shall be an excellent habitat for fish, other aquatic life and wildlife, and suitable for primary secondary contact recreation. These waters shall have excellent aesthetic value. These waters are designated for protection as Outstanding Resource Waters under 314 CMR 4.04(3).

1. Dissolved Oxygen -
   a. Shall not be less than six mg/l unless background conditions are lower;
   b. natural seasonal and daily variations above this level shall be maintained; levels shall not be lowered below 75% of saturation due to a discharge; and
   c. site-specific criteria may apply where back-ground levels are lower than specified levels or to the hypolimnion of stratified lakes where the Department determines that designated uses are not impaired.

2. Temperature -
   a. Shall not exceed 68°F (20°C) in cold water fisheries, nor 83°F (28.3°C) in warm water fisheries, and the rise in temperature due to a discharge shall not exceed 1.5°F (0.8°C); and
   b. natural seasonal and daily variations shall be maintained. There shall be no changes from background conditions that would impair any use assigned to this Class, including site-specific limits necessary to protect normal species diversity, successful migration, reproductive functions or growth of aquatic organisms.

5. Solids - These waters shall be free from floating, suspended and settleable solids in concentrations or combinations that would impair any use assigned to this class, that would cause aesthetically objectionable conditions, or that would impair the benthic biota or degrade the chemical composition of the bottom.

(b) Class B - These waters are designated as a habitat for fish, other aquatic life, and wildlife, and for primary and secondary contact recreation. Where designated they shall be suitable as a source of public water supply with appropriate treatment. They shall be suitable for irrigation and other agricultural uses and for compatible industrial cooling and process uses. These waters shall have consistently good aesthetic value.

1. Dissolved Oxygen
   a. Shall not be less than 6.0 mg/l in cold water fisheries nor less than 5.0 mg/l in warm water fisheries unless background conditions are lower;
   b. natural seasonal and daily variations above these levels shall be maintained; levels shall not be lowered below 75% of saturation in cold water fisheries nor 60% of saturation in warm water fisheries due to a discharge; and
   c. site-specific criteria may apply where background levels are lower than specified levels, to the hypolimnion of stratified lakes or where the Department determines that designated uses are not impaired.

2. Temperature -
   a. Shall not exceed 68°F (20°C) in cold water fisheries nor 83°F (28.3°C) in warm water fisheries, and the rise in temperature due to a discharge shall not exceed 3°F (1.7°C) in rivers and streams designated as cold water fisheries nor 5°F (2.8°C) in rivers and streams designated as warm water fisheries (based on the minimum expected flow for the month); in lakes and ponds the rise shall not exceed 3°F (1.7°C) in the epilimnion (based on the monthly average of maximum daily temperature); and
   b. natural seasonal and daily variations shall be maintained. There shall be no changes from

background conditions that would impair any use assigned to this Class, including site-specific limits necessary to protect normal species diversity, successful migration, reproductive functions or growth of aquatic organisms.

5. Solids - These waters shall be free from floating, suspended and settleable solids in concentrations and combinations that would impair any use assigned to this Class, that would cause aesthetically objectionable conditions, or that would impair the benthic biota or degrade the chemical composition of the bottom.

(c) Class C - These waters are designated as a habitat for fish, other aquatic life and wildlife, and for secondary contact recreation. These waters shall be suitable for the irrigation of crops used for consumption after cooking and for compatible industrial cooling and process uses. These waters shall have good aesthetic value.

1. Dissolved Oxygen -
   a. Shall not be less than 5.0 mg/l at least 16 hours of any 24-hour period and not less than 3.0 mg/l at any time unless background conditions are lower;
   b. natural seasonal and daily variations above these levels shall be maintained; levels shall not be lowered below 50% of saturation due to a discharge; and (c) site-specific criteria may apply where background levels are lower than specified levels, or to the hypolimnion of stratified lakes where the Department determines that designated uses are not impaired.
2. Temperature -
   a. Shall not exceed 85˚F (29.4˚C) nor shall the rise due to a discharge exceed 5F (2.8˚C); and
   b. Natural seasonal and daily variations shall be maintained. There shall be no changes from background conditions that would impair any use assigned to this Class, including the site-specific limits necessary to protect normal species diversity, successful migration, reproductive functions or growth of aquatic organisms.
5. Solids - These waters shall be free from floating, suspended and settleable solids in concentrations and combinations that would impair any use assigned to this Class, that would cause aesthetically objectionable conditions, or that would impair the benthic biota or degrade the chemical composition of the bottom.

Michigan*

*This language has not been reviewed for accuracy by state/tribal agency.

SOURCE: Department of Environmental Quality Environmental Response Division General Rules, Part 4. Water Quality Standards: http://www.deq.state.mi.us/documents/deq-swq-gleas-305b2002AppI.doc

R 323.1043 Definitions; A to L

Rule 43

(b) "Acceptable wildlife endpoints" means subchronic and chronic endpoints that affect reproductive or developmental success, organismal viability, or growth or any other endpoint that is, or is directly related to, a parameter that influences population dynamics.

(d) "Adverse effect" means any deleterious effect to organisms due to exposure to a substance. The term includes effects that are or may become debilitating, harmful, or toxic to the normal functions of the organism. The term does not include nonharmful effects such as tissue discoloration alone or the induction of enzymes involved in the metabolism of the substance.

(f) "Anadromous salmonids" means trout and salmon that ascend streams to spawn.

(r) "Coldwater fishery" means waterbodies that contain fish species which thrive in relatively cold water, including any of the following:
   (i) Trout.
   (ii) Salmon.
   (iii) Whitefish.
   (iv) Cisco.

(x) "Designated use" means a use of the surface waters of the state as established by these rules, including use for any of the following:
   (i) Industrial, agricultural, and public water supply.
   (ii) Recreation.

(iii) Warmwater and coldwater fisheries, other aquatic life, and wildlife.
(iv) Navigation.

(hh) "Fisheries, other aquatic life, and wildlife use" means the use of the surface waters of the state by fish, other aquatic life, and wildlife for any life history stage or activity and the protection of fish for human consumption.

R 323.1044 Definitions; M to W.
Rule 44.

(c) "Natural water temperature" means the temperature of a body of water without an influence from an artificial source or a temperature as otherwise determined by the department.

(dd) "Warmwater fishery" means a waterbody that contains fish species which thrive in relatively warm water, including any of the following:
(i) Bass.
(ii) Pike.
(iii) Walleye.
(iv) Panfish.

Minnesota

SOURCE: Minnesota Rules, Chapter 7050, Minnesota Pollution Control Agency Waters of the State, October 11, 2000: http://www.revisor.leg.state.mn.us/arule/7050/

7050.0150 Determination of Water Quality Condition and Compliance,
The intent of the state is to protect and maintain surface waters in a condition which allows for the maintenance of all existing beneficial uses. The condition of a surface water body is determined by its physical, chemical, and biological qualities.

The biological quality of any given surface water body shall be assessed by comparison to the biological integrity of a reference condition or conditions which best represents the most natural condition for that surface water body type within a geographic region. The biological quality shall be determined by reliable measures of indicative communities of fauna and flora.

7050.0200 Water Use Classifications for Waters of the State:
Subpart. 3. Class 2 waters, aquatic life and recreation. Aquatic life and recreation includes all waters of the state which do or may support fish, other aquatic life, bathing, boating, or other recreational purposes, and where quality control is or may be necessary to protect aquatic or terrestrial life or their habitats, or the public health, safety, or welfare.

Subp. 5. Class 4 waters, agriculture and wildlife. Agriculture and wildlife includes all waters of the state which are or may be used for any agriculture purposes, including stock watering and irrigation, or by waterfowl or other wildlife, and for which quality control is or may be necessary to protect terrestrial life and its habitat or the public health, safety, or welfare.

Subp. 8. Class 7 waters, limited resource value waters. Limited resource value waters include surface waters of the state which have been subject to a use attainability analysis and have been found to have limited value as a water resource... The agency, in cooperation and agreement with the Department of Natural Resources with respect to determination of fisheries values and potential, shall use this information to determine the extent to which the waters of the state demonstrate:

A. the existing and potential faunal and floral communities are severely limited by natural conditions as exhibited by poor water quality characteristics, lack of habitat, or lack of water; or
B. the quality of the resource has been significantly altered by human activity and the effect is essentially irreversible; and
C. there are limited recreational opportunities (such as fishing, swimming, wading, or boating) in and on the water resource...

7050.0222 SPECIFIC STANDARDS OF QUALITY AND PURITY FOR CLASS 2 WATERS OF THE STATE; AQUATIC LIFE AND RECREATION.

Subp. 2. Class 2A waters; aquatic life and recreation. The quality of Class 2A surface waters shall be such as to permit the propagation and maintenance of a healthy community of cold water sport or commercial fish and associated aquatic life, and their habitats. These waters shall be suitable for aquatic recreation of all kinds, including bathing, for which the waters may be usable. This class of surface waters is also protected as a source of drinking water...

Subp. 3. Class 2Bd waters. The quality of Class 2Bd surface waters shall be such as to permit the propagation and maintenance of a healthy community of cool or warm water sport or commercial fish and associated aquatic life and their habitats. These waters shall be suitable for aquatic recreation of all kinds, including bathing, for which the waters may be usable. This class of surface waters are also protected as a source of drinking water...

Subp. 4. Class 2B waters. The quality of Class 2B surface waters shall be such as to permit the propagation and maintenance of a healthy community of cool or warm water sport or commercial fish and associated aquatic life, and their habitats. These waters shall be suitable for aquatic recreation of all kinds, including bathing, for which the waters may be usable. This class of surface water is not protected as a source of drinking water...

Subp. 5. Class 2C waters. The quality of Class 2C surface waters shall be such as to permit the propagation and maintenance of a healthy community of indigenous fish and associated aquatic life, and their habitats. These waters shall be suitable for boating and other forms of aquatic recreation for which the waters may be usable...

Subp. 6. Class 2D waters. The quality of Class 2D wetlands shall be such as to permit the propagation and maintenance of a healthy community of aquatic and terrestrial species indigenous to wetlands, and their habitats. Wetlands also add to the biological diversity of the landscape. These waters shall be suitable for boating and other forms of aquatic recreation for which the wetland may be usable...

Mississippi

SOURCE: State of Mississippi Water Quality Criteria for Intrastate, Interstate and Coastal Waters, Adopted November 16, 1995: http://www.deq.state.ms.us/newweb/opchome.nsf/pages/SurfaceWaterfiles/$file/wqc.pdf

SECTION III. SPECIFIC WATER QUALITY CRITERIA

4. FISH AND WILDLIFE:
Waters in this classification are intended for fishing and for propagation of fish, aquatic life, and wildlife. Waters that meet the Fish and Wildlife Criteria shall also be suitable for secondary contact recreation. Secondary contact recreation is defined as incidental contact with the water, including wading and occasional swimming.

5. EPHEMERAL STREAM:
Waters in this classification do not support a fisheries resource and are not usable for human consumption or aquatic life. Ephemeral streams normally are natural watercourses, including natural watercourses that have been modified by channelization or manmade drainage ditches, that without the influent of point source discharges flow only in direct response to precipitation or irrigation return-water discharge in the immediate vicinity and whose channels are normally above the groundwater table. These streams may contain a transient population of aquatic life during the portion of the year when there is suitable habitat for fish survival. Normally, aquatic habitat in these streams is not adequate to support a reproductive cycle for fish and other aquatic life. Wetlands are excluded from this classification.

Waters in this classification shall be protective of wildlife and humans which may come in contact with the waters. Waters contained in ephemeral streams shall also allow maintenance of the standards applicable to all downstream waters.

Missouri

SOURCE: Missouri Rules of Department of Natural Resources Division 20—Clean Water Commission Chapter 7—Water Quality, August 31, 2000:
http://www.epa.gov/waterscience/standards/wqslibrary/mo/mo_7_wqs.pdf;
http://mosl.sos.state.mo.us/csr/10csr/10c20-7a.pdf and www.dnr.state.mo.us/water

10 CSR 20-7.031 Water Quality Standards:

(1) Definitions.

(C) Beneficial water uses...

2. Livestock and wildlife watering—Maintenance of conditions to support health in livestock and wildlife.
3. Cold-water fishery—Waters in which naturally occurring water quality and habitat conditions allow the maintenance of a naturally reproducing or stocked trout fishery and other naturally reproducing populations of recreationally important fish species.
4. Cool-water fishery—Waters in which naturally occurring water quality and habitat conditions allow the maintenance of a sensitive, high-quality sport fishery (including smallmouth bass and rock bass) and other naturally reproducing populations of recreationally important fish species.
5. Protection of aquatic life (General warm-water fishery)—Waters in which naturally occurring water quality and habitat conditions allow the maintenance of a wide variety of warm-water biota, including naturally reproducing populations of recreationally important fish species...
6. Protection of aquatic life (Limited warm-water fishery)—Waters in which natural water quality and/or habitat conditions prevent the maintenance of naturally reproducing populations of recreationally important fish species.
13. Habitat for resident and migratory wildlife species, including rare and endangered species—Waters that provide essential breeding, nesting, feeding and predator escape habitats for wildlife including water-fowl, birds, mammals, fish, amphibians and reptiles.

(D) Biocriteria—Numeric values or narrative expressions that describe the reference biological integrity of aquatic communities inhabiting waters that have been designated for aquatic-life protection.

(G) Ecoregion—A major region within the logical, hydrological, chemical and biological characteristics.

(O) Outstanding national resource waters—Waters which have outstanding national recreational and ecological significance.

(R) Reference stream reaches—Stream reaches determined by the department to be the best available representatives of ecoregion waters in a natural condition, with respect to habitat, water quality, biological integrity and diversity, watershed land use and riparian conditions.

(4) Specific Criteria

(Q) Biocriteria. The biological integrity of waters, as measured by lists or numeric diversity indices of benthic invertebrates, fish, algae or other appropriate biological indicators, shall not be significantly different from reference waters. Waters shall be compared with reference waters of similar size within an ecoregion.

Montana

SOURCE: Administrative Rules of Montana, Rule 17, Chapter 30, Water Quality, Subchapter 6, Surface Water Quality Standards and Procedures, June 30, 1996:
http://www.deq.state.mt.us/dir/Legal/Chapters/CH30-06.pdf and www.deq.state.mt.us

17.30.601 POLICY

(1) The following standards are adopted to conserve water by protecting, maintaining, and improving the quality and potability of water for public water supplies, wildlife, fish and aquatic life, agriculture, industry,

recreation, and other beneficial uses.

17.30.602 DEFINITIONS

(10)"Ephemeral stream" means a stream or part of a stream which flows only in direct response to precipitation in the immediate watershed or in response to the melting of a cover of snow and ice and whose channel bottom is always above the local water table.

(13)"Intermittent stream" means a stream or reach of a stream that is below the local water table for at least some part of the year, and obtains its flow from both surface runoff and groundwater discharge.

(17)"Naturally occurring" means conditions or material present from runoff or percolation over which man has no control or from developed land where all reasonable land, soil and water conservation practices have been applied. Conditions resulting from the reasonable operation of dams in existence as of July 1, 1971 are natural.

17.30.621 A-CLOSED CLASSIFICATION STANDARDS

(1) Waters classified A-Closed are suitable for drinking, culinary, and food processing purposes after simple disinfection. Water quality is suitable for swimming, recreation, growth, and propagation of fishes and associated aquatic life...

(3) No person may violate the following specific water quality standards for waters classified A-Closed:

(f) No increases are allowed above naturally occurring concentrations of sediment, settleable solids, oils, or floating solids, which will or are likely to create a nuisance or render the waters harmful, detrimental, or injurious to public health, recreation, safety, welfare, livestock, wild animals, birds, fish, or other wildlife.

17.30.622-17.30.627 CLASSIFICATION STANDARDS

A-1, B-1, B-2, B-3, C-1, and C-2 classification standards state that water quality must be suitable for...growth and propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers....[and other uses as assigned for each class]. [The following condition applies to these classifications:]

(3) No person may violate the following specific water quality standards for waters classified A-1:

(f) No increases are allowed above naturally occurring concentrations of sediment, settleable solids, oils, or floating solids, which will or are likely to create a nuisance or render the waters harmful, detrimental, or injurious to public health, recreation, safety, welfare, livestock, wild animals, birds, fish, or other wildlife.

17.30.628 I CLASSIFICATION STANDARDS

(1) The goal of the state of Montana is to have these waters fully support the following uses: drinking, culinary, and food processing purposes after conventional treatment; bathing, swimming, and recreation; growth and propagation of fishes and associated aquatic life, waterfowl, and furbearers; and agricultural and industrial water supply...

17.30.629 C-3 CLASSIFICATION STANDARDS

(1) Waters classified C-3 are suitable for bathing, swimming and recreation, growth and propagation of non-salmonid fishes and associated aquatic life, waterfowl and furbearers...

Nebraska

SOURCE: Title 117 - Nebraska Surface Water Quality Standards, Nebraska Department of Environmental Quality, Chapter 4: Standards for Water Quality, August 22, 2000: http://www.deq.state.ne.us/

001 It is the public policy of the State of Nebraska to protect and improve the quality of surface water for human consumption, wildlife, fish and other aquatic life, industry, recreation, and other productive, beneficial uses.

The beneficial uses defined by these standards are:

Aquatic Life

Coldwater (Class A and B)

Warmwater (Class A and B)

003.01G Biological Criteria. Any human activity causing water pollution which would significantly degrade the biological integrity of a body of water or significantly impact or displace an identified "key species" shall not be allowed except as specified in Chapter 2.

003.01G1 Key Species. Key species are identified endangered, threatened, sensitive, or recreationally-important aquatic species. Key species are designated by stream segment (Chapter 5). The following list defines the aquatic species considered by the Department to be key species.

COMMON NAME	SCIENTIFIC NAME
Endangered Species:	
Pallid sturgeon	*Scaphirhynchus albus*
Topeka shiner	*Notropis topeka*
Threatened Species:	
Lake sturgeon	*Acipenser fulvescens*
Northern redbelly dace	*Phoxinus eos*
Pearl dace	*Semotilus margarita*
Finescale dace	*Phoxinus neogaeus*
Blacknose shiner	*Notropis heterolepis*
Sensitive Species:	
Lake chub	*Couesius plumbeus*
Brook stickleback	*Culea inconstans*
Iowa darter	*Etheostoma exile*
Johnny darter	*Etheostoma nigrum*
Orangethroat darter	*Etheostoma spectabile*
Blacknose dace	*Rhinichthys atratulus*
Grass pickerel	*Esox americanus*
Pumpkinseed	*Lepomis gibbosus*
Golden shiner	*Notemigonus crysoleucas*
Common shiner	*Notropis cornutus*

COMMON NAME	SCIENTIFIC NAME
Recreationally-Important Species:	
Shovelnose sturgeon	*Scaphirhynchus platorynchus*
Paddlefish	*Polyodon spathula*
Brook trout	*Salvelinus fontinalis*
Brown trout	*Salmo trutta*
Rainbow trout	*Oncorhynchus mykiss*
Northern pike	*Esox lucius*
Muskellunge	*Esox masquinongy*
Blue catfish	*Ictalurus furcatus*
Channel catfish	*Ictalurus punctatus*
Flathead catfish	*Pylodictis olivaris*
Striped bass	*Morone saxatilis*
White bass	*Morone chrysops*
Rock bass	*Ambloplites rupestris*
Largemouth bass	*Micropterus salmoides*
Smallmouth bass	*Micropterus dolomieui*
Spotted bass	*Micropterus punctulatus*
Redear sunfish	*Lepomis microlophus*
Bluegill	*Lepomis macrochirus*
Black crappie	*Pomoxis nigromaculatus*
White crappie	*Pomoxis annularis*
Yellow perch	*Perca flavescens*
Sauger	*Stizostedion canadense*
Walleye	*Stizostedion vitreum vitreum*

[1] Endangered, threatened, and recreationally-important aquatic species are not included.

003.02 Site-Specific Criteria for Aquatic Life.

003.02A1 The following are acceptable conditions for developing site-specific criteria.

003.02A1a Resident species of a water body are more or less sensitive than those species used to develop a water quality criterion.

003.02A1a(1) Natural adaptive processes have enabled a viable, balanced aquatic community to exist in waters where natural background levels of a chemical exceed the criterion (e.g., resident species have evolved a genetically-based greater resistance to high concentrations of a chemical).

003.02A1a(2) The composition of aquatic species in a water body is different from those used in deriving a criterion (e.g., most of the species considered among the most sensitive, such as salmonids or the cladoceran, Daphnia magna, which were used in developing a criterion, are absent from a water body).

003.02A3 Site-specific criteria shall protect all life stages of resident species year-round (or seasonally for seasonally dependent criteria) and prevent acute and chronic toxicity in all parts of a water body...

Nevada

SOURCE: Nevada Administrative Code, Chapter 445A, Standards for Water Quality, September 2000: http://www.ndep.state.nv.us/nac/445a119.pdf

NAC 445A.119 Criteria for water quality for designated beneficial uses. The water quality criteria for designated beneficial uses for the various waters of the state are in the following table.

[NOTE: In this section of NV's standards, the table titled *Water Quality Criteria for Designated Beneficial Uses* includes Aquatic Life with the following levels: Warmwater: propagation and put and take and Coldwater:

propagation and put and take.]

NAC 445A.122 Standards applicable to beneficial uses.

1. The following standards are intended to protect both existing and designated beneficial uses and must not be used to prohibit the use of the water as authorized under Title 48 of NRS:
   (c) Aquatic life. The water must be suitable as a habitat for fish and other aquatic life existing in a body of water. This does not preclude the reestablishment of other fish or aquatic life.
   (h) Propagation of wildlife. The water must be suitable for the propagation of wildlife and waterfowl without treatment.
   (i) Waters of extraordinary ecological or aesthetic value. The unique ecological or aesthetic value of the water must be maintained.

NAC 445A.124 Class A waters: Description; beneficial uses; quality standards.

1. Class A waters include waters or portions of waters located in areas of little human habitation, no industrial development or intensive agriculture and where the watershed is relatively undisturbed by man's activity.
2. The beneficial uses of class A waters are... aquatic life, propagation of wildlife, irrigation, watering of livestock, recreation including contact with the water and recreation not involving contact with the water.

NAC 445A.125 Class B waters: Description; beneficial uses; quality standards.

1. Class B waters include waters or portions of waters which are located in areas of light or moderate human habitation, little industrial development, light-to-moderate agricultural development and where the watershed is only moderately influenced by man's activity.
2. The beneficial uses of class B water are ...aquatic life and propagation of wildlife, recreation involving contact with the water...

NAC 445A.126 Class C waters: Description; beneficial uses; quality standards.

1. Class C waters include waters or portions of waters which are located in areas of moderate-to-urban human habitation, where industrial development is present in moderate amounts, agricultural practices are intensive and where the watershed is considerably altered by man's activity.
2. The beneficial uses of class C water are ... aquatic life, propagation of wildlife...

NAC 445A.127 Class D waters: Description; beneficial uses; quality standards.

1. Class D waters include waters or portions of waters located in areas of urban development, highly industrialized or intensively used for agriculture or a combination of all the above and where effluent sources include a multiplicity of waste discharges from the highly altered watershed.
2. The beneficial uses of class D waters are ... aquatic life, propagation of wildlife...

New Hampshire

SOURCE: New Hampshire Code of Administrative Rules Chapter Env-Ws 1700 Surface Water Quality Regulations, December 10, 1999: http://www.des.state.nh.us/wmb/Env-Ws1700.pdf

PART Env-Ws 1702 DEFINITIONS

Env-Ws 1702.04 "Benthic community" mean the community of plants and animals that live on, over, or in the substrate of the surface water.

Env-Ws 1702.07 "Biological integrity" means the ability of an aquatic ecosystem to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of similar natural habitats of a region.

Env-Ws 1702.08 "Biota" means species of plants or animals occurring in surface waters.

PART Env-Ws 1703 WATER QUALITY STANDARDS

Env-Ws 1703.01 Water Use Classifications.
   (b) All surface waters shall be restored to meet the water quality criteria for their designated classification

including existing and designated uses, and to maintain the chemical, physical, and biological integrity of surface waters.

(c) All surface waters shall provide, wherever attainable, for the protection and propagation of fish, shellfish and wildlife, and for recreation in and on the surface waters.

Env-Ws 1703.19 Biological and Aquatic Community Integrity.

(a) The surface waters shall support and maintain a balanced, integrated, and adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of similar natural habitats of a region.

(b) Differences from naturally occurring conditions shall be limited to non-detrimental differences in community structure and function.

PART Env-Ws 1707 MIXING ZONES

Env-Ws 1707.02 Minimum Criteria. Mixing zones shall be subject to site specific criteria that, as a minimum:

(b) Do not interfere with biological communities or populations of indigenous species;

(f) Do not impinge upon spawning grounds and/or nursery areas of any indigenous aquatic species;

(g) Do not result in the mortality of any plants, animals, humans, or aquatic life within the mixing zone.

New Jersey

SOURCE: New Jersey Administrative Code 7:9-B (Chapter 9B. Surface Water Quality Standards), as amended May 18, 1998: http://www.state.nj.us/dep/watershedmgt/swqs/98swqs_web.pdf

7:9B-1.4 Definitions

"Anadromous fish" means fish that spend most of their life in saline waters and migrate to fresh waters to spawn.

"Aquatic substrata" means soil material and associated biota underlying the water.

"Biota" means the animal and plant life of an ecosystem; flora and fauna collectively.

"Diadromous fish" means fish that spend most of their life in one type of water, either fresh or saline, and migrate to the other type to spawn.

"FW1" means those fresh waters, as designated in N.J.A.C. 7:9B-1.15(h) Table 6, that are to be maintained in their natural state of quality (set aside for posterity) and not subjected to any man-made wastewater discharges or increases in runoff from anthropogenic activities. These waters are set aside for posterity because of their clarity, color, scenic setting, other characteristic of aesthetic value, unique ecological significance, exceptional recreational significance, exceptional water supply significance, or exceptional fisheries resource(s).

"FW2" means the general surface water classification applied to those fresh waters that are not designated as FW1 or Pinelands Waters.

"Important species" means species that are commercially valuable (for example, within the top 10 species landed, by dollar value); recreationally valuable; threatened or endangered; critical to the organization and/or maintenance of the ecosystem; or other species necessary in the food web for the well-being of the species identified in this definition.

"Measurable changes" means changes measured or determined by a biological, chemical, physical, or analytical method, conducted in accordance with USEPA approved methods as identified in 40 C.F.R. 136 or other analytical methods (for example, mathematical models, ecological indices) approved by the Department, that might adversely impact a water use (including, but not limited to, aesthetics).

"Natural water quality" means the water quality that would exist in a waterway or a waterbody without the addition of water or waterborne substances from artificial origin.

"Outstanding National Resource Waters" means high quality waters that constitute an outstanding national resource (for example, waters of National/State Parks and Wildlife Refuges and waters of exceptional recreational or ecological significance) as designated in N.J.A.C. 7:9B-1.15(i).

"SC" means the general surface water classification applied to coastal saline waters.

"SE" means the general surface water classification applied to saline waters of estuaries.

"Trout maintenance waters" means waters designated at N.J.A.C. 7:9B-1.15(b) through (g) for the support of trout throughout the year.

"Trout production waters" means waters designated at N.J.A.C. 7:9B-1.15(b) through (g) for use by trout for spawning or nursery purposes during their first summer.

7:9B-1.5 Statements of policy

(a) General policies are as follows:

2. Water is vital to life and comprises an invaluable natural resource which is not to be abused by any segment of the State's population or economy. It is the policy of the State to restore, maintain and enhance the chemical, physical and biological integrity of its waters, to protect the public health, to safeguard the aquatic biota, protect scenic and ecological values, and to enhance the domestic, municipal, recreational, industrial, agricultural and other reasonable uses of the State's waters.
3. Toxic substances in waters of the State shall not be at levels that are toxic to humans or the aquatic biota, or that bioaccumulate in the aquatic biota so as to render them unfit for human consumption.

(f) Bioassay and biomonitoring policies are as follows:

1. Bioassay test species selection criteria follow:
   i. The objective of the Department is to use test species for toxicity testing bioassays that are representative of the more sensitive aquatic biota from the different trophic levels of the waters in question.
   ii. Test species need not be indigenous to, nor occur in the waters in question.
   iii. When the bioassay test protocol being utilized falls under the scope of N.J.A.C. 7:18 the Department shall designate the approved representative species considered to be the most sensitive to the discharge.

2. Acute definitive bioassay tests, in accordance with N.J.A.C. 7:18, will normally be utilized in determining the toxicity of a discharge to the aquatic biota.
3. The Department, in order to further characterize the toxicity of a discharge, may allow or require the use of other procedures including, but not limited to:
   iii. Measures of the structure and function of the aquatic community in the receiving waters.

7:9B-1.12 Designated uses of FW1, PL, FW2, SE1, SE2, SE3, and SC waters

(a) In all FW1 waters the designated uses are:

1. Set aside for posterity to represent the natural aquatic environment and its associated biota;
3. Maintenance, migration and propagation of the natural and established aquatic biota...

(b) In all PL waters the designated uses are:

2. Maintenance, migration and propagation of the natural and established biota indigenous to this unique ecological system;...

(c) In all FW2 waters the designated uses are:

1. Maintenance, migration and propagation of the natural and established biota...

(d) In all SE1 waters the designated uses are:

2. Maintenance, migration and propagation of the natural and established biota....

(e) In all SE2 waters the designated uses are:

1. Maintenance, migration and propagation of the natural and established biota;
2. Migration of diadromous fish;
3. Maintenance of wildlife;...

(f) In all SE3 waters the designated uses are:
   2. Maintenance and migration of fish populations;
   3. Migration of diadromous fish;
   4. Maintenance of wildlife;...

(g) In all SC waters the designated uses are:
   1. Maintenance, migration and propagation of the natural and established biota;...

New Mexico

SOURCE: State of New Mexico Standards For Interstate And Intrastate Surface Waters, Title 20 Environmental Protection, Chapter 6 Water Quality, Standards For Interstate And Intrastate Surface Waters (20.6.4.12 New Mexico Administrative Code), New Mexico Water Quality Control Commission, December 16, 2001: http://www.nmenv.state.nm.us/NMED_regs/swqb/20_6_4_nmac.html#12 and http://www.nmenv.state.nm.us

20.6.4.7 DEFINITIONS:

I. "Coldwater fishery" means a surface water of the State where the water temperature and other characteristics are suitable for the support or propagation or both of coldwater fishes.

U. "High quality coldwater fishery" means a perennial surface water of the State in a minimally disturbed condition which has considerable aesthetic value and is a superior coldwater fishery habitat. A surface water of the State to be so categorized must have water quality, stream bed characteristics, and other attributes of habitat sufficient to protect and maintain a propagating coldwater fishery.

BB. "Limited warmwater fishery" means a surface water of the State where intermittent flow may severely limit the ability of the reach to sustain a natural fish population on a continuous annual basis; or a surface water of the State where historical data indicate that water temperature may routinely exceed 32.2˚C (90˚F).

DD. "Marginal coldwater fishery" means a surface water of the State known to support a coldwater fish population during at least some portion of the year, even though historical data indicate that the maximum temperature in the surface water of the State may exceed 20˚C (68˚F).

XX. "Warmwater fishery" means a surface water of the State where the water temperature and other characteristics are suitable for the support or propagation or both of warmwater fishes.

CCC. "Wetlands" means those areas which are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soft conditions in New Mexico. Constructed wetlands used for wastewater treatment purposes are not included in this definition.

DDD. "Wildlife habitat" means a surface water of the State used by plants and animals not considered as pathogens, vectors for pathogens or intermediate hosts for pathogens for humans or domesticated livestock and plants.

20.6.4.12. GENERAL STANDARDS.

A. Bottom Deposits: Surface waters of the State shall be free of water contaminants from other than natural causes that will settle and damage or impair the normal growth, function, or reproduction of aquatic life or significantly alter the physical or chemical properties of the bottom.

20.6.4.14. USE ATTAINABILITY ANALYSIS.

D. Physical, chemical and biological evaluations of surface waters of the State other than lakes and reservoirs for purposes of use attainability analyses or equivalent studies shall be conducted according to the procedures outlined in the "Technical Support Manual: Waterbody Surveys and Assessments for Conducting Use Attainability Analyses," ...

E. Physical, chemical and biological evaluations of lakes and reservoirs for purposes of use attainability analyses or equivalent studies shall be conducted according to the procedures outlined in the "Technical Support Manual' Waterbody Surveys and Assessments for Conducting Use Attainability Analyses, Volume III: Lake Systems,"...

F. A use attainability analysis or equivalent study should include any applicable information concerning the following:

   5. A physical and biological evaluation of the surface water of the State to be reviewed to identify any factors unrelated to water quality which impair attainment of designated uses and to determine which designated uses are feasible to attain in such surface water of the State given existing physical limitations,

   7. An evaluation of the aquatic and terrestrial biota utilizing the surface water of the State to determine resident species and which species could potentially exist in such water if physical and chemical factors impairing a designated use are corrected.

New York

SOURCE: Official Compilation of Codes, Rules, and Regulations of the State of New York, Title 6, Environmental Conservation Rules and Regulations, Chapter X, Division of Water Resources, Part 701, Classifications-Surface Waters and Groundwaters, amended March 1998:
http://www.dec.state.ny.us/website/regs/701.htm

§ 701.2 Class N fresh surface waters.

(a) The best usages of Class N waters are the enjoyment of water in its natural condition and, where compatible, as a source of water for drinking or culinary purposes, bathing, fishing, fish propagation, and recreation.

§ 701.3 Class AA-Special (AA-S) fresh surface waters.

(a) The best usages of Class AA-S waters are: a source of water supply for drinking, culinary or food processing purposes; primary and secondary contact recreation; and fishing. The waters shall be suitable for fish propagation and survival.

§ 701.4 Class A-Special (A-S) fresh surface waters.

(a) The best usages of Class A-S waters are: a source of water supply for drinking, culinary or food processing purposes; primary and secondary contact recreation; and fishing. The waters shall be suitable for fish propagation and survival.

§ 701.5 Class AA fresh surface waters.

(a) The best usages of Class AA waters are: a source of water supply for drinking, culinary or food processing purposes; primary and secondary contact recreation; and fishing. The waters shall be suitable for fish propagation and survival.

§ 701.6 Class A fresh surface waters.

(a) The best usages of Class A waters are: a source of water supply for drinking, culinary or food processing purposes; primary and secondary contact recreation; and fishing. The waters shall be suitable for fish propagation and survival.

§ 701.7 Class B fresh surface waters.

The best usages of Class B waters are primary and secondary contact recreation and fishing. These waters shall be suitable for fish propagation and survival.

§ 701.8 Class C fresh surface waters.
The best usage of Class C waters is fishing. These waters shall be suitable for fish propagation and survival. The water quality shall be suitable for primary and secondary contact recreation, although other factors may limit the use for these purposes.

§ 701.9 Class D fresh surface waters.
The best usage of Class D waters is fishing. Due to such natural conditions as intermittency of flow, water conditions not conducive to propagation of game fishery, or stream bed conditions, the waters will not support fish propagation. These waters shall be suitable for fish survival. The water quality shall be suitable for primary and secondary contact recreation, although other factors may limit the use for these purposes.

North Carolina

SOURCE: North Carolina Administrative Code, Title 15A Environment and Natural Resources, Subchapter 2B Surface Water Standards: Monitoring, January 1, 2002:
http://h2o.enr.state.nc.us/admin/rules/rb010102.pdf and www.esb.enr.state.nc.us

15A NCAC 02B .0101 General Procedures
(e) The following are supplemental classifications:
- (1) Trout waters (Tr): freshwaters protected for natural trout propagation and survival of stocked trout.
- (2) Swamp waters (Sw): waters which have low velocities and other natural characteristics which are different from adjacent streams.
- (4) Outstanding Resource Waters (ORW): unique and special waters of exceptional state or national recreational or ecological significance which require special protection to maintain existing uses.
- (5) High Quality Waters (HQW): waters which are rated as excellent based on biological and physical/chemical characteristics through Division monitoring or special studies, native and special native trout waters (and their tributaries) designated by the Wildlife Resources Commission, primary nursery areas (PNA) designated by the Marine Fisheries Commission and other functional nursery areas designated by the Marine Fisheries Commission, all water supply watersheds which are either classified as WS-I or WS-II or those for which a formal petition for reclassification as WS-I or WS-II has been received from the appropriate local government and accepted by the Division of Water Quality and all Class SA waters.
- (7) Unique wetland (UWL): wetlands of exceptional state or national ecological significance which require special protection to maintain existing uses. These wetlands may include wetlands that have been documented to the satisfaction of the Commission as habitat essential for the conservation of state or federally listed threatened or endangered species.

15A NCAC 02B.0202 Definitions

- (11) Biological integrity means the ability of an aquatic ecosystem to support and maintain a balanced and indigenous community of organisms having species composition, diversity, population densities and functional organization similar to that of reference conditions.

15A NCAC 02B .0211 Fresh Surface Water Quality Standards for Class C Waters
- (1) Best Usage of Waters. Aquatic life propagation and maintenance of biological integrity (including fishing, and fish), wildlife, secondary recreation, agriculture and any other usage except for primary recreation or as a source of water supply for drinking, culinary or food processing purposes;
- (2) Conditions Related to Best Usage. The waters shall be suitable for aquatic life propagation and maintenance of biological integrity, wildlife, secondary recreation, and agriculture; sources of water pollution which preclude any of these uses on either a short-term or long-term basis shall be considered to be violating a water quality standard;

15A NCAC 02B .0212, .0214-.0216, .0218-.0219 Fresh Surface Water Quality Standards for Class WS-I -WS-V and Class B Waters
...Water quality standards applicable to Class C waters as described in Rule .0211 of this Section also apply to Class WS-I waters [and other uses as assigned for each class].

15A NCAC 02B .0220 TIDAL SALT WATER QUALITY STANDARDS FOR CLASS SC WATERS

General. The water quality standards for all tidal salt waters are the basic standards applicable to Class SC waters. Additional and more stringent standards applicable to other specific tidal salt water classifications are specified in Rules .0221 and .0222 of this Section.

(1) Best Usage of Waters. Aquatic life propagation and maintenance of biological integrity (including fishing, fish and functioning PNAs [Primary Nursery Areas]), wildlife, secondary recreation, and any other usage except primary recreation or shellfishing for market purposes.

(2) Conditions Related to Best Usage. The waters shall be suitable for aquatic life propagation and maintenance of biological integrity, wildlife, and secondary recreation; Any source of water pollution which precludes any of these uses, including their functioning as PNAs, on either a short-term or a long-term basis shall be considered to be violating a water quality standard.

15A NCAC 02B .0221 Tidal Salt Water Quality Standards for Class SA Waters

The following water quality standards apply to surface waters that are used for shellfishing for market purposes and are classified SA. Water quality standards applicable to Class SC waters as described in Rule .0220 of this Section also apply to Class SA waters.

(1) Best Usage of Waters. Shellfishing for market purposes and any other usage specified by the "SB" or "SC" classification...

15A NCAC 02B .0222 Tidal Salt Water Quality Standards for Class SB Waters

The following water quality standards apply to surface waters that are used for primary recreation, including frequent or organized swimming, and are classified SB. Water quality standards applicable to Class SC waters [as] described in Rule .0220 of this Section also apply to SB waters...

15A NCAC 02B .0225 Outstanding Resource Waters

(a) General In addition to the existing classifications, the Commission may classify unique and special surface waters of the state as outstanding resource waters (ORW) upon finding that such waters are of exceptional state or national recreational or ecological significance and that the waters have exceptional water quality while meeting the following conditions:
   (1) that the water quality is rated as excellent based on physical, chemical or biological information...

(b) Outstanding Resource Values. In order to be classified as ORW, a water body must exhibit one or more of the following values or uses to demonstrate it is of exceptional state or national recreational or ecological significance:
   (1) there are outstanding fish (or commercially important aquatic species) habitat and fisheries;
   (5) the waters are of special ecological or scientific significance such as habitat for rare or endangered species or as areas for research and education.

North Dakota

SOURCE: Standards of Water Quality for State of North Dakota, Rule 33-16-02, North Dakota State Department of Health and Consolidated Laboratories, June 1, 2001:
http://www.epa.gov/ost/standards/wqslibrary/

33-16-02-08. General water quality standards.

2. **Narrative Biological Goal**

   a. Goal. The biological condition of surface waters shall be similar to that of sites or waterbodies determined by the department to be regional reference sites.

   b. Definitions:
      (1) “Assemblage” means an association of aquatic organisms of similar taxonomic classification living in the same area. Examples of assemblages include, but are not limited to, fish, macroinvertebrates, algae, and vascular plants.
      (2) “Aquatic organism”means any plant or animal which lives at least part of its life cycle in water.
      (3) “Biological condition” means the taxonomic composition, richness, and functional organization of an assemblage of aquatic organisms at a site or within a water body.
      (4) “Functional organization” means the number of species or abundance of organisms within an assemblage which perform the same or similar ecological functions.

(5) “Metric” means an expression of biological community composition, richness, or function which displays a predictable, measurable change in value along a gradient of pollution or other anthropogenic disturbance.
(6) “Regional reference sites” are sites or water bodies which are determined by the department to be representative of sites or water bodies of similar type (e.g., hydrology and ecoregion) and are least impaired with respect to habitat, water quality, watershed land use, and riparian and biological condition.
(7) “Richness” means the absolute number of taxa in an assemblage at a site or within a water body.
(8) “Taxonomic composition” means the identity and abundance of species or taxonomic groupings within an assemblage at a site or within a water body.

c. Implementation. The intent of the state in adopting a narrative biological goal is solely to provide an additional assessment method that can be used to identify impaired surface waters. Regulatory or enforcement actions based solely on a narrative biological goal, such as the development and enforcement of North Dakota pollutant discharge elimination system permit limits, are not authorized. However, adequate and representative biological assessment information may be used in combination with other information to assist in determining whether designated uses are attained and to assist in determining whether new or revised chemical-specific permit limitations may be needed. Implementation will be based on the comparison of current biological conditions at a particular site to the biological conditions deemed attainable based on regional reference sites. In implementing a narrative biological goal, biological condition may be expressed through an index composed of multiple metrics or through appropriate statistical procedures.

33-20-02-09. Surface water classifications, mixing zones, and numeric standards.

1. **Classifications**...

a. Class I streams. The quality of the waters in this class shall be suitable for the propagation and/or protection of resident fish species and other aquatic biota and for swimming, boating, and other water recreation. The quality of the waters shall be for irrigation, stock watering, and wildlife without injurious effects. After treatment consisting of coagulation, settling, filtration, and chlorination, or equivalent treatment processes, the water quality shall meet the bacteriological, physical, and chemical requirements of the department for municipal or domestic use.

b. Class IA streams. The quality of the waters in this class shall be the same as the quality of class I streams, except that treatment for municipal use may also require softening to meet the requirements of the department.

c. Class II streams. The quality of the waters in this class shall be the same as the quality of class I streams, except that additional treatment may be required to meet the drinking water requirements of the department. Streams in this classification may be intermittent in nature which would make these waters of limited value for beneficial uses such as municipal water, fish life, or irrigation.

d. Class III streams. The quality of the waters in this class shall be suitable for agricultural and industrial uses such as stock watering, irrigation, washing, and cooling. These streams have low average flows and, generally, prolonged periods of no flow. They are of limited seasonal value for immersion recreation, fish life, and aquatic biota. The quality of these waters must be maintained to protect recreation, fish, and aquatic biota.

Ohio

SOURCE: Ohio Administrative Code, Chapter 3745-1-07 Water use designations and statewide criteria, February 22, 2002: http://www.epa.state.oh.us/dsw/rules/01-07.pdf

(A) Water quality standards contain two distinct elements: designated uses; and numerical or narrative criteria designed to protect and measure attainment of the uses.

(1) Each water body in the state is assigned one or more aquatic life habitat use designations. Each water body may be assigned one or more water supply use designations and/or one recreational use designation. These use designations are defined in paragraph (B) of this rule. Water bodies are assigned use designations in rules 3745-1-08 to 3745-1-32 of the Administrative Code. In addition, a water body may be assigned designations as described in the antidegradation rule (rule 3745-1-05 of the Administrative Code).

(6) Biological criteria presented in table 7-14 of this rule provide a direct measure of attainment of the warmwater habitat, exceptional warmwater habitat and modified warmwater habitat aquatic life uses. Biological criteria and the exceptions to chemical-specific or whole-effluent criteria allowed by this paragraph do not apply to any other use designations.
  (a) Demonstrated attainment of the applicable biological criteria in a water body will take precedence over the application of selected chemical-specific aquatic life or whole-effluent criteria associated with these uses when the director, upon considering appropriately detailed chemical, physical and biological data, finds that one or more chemical-specific or whole-effluent criteria are inappropriate. In such cases the options which exist include:
    (i) The director may develop, or a discharger may provide for the director's approval, a justification for a site-specific water quality criterion according to methods described in "Water Quality Standards Handbook, 1983, U.S. EPA Office of Water";
    (ii) The director may proceed with establishing water quality based effluent limits consistent with attainment of the designated use.
  (b) Demonstrated nonattainment of the applicable biological criteria in a water body with concomitant evidence that the associated chemical-specific aquatic life criteria and whole-effluent criteria are met will cause the director to seek and establish, if possible, the cause of the nonattainment of the designated use. The director shall evaluate the existing designated use and, where not attainable, propose to change the designated use. Where the designated use is attainable and the cause of the nonattainment has been established, the director shall, wherever necessary and appropriate, implement regulatory controls or make other recommendations regarding water resource management to restore the designated use...

(B) Use designations are defined as follows:
  (1) Aquatic life habitat
    (a) "Warmwater" - these are waters capable of supporting and maintaining a balanced, integrated, adaptive community of warmwater aquatic organisms having a species composition, diversity, and functional organization comparable to the twenty-fifth percentile of the identified reference sites within each of the following ecoregions: the interior plateau ecoregion, the Erie/Ontario lake plains ecoregion, the western Allegheny plateau ecoregion and the eastern corn belt plains ecoregion. For the Huron/Erie lake plains ecoregion, the comparable species composition, diversity and functional organization are based upon the ninetieth percentile of all sites within the ecoregion. For all ecoregions, the attributes of species composition, diversity and functional organization will be measured using the index of biotic integrity, the modified index of well-being and the invertebrate community index as defined in "Biological Criteria for the Protection of Aquatic Life: Volume II, Users Manual for Biological Field Assessment of Ohio Surface Waters," as cited in paragraph (B) of rule 3745-1-03 of the Administrative Code. In addition to those water body segments designated in rules 3745-1-08 to 3745-1-32 of the Administrative Code, all upground storage reservoirs are designated warmwater habitats. Attainment of this use designation (except for upground storage reservoirs) is based on the criteria in table 7-14 of this rule. A temporary variance to the criteria associated with this use designation may be granted as described in paragraph (F) of rule 3745-1-01 of the Administrative Code.
    (b) "Limited warmwater" - these are waters that were temporarily designated in the 1978 water quality standards as not meeting specific warmwater habitat criteria. Criteria for the support of this use designation are the same as the criteria for the support of the use designation warmwater habitat. However, individual criteria are varied on a case-by-case basis and supersede the criteria for warmwater habitat where applicable. Any exceptions from warmwater habitat criteria apply only to specific criteria during specified time periods and/or flow conditions. The adjusted criteria and conditions for specified stream segments are denoted as comments in rules 3745-1-08 to 3745-1-30 of the Administrative Code. Stream segments currently designated limited warmwater habitats will undergo use attainability analyses and will be redesignated other aquatic life habitats. No additional stream segments will be designated limited warmwater habitats.
    (c) "Exceptional warmwater" - these are waters capable of supporting and maintaining an exceptional or unusual community of warmwater aquatic organisms having a species composition, diversity, and functional organization comparable to the seventy-fifth percentile of the identified reference sites on a statewide basis. The attributes of species composition, diversity and functional organization will be measured using the index of biotic integrity, the modified index of well-being and the invertebrate community index as defined in "Biological Criteria for the Protection of

Aquatic Life: Volume II, Users Manual for Biological Field Assessment of Ohio Surface Waters," as cited in paragraph (B) of rule 3745-1-03 of the Administrative Code. In addition to those water body segments designated in rules 3745-1-08 to 3745-1-32 of the Administrative Code, all lakes and reservoirs, except upground storage reservoirs, are designated exceptional warmwater habitats. Attainment of this use designation (except for lakes and reservoirs) is based on the criteria in table 7-14 of this rule. A temporary variance to the criteria associated with this use designation may be granted as described in paragraph (F) of rule 3745-1-01 of the Administrative Code.

(d) "Modified warmwater" - these are waters that have been the subject of a use attainability analysis and have been found to be incapable of supporting and maintaining a balanced, integrated, adaptive community of warmwater organisms due to irretrievable modifications of the physical habitat. Such modifications are of a long-lasting duration (i.e., twenty years or longer) and may include the following examples: extensive stream channel modification activities permitted under sections 401 and 404 of the act or Chapter 6131. of the Revised Code, extensive sedimentation resulting from abandoned mine land runoff, and extensive permanent impoundment of free-flowing water bodies. The attributes of species composition, diversity and functional organization will be measured using the index of biotic integrity, the modified index of well-being and the invertebrate community index as defined in "Biological Criteria for the Protection of Aquatic Life: Volume II, Users Manual for Biological Field Assessment of Ohio Surface Waters," as cited in paragraph (B) of rule 3745-1-03 of the Administrative Code. Attainment of this use designation is based on the criteria in table 7-14 of this rule. Each water body designated modified warmwater habitat will be listed in the appropriate use designation rule (rules 3745-1-08 to 3745-1-32 of the Administrative Code) and will be identified by ecoregion and type of physical habitat modification as listed in table 7-14 of this rule. The modified warmwater habitat designation can be applied only to those waters that do not attain the warmwater habitat biological criteria in table 7-14 of this rule because of irretrievable modifications of the physical habitat. All water body segments designated modified warmwater habitat will be reviewed on a triennial basis (or sooner) to determine whether the use designation should be changed. A temporary variance to the criteria associated with this use designation may be granted as described in paragraph (F) of rule 3745-1-01 of the Administrative Code.

(e) "Seasonal salmonid" - these are rivers, streams and embayments capable of supporting the passage of salmonids from October to May and are water bodies large enough to support recreational fishing. This use will be in effect the months of October to May. Another aquatic life habitat use designation will be enforced the remainder of the year (June to September). A temporary variance to the criteria associated with this use designation may be granted as described in paragraph (F) of rule 3745-1-01 of the Administrative Code.

(f) "Coldwater" - these are waters that meet one or both of the characteristics described in paragraphs (B)(1)(f)(i) and (B)(1)(f)(ii) of this rule. A temporary variance to the criteria associated with this use designation may be granted as described in paragraph (F) of rule 3745-1-01 of the Administrative Code.

(i) "Coldwater habitat, inland trout streams" -these are waters which support trout stocking and management under the auspices of the Ohio department of natural resources, division of wildlife, excluding waters in lake run stocking programs, lake or reservoir stocking programs, experimental or trial stocking programs, and put and take programs on waters without, or without the potential restoration of, natural coldwater attributes of temperature and flow. The director shall designate these waters in consultation with the director of the Ohio department of natural resources.

(ii) "Coldwater habitat, native fauna" - these are waters capable of supporting populations of native coldwater fish and associated vertebrate and invertebrate organisms and plants on an annual basis. The director shall designate these waters based upon results of use attainability analyses.

(g) "Limited resource water" - these are waters that have been the subject of a use attainability analysis and have been found to lack the potential for any resemblance of any other aquatic life habitat as determined by the biological criteria in table 7-14 of this rule. The use attainability analysis must demonstrate that the extant fauna is substantially degraded and that the potential for recovery of the fauna to the level characteristic of any other aquatic life habitat is realistically precluded due to natural background conditions or irretrievable human-induced conditions. All water body segments designated limited resource water will be reviewed on a triennial basis (or sooner) to determine whether the use designation should be changed. Limited resource waters are also termed nuisance prevention for some water bodies designated in rules 3745-1-08 to 3745-1-30 of the Administrative Code. A temporary variance to the criteria associated with this use designation may be granted as described in paragraph (F) of rule 3745-1-01 of the Administrative Code. Waters designated limited resource water will be assigned one or more of the following causative factors. These causative factors will be listed as comments in rules 3745-1-08 to 3745-1-30 of the Administrative Code.

(i) "Acid mine drainage" - these are surface waters with sustained pH values below 4.1 s.u. or with intermittently acidic conditions combined with severe streambed siltation, and have a demonstrated biological performance below that of the modified warmwater habitat biological criteria.

(ii) "Small drainageway maintenance" - these are highly modified surface water drainageways (usually less than three square miles in drainage area) that do not possess the stream morphology and habitat characteristics necessary to support any other aquatic life habitat use. The potential for habitat improvements must be precluded due to regular stream channel maintenance required for drainage purposes.

(iii) Other specified conditions.

(2) Nuisance prevention This use designation is being replaced by the limited resource water use designation described in paragraph (A)(1)(g) of this rule. All water body segments currently designated nuisance prevention in rules 3745-1-08 to 3745-1-30 of the Administrative Code must meet the limited resource water criteria in this rule. All references to the nuisance prevention use designation in rules 3745-1-08 to 3745-1-30 of the Administrative Code will be phased out over time and replaced with limited resource water.

(3) Water supply

(a) "Public" - these are waters that, with conventional treatment, will be suitable for human intake and meet federal regulations for drinking water. Criteria associated with this use designation apply within five hundred yards of surface water intakes. Although not necessarily included in rules 3745-1-08 to 3745-1-30 of the Administrative Code, the bodies of water with one or more of the following characteristics are designated public water supply: (i) All publicly owned lakes and reservoirs, with the exception of Piedmont reservoir;
(ii) All privately owned lakes and reservoirs used as a source of public drinking water; (iii) All surface waters within five hundred yards of an existing public water supply surface water intake; (iv) All surface waters used as emergency water supplies.

(b) "Agricultural" - these are waters suitable for irrigation and livestock watering without treatment.

(c) "Industrial" - these are waters suitable for commercial and industrial uses, with or without treatment. Criteria for the support of the industrial water supply use designation will vary with the type of industry involved.

(4) Recreation. These use designations are in effect only during the recreation season, which is the period from May first to October fifteenth, for all water bodies except those designated seasonal salmonid habitat. The recreation season for streams designated seasonal salmonid habitat is June first to September thirtieth.

(a) "Bathing waters" - these are waters that, during the recreation season are suitable for swimming where a lifeguard and/or bathhouse facilities are present, and include any additional such areas where the water quality is approved by the director. Water bodies assigned the bathing waters use designation are not necessarily indicated in rules 3745-1-08 to 3745-1-30 of the Administrative Code but include local areas of those water bodies meeting this definition.

(b) "Primary contact" - these are waters that, during the recreation season, are suitable for full-body contact recreation such as, but not limited to, swimming, canoeing, and scuba diving with minimal threat to public health as a result of water quality. In addition to those water body segments designated in rules 3745-1-08 to 3745-1-32 of the Administrative Code, all lakes and reservoirs, except upground storage reservoirs and those lakes and reservoirs meeting the definition of bathing waters, are designated primary contact recreation.

(c) "Secondary contact" - these are waters that, during the recreation season, are suitable for partial body contact recreation such as, but not limited to, wading with minimal threat to public health as a result of water quality.

(C) Protection of aquatic life - whole-effluent approach. Whole-effluent toxicity levels shall be applied in accordance with rules 3745-2-09 and 3745-33-07 of the Administrative Code.

Table 7-14
Biological criteria for warmwater, exceptional warmwater and modified warmwater habitats. Description and derivation of indices and ecoregions are contained in "Biological Criteria for the Protection of Aquatic Life: Volume II, Users Manual for Biological Field Assessment of Ohio Surface Waters" cited in paragraph (B) of rule 3745-1-03 of the Administrative Code. These criteria do not apply to the Ohio river, lakes or Lake Erie river mouths

Index	Modified Warmwater Habitat				
Sampling Site Ecoregion[1]	Channel Modif.	Mine Affected	Impounded	Warmwater Habitat	Exceptional Warmwater Habitat
(A) Index of biotic integrity (fish)					
(1) Wading sites*					
HELP	22	–	–	32	50
IP	24	–	–	40	50
EOLP	24	–	–	38	50
WAP	24	24	–	44	50
ECBP	24	–	–	40	50
(2) Boat sites[2]					
HELP	20	–	*22*	34	48
IP	24	–	30	38	48
EOLP	24	–	30	40	48
WAP	24	24	30	40	48
ECBP	24	–	30	42	48
(3) Headwater sites**					
HELP	20	–	–	28	50
IP	24	–	–	40	50
EOLP	24	–	–	40	50
WAP	24	24	–	44	50
ECBP	24	–	–	40	50

* Sampling methods descriptions are found in the "Manual of Ohio EPA Surveillance Methods and Quality Assurance Practices," cited in paragraph (B) of rule 3745-1-03 of the Administrative Code.

** Modification of the IBI that applies to sites with drainage areas less than twenty square miles.

Index	Modified Warmwater Habitat				
Sampling Site Ecoregion[1]	Channel Modif.	Mine Affected	Impounded	Warmwater Habitat	Exceptional Warmwater Habitat
(B) Modified index of well-being (fish)[***]					
(1) Wading sites[2]					
HELP	5.6	—	—	7.3	9.4
IP	6.2	—	—	8.1	9.4
EOLP	6.2	—	—	7.9	9.4
WAP	6.2	5.5	—	8.4	9.4
ECBP	6.2	—	—	8.3	9.4
(2) Boat sites[2]					
HELP	5.7	—	5.7	8.6	9.6
IP	5.8	—	6.6	8.7	9.6
EOLP	5.8	—	6.6	8.7	9.6
WAP	5.8	5.4	6.6	8.6	9.6
ECBP	5.8	—	6.6	8.5	9.6
(C) Invertebrate community index (macroinvertebrates)					
(1) Artificial substrate samplers[2]					
HELP	22	–	–	34	46
IP	22	–	–	30	46
EOLP	22	–	–	34	46
WAP	22	30	–	36	46
ECBP	22	–	–	36	46

Oklahoma

SOURCE: Oklahoma Administrative Code, Title 785, Oklahoma Water Resources Board Rules, Chapter 45 Oklahoma Water Quality Standards, August 13, 2001:
http://www.oklaosf.state.ok.us/~owrb/rules/Chap45.pdf,
http://www.oklaosf.state.ok.us/~owrb/rules/Chap46.pdf and www.state.ok.us/~owrb

785:45-1-2. Definitions
"Benthic macroinvertebrates" means invertebrate animals that are large enough to be seen by the unaided eye, can be retained by a U. S. Standard No. 30 sieve, and live at least part of their life cycles within or upon available substrate in a body of water or water transport system.

[***] Does not apply to sites with drainage areas less than twenty square miles.

"Intolerant climax fish community" means habitat and water quality adequate to support game fishes or other sensitive species introduced or native to the biotic province or ecological region, which require specific or narrow ranges of high quality environmental conditions.

"Sensitive representative species" means Ceriodaphnia dubia, Daphnia magna, Daphnia pulex, Pimphales promelas (Fathead minnow), Lepomis macrochirus (Bluegill sunfish), or other sensitive organisms indigenous to a particular waterbody.

"Warm Water Aquatic Community" means a subcategory of the beneficial use category "Fish and Wildlife Propagation" where the water quality and habitat are adequate to support intolerant climax fish communities and includes an environment suitable for the full range of warm water benthos.

"Water quality" means physical, chemical, and biological characteristics of water which determine diversity, stability, and productivity of the climax biotic community or affect human health.

785:45-5-12. Fish and wildlife propagation

(b) Habitat Limited Aquatic Community subcategory.
  (1) Habitat limited aquatic community means a subcategory of the beneficial use "Fish and Wildlife Propagation" where the water chemistry and habitat are not adequate to support a "Warm Water Aquatic Community" because:
    (A) Naturally occurring water chemistry prevents the attainment of the use; or
    (B) Naturally occurring ephemeral, intermittent or low flow conditions or water levels prevent the attainment of the use, unless these conditions may be compensated for by the discharge of a sufficient volume of effluent to enable uses to be met; or
    (C) Human caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place; or
    (D) Dams, diversions or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the waterbody to its original condition or to operate such modification in a way that would result in the attainment of the use; or
    (E) Physical conditions related to the natural features of the waterbody, such as the lack of a proper substrate, cover, flow, depth, pools, riffles, and the like, unrelated to water quality, preclude attainment of the "Warm Water Aquatic Community" beneficial use.
  (2) Habitat Limited Aquatic Community may also be designated where controls more stringent than those required by sections 301(b) and 306 of the federal Clean Water Act as amended, which would be necessary to meet standards or criteria associated with the beneficial use subcategories of Cool Water Aquatic Community or Warm Water Aquatic Community, would result in substantial and widespread economic and social impact.

(c) Warm Water Aquatic Community subcategory. Warm Water Aquatic Community means a subcategory of the beneficial use category "Fish and Wildlife Propagation" where the water quality and habitat are adequate to support climax fish communities.

(d) Cool Water Aquatic Community subcategory. Cool Water Aquatic Community means a subcategory of the beneficial use category "Fish and Wildlife Propagation" where the water quality, water temperature and habitat are adequate to support cool water climax fish communities and includes an environment suitable for the full range of cool water benthos. Typical species may include smallmouth bass, certain darters and stoneflies.

(e) Trout Fishery subcategory. Trout Fishery (Put and Take) means a subcategory of the beneficial use category "Fish and Wildlife Propagation" where the water quality, water temperature and habitat are adequate to support a seasonal put and take trout fishery. Typical species may include trout.

(f) Criteria used in protection of fish and wildlife propagation. The narrative and numerical criteria to maintain and protect the use of "Fish and Wildlife Propagation" and its subcategories shall include...
  (5) Biological Criteria.
    (A) Aquatic life in all waterbodies designated Fish and Wildlife Propagation (excluding waters designated "Trout, put-and-take") shall not exhibit degraded conditions as indicated by one or

both of the following:

(i) comparative regional reference data from a station of reasonably similar watershed size or flow, habitat type and Fish and Wildlife beneficial use subcategory designation or

(ii) by comparison with historical data from the waterbody being evaluated.

(B) Compliance with the requirements of 785:45-5-12(f)(5) shall be based upon measures including, but not limited to, diversity, similarity, community structure, species tolerance, trophic structure, dominant species, indices of biotic integrity (IBI's), indices of well being (IWB's), or other measures.

785:46-15-5. Assessment of Fish and Wildlife Propagation support

(e) **Biological criteria.**

(1) If data demonstrate that an assemblage of fish or macro invertebrates from a waterbody is significantly degraded, according to 785:45-5-12(f)(5), from that expected for thesubcategory of Fish and Wildlife Propagation designated in OAC 785:45 for that waterbody, then that subcategory may be deemed by the appropriate state environmental agency to be not supported.

(2) All physical assessments and biological collections shall be performed in accordance with the requirements set forth in OWRB Technical Report No. 99-3 entitled "Standard Operating Procedures for Stream Assessments and Biological Collections Related to Biological Criteria in Oklahoma".

(3) Evaluation of the biological collections shall include identification of fish samples to species level.

(4) The determination of whether the use of Fish and Wildlife Propagation is supported in wadeable streams in Oklahoma ecoregions shall be made according to all of the requirements of this subsection (e), the application of Appendix C of this Chapter, and the special provisions in subsections (g) through (i), where applicable, of this Section. Streams with undetermined use support status shall be subject to additional investigation that considers stream order, habitat factors and local reference streams before the use support determination is made.

(f) **Turbidity.** The criteria for turbidity stated in 785:45-5-12(f)(7) shall constitute the screening levels for turbidity. The tests for use support shall follow the default protocol in 785:46-15-4(b).

(g) **Special provisions for Ouachita Mountains wadeable streams**. The determination of whether the use of Fish and Wildlife Propagation is supported for wadeable streams located in the Ouachita Mountains ecoregion shall be made according to the application of Appendix C of this Chapter, together with this subsection, as follows:

(1) Where designated, the subcategory of Warm Water Aquatic Community shall be deemed fully supported if the application of Appendix C produces a score of 35 or more. Such subcategory shall be deemed not supported if the application of Appendix C produces a score of 24 or less. If a score is 25 to 34 inclusive, the issue of whether this subcategory is supported shall be deemed undetermined.

(2)Where designated, the subcategory of Habitat Limited Aquatic Community shall be deemed fully supported if the application of Appendix C produces a score of 27 or more. Such subcategory shall be deemed not supported if the application of Appendix C produces a score of 18 or less. If a score is 19 to 26 inclusive, the issue of whether this subcategory is supported shall be deemed undetermined.

(h) **Special provisions for Arkansas Valley wadeable streams.** The determination of whether the use of Fish and Wildlife Propagation is supported for wadeable streams located in the Arkansas Valley ecoregion shall be made according to the application of Appendix C of this Chapter, together with this subsection, as follows:

(1) Where designated, the subcategory of Warm Water Aquatic Community shall be deemed fully supported if the application of Appendix C produces a score of 35 or more. Such subcategory shall be deemed not supported if the application of Appendix C produces a score of 24 or less. If a score is 25 to 34 inclusive, the issue of whether this subcategory is supported shall be deemed undetermined.

(2) Where designated, the subcategory of Habitat Limited Aquatic Community shall be deemed fully supported if the application of Appendix C produces a score of 27 or more. Such subcategory shall be deemed not supported if the application of Appendix C produces a score of 18 or less. If a score is 19 to 26 inclusive, the issue of whether this subcategory is supported shall be deemed undetermined.

(i) **Special provisions for Boston Mountains and Ozark Highlands wadeable streams.** The determination of whether the use of Fish and Wildlife Propagation is supported for wadeable streams located in the Boston Mountains and Ozark Highlands ecoregions shall be made according to the

application of Appendix C of this Chapter, together with this subsection, as follows:
(1) Where designated, the subcategory of Cool Water Aquatic Community shall be deemed fully supported if the application of Appendix C produces a score of 37 or more. Such subcategory shall be deemed not supported if the application of Appendix C produces a score of 29 or less. If a score is 30 to 36 inclusive, the issue of whether this subcategory is supported shall be deemed undetermined.
(2) Where designated, the subcategory of Warm Water Aquatic Community shall be deemed fully supported if the application of Appendix C produces a score of 31 or more. Such subcategory shall be deemed not supported if the application of Appendix C produces a score of 22 or less. If a score is 23 to 30 inclusive, the issue of whether this subcategory is supported shall be deemed undetermined.

(j) **Special provisions for Central Irregular Plains wadeable streams.** The determination of whether the use of Fish and Wildlife Propagation is supported for wadeable streams located in the Central Irregular Plains ecoregion shall be made according to the application of Appendix C of this Chapter, together with this subsection, as follows:
(1) Where designated, the subcategory of Cool Water Aquatic Community shall be deemed fully supported if the application of Appendix C produces a score of 35 or more. Such subcategory shall be deemed not supported if the application of Appendix C produces a score of 28 or less. If a score is 29 to 34 inclusive, the issue of whether this subcategory is supported shall be deemed undetermined.
(2) Where designated, the subcategory of Warm Water Aquatic Community shall be deemed fully supported if the application of Appendix C produces a score of 30 or more. Such subcategory shall be deemed not supported if the application of Appendix C produces a score of 22 or less. If a score is 23 to 29 inclusive, the issue of whether this subcategory is supported shall be deemed undetermined.
3) Where designated, the subcategory of Habitat Limited Aquatic Community shall be deemed fully supported if the application of Appendix C produces a score of 25 or more. Such subcategory shall be deemed not supported if the application of Appendix C produces a score of 16 or less. If a score is 17 to 24 inclusive, the issue of whether this subcategory is supported shall be deemed undetermined.

SOURCE: Added at 17 Ok Reg 1775, effective 7/1/2000; Amended at 18 Ok Reg 3379, effective 8/13/2001; Amended at 19 Ok Reg 2524-2526, eff 7/1/2002

APPENDIX C. INDEX OF BIOLOGICAL INTEGRITY

		5	3	1	SCORE
Sample Composition	Total no. of species	See figure 1*	2.49 -1.50	<1.50	
	Shannon diversity** based upon numbers	>2.50	2 - 3	<2	
	No. of sunfish species	>3	4 - 3	<3	
	No. of species comprising 75% of sample	>5	3 - 5	<3	
	No. of intolerant species <100mi2 area >100mi2 area	>5			
	Percentage of tolerant species	See figure 3*			
Fish Condition	Percentage of lithophils	>36	18 - 36	<18	
	Percentage of DELT anomalies***	<0.1	0.1 -1.3	>1.3	
	Fish numbers (total individuals)	>200	200 - 75	<75	

**Figure 2. Number of Intolerant Species* and *Figure 3. Percent Tolerant Species*, (Unofficial) Oklahoma

Administrative Code, Title 785, Oklahoma Water Resources Board Rules, Chapter 46. Implementation of Oklahoma Water Quality Standards, p. 47, 48.

**$d = - \sum \frac{n_i}{N} In \frac{n_i}{N}$

***DELT = deformities, eroded fins, lesions, tumors

Oregon

SOURCE: Oregon Administrative Rules: Chapter 340 Department of Environmental Quality, Water Pollution, Division 41 State-Wide Water Quality Management Plan; Beneficial Uses, Policies, Standards, and Treatment Criteria for Oregon, amended February 15, 2001:
http://arcweb.sos.state.or.us/rules/OARS_300/OAR_340/340_041.html and
http://www.deq.state.or.us/lab/biomon/bio-rpt.htm

340-04l-0006 Definitions

(32) "Aquatic Species" means any plants or animals which live at least part of their life cycle in waters of the State.

(33) "Biological Criteria" means numerical values or narrative expressions that describe the biological integrity of aquatic communities inhabiting waters of a given designated aquatic life use.

(35) "Indigenous" means supported in a reach of water or known to have been supported according to historical records compiled by State and Federal agencies or published scientific literature.

(36) "Resident Biological Community" means aquatic life expected to exist in a particular habitat when water quality standards for a specific ecoregion, basin, or water body are met. This shall be established by accepted biomonitoring techniques.

(37) "Without Detrimental Changes in the Resident Biological Community" means no loss of ecological integrity when compared to natural conditions at an appropriate reference site or region.

(38) "Ecological Integrity" means the summation of chemical, physical and biological integrity capable of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat of the region.

(39) "Appropriate Reference Site or Region" means a site on the same water body, or within the same basin or ecoregion that has similar habitat conditions, and represents the water quality and biological community attainable within the areas of concern.

(40) "Critical Habitat" means those areas which support rare, threatened or endangered species, or serve as sensitive spawning and rearing areas for aquatic life.

(41) "High Quality Waters" means those waters which meet or exceed those levels that are necessary to support the propagation of fish, shellfish, and wildlife and recreation in and on the water, and other designated beneficial uses.

(42) "Outstanding Resource Waters" means those waters designated by the Environmental Quality Commission where existing high quality waters constitute an outstanding state or national resource based on their extraordinary water quality or ecological values, or where special water quality protection is needed to maintain critical habitat areas.

(51) "Cold-Water Aquatic Life" -- The aquatic communities that are physiologically restricted to cold water,

composed of one or more species sensitive to reduced oxygen levels. Including but not limited to Salmonidae and cold-water invertebrates.

(52) "Cool-Water Aquatic Life" -- The aquatic communities that are physiologically restricted to cool waters, composed of one or more species having dissolved oxygen requirements believed similar to the cold-water communities. Including but not limited to Cottidae, Osmeridae, Acipenseridae, and sensitive Centrarchidae such as the small-mouth bass.

(53) "Warm-Water Aquatic Life" -- The aquatic communities that are adapted to warm-water conditions and do not contain either cold- or cool-water species.

(57) "Ecologically Significant Cold-Water Refuge" exists when all or a portion of a waterbody supports stenotypic cold-water species (flora or fauna) not otherwise widely supported within the subbasin, and either:
(a) Maintains cold-water temperatures throughout the year relative to other segments in the subbasin, providing summertime cold-water holding or rearing habitat that is limited in supply, or;
(b) Supplies cold water to a receiving stream or downstream reach that supports cold-water biota.

340-041-0027 Biological Criteria
Waters of the state shall be of sufficient quality to support aquatic species without detrimental changes in the resident biological communities.

Pennsylvania

SOURCE: Pennsylvania Code Chapter 93, Title 25, § 93.3, 93.4, 93.6. General water quality criteria, amended November 17, 2000: http://www.pacode.com/secure/data/025/chapter93/s93.3.html,
http://www.pacode.com/secure/data/025/chapter93/s93.4.html
http://www.pacode.com/secure/data/025/chapter93/s93.6.html
www.dep.state.pa.us

§ 93.3. Protected water uses.
Water uses which shall be protected, and upon which the development of water quality criteria shall be based, are set forth, accompanied by their identifying symbols, in Table 1:

Table 1

Symbol	Protected Use
Aquatic Life	
CWF	Cold Water Fishes—Maintenance or propagation, or both, of fish species including the family Salmonidae and additional flora and fauna which are indigenous to a cold water habitat.
WWF	Warm Water Fishes—Maintenance and propagation of fish species and additional flora and fauna which are indigenous to a warm water habitat.
MF	Migratory Fishes—Passage, maintenance and propagation of anadromous and catadromous fishes and other fishes which ascend to flowing waters to complete their life cycle.

Symbol	Protected Use
TSF	Trout Stocking—Maintenance of stocked trout from February 15 to July 31 and maintenance and propagation of fish species and additional flora and fauna which are indigenous to a warm water habitat.
Water Supply	
AWS	Wildlife Water Supply—Use for waterfowl habitat and for drinking and cleansing by wildlife.
Special Protection	
HQ	High Quality Waters
EV	Exceptional Value Waters

§ 93.4. Statewide water uses.

(a) Statewide water uses. Except when otherwise specified in law or regulation, the uses set forth in Table 2 apply to all surface waters. These uses shall be protected in accordance with this chapter, Chapter 96 (relating to water quality standards implementation) and other applicable State and Federal laws and regulations.

Table 2

Symbol	Protected Use
Aquatic Life	
WWF	Warm Water Fishes
AWS	Wildlife Water Supply

§ 93.6. General water quality criteria.

(a) Water may not contain substances attributable to point or nonpoint source discharges in concentration or amounts sufficient to be inimical or harmful to the water uses to be protected or to human, animal, plant or aquatic life.

Rhode Island

SOURCE: State of Rhode Island And Providence Plantations Department of Environmental Management Water Resources, Water Quality Regulations, Regulation EVM 112-88.97-1, amended June 23, 2000: http://www.epa.gov/waterscience/standards/wqslibrary/ri/ri_1_wqr.pdf, and http://www.state.ri.us/dem/pubs/regs/REGS/WATER/QUALREGS.PDF

Rule 7. - DEFINITIONS

"Outstanding National Resource Waters (ONRW)" means waters of National and State Parks, Wildlife Refuges, and other such waters designated as having special recreational or ecological value.

"Special Resource Protection Waters (SRPW)" means surface waters identified by the Director as having significant recreational or ecological uses, and may include but are not limited to: wildlife refuge or management areas; public drinking water supplies; State and Federal parks; State and Federal designated Estuarine Sanctuary Areas; waterbodies containing critical habitats, including but not limited to waterbodies identified by the RIDEM Natural Heritage Program as critical habitat for rare or endangered species; wetland types or specific wetlands listed as rare, threatened, endangered, of special interest or of special concern by the Rhode Island Natural Heritage Program; waterbodies identified by the U. S. Department of the Interior on the Final List of Rivers for potential inclusion in the National Wild and Scenic Rivers System.

"Undesirable or Nuisance Species" means any plant or animal aquatic species which becomes so numerous due to pollutants or physical or hydrological modifications that it interferes with, or indicates an impairment of, the designated use(s) of a waterbody.

"Use Attainability Analyses" means a structured scientific assessment of the factors affecting the attainment of a use which may include physical, chemical, biological, and economic factors. The physical, chemical and biological factors affecting the attainment of a use shall be evaluated through a waterbody survey and assessment. Waterbody surveys and assessments shall be sufficiently detailed to evaluate at a minimum:

a. current aquatic uses achieved in the waterbody;
b. causes of any impairment of the aquatic uses and why the impairment cannot be rectified; and
c. aquatic uses(s) that can be attained based on the physical, chemical, and biological characteristics of the water body.

Rule 8. - SURFACE WATER QUALITY STANDARDS

B. Water Use Classification
   (1) Freshwater: Class A, Class B, Class B1, and Class C waters are designated... for fish and wildlife habitat...
   (2) Seawater: Class SA, Class SB, Class SB1, and Class SC waters are designated for ... fish and wildlife habitat...

D. Water Quality Criteria - The following physical, chemical and biological criteria are parameters of minimum water quality necessary to support the surface water use classifications of rule 8.B. and shall be applicable to all waters of the State.
   (1) General Criteria - The following minimum criteria are applicable to all waters of the State, unless criteria specified for individual classes are more stringent:
      (a) At a minimum, all waters shall be free of pollutants in concentrations or combinations or from anthropogenic activities subject to these regulations that:
         i. Adversely affect the composition of fish and wildlife;
         ii. Adversely affect the physical, chemical, or biological integrity of the habitat;
         iii. Interfere with the propagation of fish and wildlife;
         iv. Adversely alter the life cycle functions, uses, processes and activities of fish and wildlife;...
      (b) Aesthetics - all waters shall be free from pollutants in concentrations or combinations that:
         iv. Result in the dominance of species of fish and wildlife to such a degree as to create a nuisance or interfere with the existing or designated uses.

South Carolina

SOURCE: South Carolina Regulation 61-68, Water Classification and Standards, September 28, 2001: http://www.lpitr.state.sc.us/coderegs/chap61/61-69.htm, and
http://www.scstatehouse.net/coderegs/c061c.htm#61-68

61-68. Water Classifications and Standards

B. DEFINITIONS.
   1. Biological assessment means an evaluation of the biological condition of a waterbody using biological surveys and other direct measurements of resident biota in surface waters and sediments.

   18. Biological criteria, also known as biocriteria, mean narrative expressions or numeric values of the biological characteristics of aquatic communities based on appropriate reference conditions. Biological criteria serve as an index of aquatic community health.

F. NARRATIVE BIOLOGICAL CRITERIA.
   1. Narrative biological criteria are contained in this regulation and are described throughout the sections where applicable. The following are general statements regarding these narrative biological criteria.
      a. Narrative biological criteria in Section A.4. describe the goals of the Department to maintain and improve all surface waters to a level that provides for the survival and propagation of a balanced indigenous aquatic community of fauna and flora. These narrative criteria are determined by the

Department based on the condition of the waters of the State by measurements of physical, chemical, and biological characteristics of the waters according to their classified uses.

b. Section C.10. describes narrative biological criteria relative to surface water mixing zones and specifies requirements necessary for the protection and propagation of a balanced indigenous aquatic community.

c. Narrative biological criteria shall be consistent with the objective of maintaining and improving all surface waters to a level that provides for the survival and propagation of a balanced indigenous aquatic community of fauna and flora attainable in waters of the State; and in all cases shall protect against degradation of the highest existing or classified uses or biological conditions in compliance with the Antidegradation Rules contained in this regulation. Section D.1.a describes narrative biological criteria relative to activities in Outstanding National Resource Waters, Outstanding Resource Waters and Shellfish Harvesting Waters.

d. In order to determine the biological quality of the waters of the State, it is necessary that the biological component be assessed by comparison to a reference condition(s) based upon similar hydrologic and watershed characteristics that represent the optimum natural condition for that system. Such reference condition(s) or reaches of waterbodies shall be those observed to support the greatest variety and abundance of aquatic life in the region as is expected to be or would be with a minimal amount of disturbance from anthropogenic sources. Impacts from urbanization and agriculture should be minimal and natural vegetation should dominate the land cover. There should also be an appropriate diversity of substrate. Reference condition(s) shall be determined by consistent sampling and reliable measures of selected indicative communities of flora and fauna as established by the Department and may be used in conjunction with acceptable physical, chemical, and microbial water quality measurements and records judged to be appropriate for this purpose. Narrative biological criteria relative to activities in all waters are described in Section E.

e. In the Class Descriptions, Designations, and Specific Standards for Surface Waters Section, all water use classifications protect for a balanced indigenous aquatic community of fauna and flora. In addition, Trout Natural and Trout Put, Grow, and Take classifications protect for reproducing trout populations and stocked trout populations, respectively.

Antidegradation Rules.

8. Trout Waters. The State recognizes three types of trout waters: Natural; Put, Grow, and Take; and Put and Take.
   a. Natural (TN) are freshwaters suitable for supporting reproducing trout populations and a cold water balanced indigenous aquatic community of fauna and flora. Also suitable for primary and secondary contact recreation and as a source for drinking water supply after conventional treatment in accordance with the requirements of the Department. Suitable for fishing and the survival and propagation of a balanced indigenous aquatic community of fauna and flora. Suitable also for industrial and agricultural uses.
   b. Put, Grow, and Take (TPGT) are freshwaters suitable for supporting growth of stocked trout populations and a balanced indigenous aquatic community of fauna and flora. Also suitable for primary and secondary contact recreation and as a source for drinking water supply after conventional treatment in accordance with the requirements of the Department. Suitable for fishing and the survival and propagation of a balanced indigenous aquatic community of fauna and flora. Suitable also for industrial and agricultural uses.
   c. Put and Take (TPT) are freshwaters suitable for primary and secondary contact recreation and as a source for drinking water supply after conventional treatment in accordance with the requirements of the Department. Suitable for fishing and the survival and propagation of a balanced indigenous aquatic community of fauna and flora. Suitable also for industrial and agricultural uses. The standards of Freshwaters classification protect these uses.

South Dakota

SOURCE: Administrative Rules of South Dakota, Article 74:51, Surface Water Quality Standards, effective January 27, 1999: http://legis.state.sd.us/rules/rules/7451.htm#74:51:01 and http://www.state.sd.us/denr/denr.html

74:51:01:01. Definitions.

(4) "Aquatic life," an organism dependent on the water environment to either propagate or survive, or both;

(5) "Aquatic community," an association of interacting populations and stages of aquatic life in a given water body or habitat;

(10) "Biological integrity," the ability to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat of the region;

(13) "Coldwater aquatic life," aquatic life including fish of the family Salmonidae, for example, trout and salmon;

(14) "Coldwater marginal fish life propagation," a beneficial use assigned to surface waters of the state which support aquatic life and are suitable for stocked catchable-size coldwater fish during portions of the year, but which, because of critical natural conditions including low flows, siltation, or warm temperatures, are not suitable for a permanent coldwater fish population. Warmwater fish may also be present;

(15) "Coldwater permanent fish life propagation," a beneficial use assigned to surface waters of the state which are capable of supporting aquatic life and are suitable for supporting a permanent population of coldwater fish from natural reproduction or fingerling stocking. Warmwater fish may also be present;

(27) "High-quality fishery waters," surface waters of the state designated for the beneficial use of coldwater permanent fish life propagation, coldwater marginal fish life propagation, or warmwater permanent fish life propagation;

(30) "Impairment," a detrimental effect on the aquatic community caused by an impact that prevents attainment of the designated use;

(57) "Warmwater aquatic life," aquatic life including the Ictaluridae, Centrarchidae, and Cyprinidae families of fish, for example, catfish, sunfish, and minnows, respectively;

(58) "Warmwater marginal fish life propagation," a beneficial use assigned to surface waters of the state which will support aquatic life and more tolerant species of warmwater fish naturally or by frequent stocking and intensive management but which suffer frequent fish kills because of critical natural conditions;

(59) "Warmwater permanent fish life propagation," a beneficial use assigned to surface waters of the state which support aquatic life and are suitable for the permanent propagation or maintenance, or both, of warmwater fish;

(60) "Warmwater semipermanent fish life propagation waters," a beneficial use assigned to surface waters of the state which support aquatic life and are suitable for the propagation or maintenance, or both, of warmwater fish but which may suffer occasional fish kills because of critical natural conditions;

62) "Wetlands," those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions including swamps, marshes, bogs, and similar areas;

(63) "Fish and wildlife propagation, recreation, and stock watering," a beneficial use classification assigned to all surface waters of the state which may support recreation in and on the water and fish and aquatic life, when sufficient quantities of water are present for sufficient duration to support those uses; provide habitat for aquatic and semi-aquatic wild animals and fowl; provide natural food chain maintenance; and are of suitable quality for watering domestic and wild animals;

74:51:01:12. Biological integrity of waters.
All waters of the state must be free from substances, whether attributable to human-induced point source discharges or nonpoint source activities, in concentrations or combinations which will adversely impact the structure and function of indigenous or intentionally introduced aquatic communities.

Tennessee

SOURCE: Rules of the Tennessee Department of Health and Tennessee Department of Environment and Conservation, Chapter 1200-4-3 General Water Quality Criteria, revised October 1999: http://www.state.tn.us/sos/rules/1200/1200-04/1200-04-03.pdf and www.state.tn.us/environment

1200-4-3-.03 Criteria for Water Uses:
(3) Fish and Aquatic Life.
   (j) Biological Integrity - The waters shall not be modified through the addition of pollutants or through physical alteration to the extent that the diversity and/or productivity of aquatic biota within the receiving waters are substantially decreased or adversely affected, except as allowed under 1200-4-3-.06. The condition of biological communities will be measured by use of metrices suggested in guidance such as Rapid Bioassessment Protocols for Use in Streams and Rivers (EPA/444/4-89-001) or other scientifically defensible methods. Effects to biological populations will be measured by comparisons to upstream conditions or to appropriately selected reference sites in the same ecoregion.

Texas

SOURCE: Texas Administrative Code, Title 30 Environmental Quality, Part 1, Texas Natural Resource Conservation Commission, Chapter 307, Texas Surface Water Quality Standards, amended effective August 17, 2000: http://info.sos.state.tx.us:80/pub/plsql/readtac$ext.ViewTAC?tac_view=4&ti=30&pt=1&ch=307&rl=Y

Rule 307.3 Definitions and Abbreviations
(a) Definitions
   (9) Biological integrity--The species composition, diversity, and functional organization of a community of organisms in an environment relatively unaffected by pollution.

   (27) Incidental fishery--A level of fishery which applies to water bodies that are not considered to have a sustainable fishery but which have an aquatic life use of limited, intermediate, high, or exceptional.

   (45) Seagrass propagation--A water-quality-related existing use which applies to saltwater with significant stands of submerged seagrass.

   (50) Significant aquatic life use--A broad characterization of aquatic life which indicates that a subcategory of aquatic life use (limited, intermediate, high, or exceptional) is applicable. Some aquatic life is expected to be present even in water bodies which are not designated for specific categories of aquatic life use. Some provisions to protect aquatic life applies to any water body in the state whether an aquatic life use is assigned or not.

Rule 307.7 Site-specific Uses and Criteria
(a) Aquatic life. The establishment of numerical criteria for aquatic life is highly dependent on desired use, sensitivities of usual aquatic communities, and local physical and chemical characteristics. Five subcategories of aquatic life use are established. They include limited, intermediate, high, and exceptional aquatic life and oyster waters. Aquatic life use subcategories designated for segments listed in Appendix A of §307.10 of this title recognize the natural variability of aquatic community requirements and local environmental conditions.

(b) Appropriate uses and criteria for site-specific standards are defined as follows.

(3) Aquatic life. The establishment of numerical criteria for aquatic life is highly dependent on desired use, sensitivities of usual aquatic communities, and local physical and chemical characteristics. Five subcategories of aquatic life use are established. They include limited, intermediate, high, and exceptional aquatic life and oyster waters. Aquatic life use subcategories designated for segments listed in Appendix A of §307.10 of this title recognize the natural variability of aquatic community requirements and local environmental conditions.

(5) Additional uses. Other basic uses, such as navigation, agricultural water supply, industrial water supply, seagrass propagation, and wetland water quality functions will be maintained and protected for all water in the state in which these uses can be achieved

Table 4: Aquatic Life Subcategories (Figure: 30 TAC §307.7(b)(3)(A)(i))

Aquatic Life Use Subcategory	Dissolved Oxygen, mg/L			Aquatic Life Attributes					
	Freshwater mean/ minimum	Freshwater in Spring mean/ minimum	Saltwater mean/ minimum	Habitat Characteristics	Species Assemblage	Sensitive Species	Diversity	Species Richness	Trophic Structure
Exceptional	6.0/4.0	6.0/5.0	5.0/4.0	Outstanding natural variability	Exceptional or unusual	Abundant	Exceptionally high	Exceptionally high	Balanced
High	5.30/3.0	5.5/4.5	4.0/3.0	Highly diverse	Usual association of regionally expected species	Present	High	High	Balanced to slightly imbalanced
Intermediate	4.0/3.0	5.0/4.0	3.0/2.0	Moderately diverse	Some expected species	Very low in abundance	Moderate	Moderate	Moderately imbalanced
Limited	3.0/2.0	4.0/3.0		Uniform	Most regionally expected species absent	Absent	Low	Low	Severely imbalanced

Utah

SOURCE: Title R317. Environmental Quality, Water Quality, R317-1. Definitions and General Requirements and Rule R317.2 Standards of Quality for Waters of the State, as in effect January 1, 2002: http://www.rules.state.ut.us/publicat/code/r317/r317-001.htm#T1 , and http://www.rules.state.ut.us/publicat/code/r317/r317-002.htm#T7

R317-1-1. Definitions

1.20 "Pollution" means such contamination, or other alteration of the physical, chemical, or biological properties of any waters of the state, or such discharge of any liquid, gaseous or solid substance into any waters of the state as will create a nuisance or render such waters harmful or detrimental or injurious to public health, safety or welfare, or to domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or to livestock, wild animals, birds, fish or other aquatic life.

317-2-6. Use Designations

6.3 Class 3 -- Protected for use by aquatic wildlife.

(a) Class 3A -- Protected for cold water species of game fish and other cold water aquatic life, including the necessary aquatic organisms in their food chain.

(b) Class 3B -- Protected for warm water species of game fish and other warm water aquatic life, including the necessary aquatic organisms in their food chain.

(c) Class 3C -- Protected for nongame fish and other aquatic life, including the necessary aquatic organisms in their food chain.

(d) Class 3D -- Protected for waterfowl, shore birds and other water-oriented wildlife not included in Classes 3A, 3B, or 3C, including the necessary aquatic organisms in their food chain.

(e) Class 3E -- Severely habitat-limited waters. Narrative standards will be applied to protect these waters for aquatic wildlife.

6.5 Class 5 -- The Great Salt Lake. Protected for primary and secondary contact recreation, aquatic wildlife, and mineral extraction.

Vermont

SOURCE: Vermont Water Quality Standards, effective July 2, 2000:
http://www.state.vt.us/wtrboard/docs/adoptedwqs.pdf

Section 1-01B. Applicability and Definitions

5. **Aquatic biota** means all organisms that, as part of their natural life cycle, live in or on waters.

6. **Aquatic habitat** means the physical, chemical, and biological components of the water environment.

10. **Biological integrity** means the ability of an aquatic ecosystem to support and maintain, when consistent with reference conditions, a community of organisms that is not dominated by any particular species or functions (balanced), is fully functional (integrated), and is resilient to change or impact (adaptive), and which has the expected species composition, diversity, and functional organization.

20. **Functional component** of the aquatic ecosystem means a portion of the aquatic biological community identified by its role in the processing of energy within the aquatic ecosystem (e.g., primary producers, predators, detritivores, etc.).

23. **Intolerant aquatic organisms** means those organisms which are particularly sensitive to, and likely to be adversely affected by, the stress of pollution, flow modification or habitat alteration (e.g., mayflies and stoneflies).

29. **Natural condition** means the condition representing chemical, physical, and biological characteristics that occur naturally with only minimal effects from human influences.

39. **Reference condition** means the range of chemical, physical, and biological characteristics of waters minimally affected by human influences. In the context of an evaluation of biological indices, or where necessary to perform other evaluations of water quality, the reference condition establishes attainable chemical, physical, and biological conditions for specific water body types against which the condition of waters of similar water body type is evaluated.

44. **Taxonomic component of the aquatic ecosystem** means a portion of the biological community identified by a hierarchical classification system for identifying biological organisms that uses physical and biological characteristics (e.g., Insecta: Plecoptera: Perlidae: Agnetina capitata).

45. **Tolerant aquatic organisms** means organisms (e.g., midges and annelids) that, although they may be affected by the stress of pollution, flow modification or habitat alteration, are less sensitive and less likely to be adversely affected than are intolerant aquatic organisms.

Section 3-01C. Numeric Biological Criteria

C. Numeric Biological Indices
   1. In addition to other applicable provisions of these rules and other appropriate methods of evaluation, the Secretary may establish and apply numeric biological indices to determine whether there is full support of aquatic biota and aquatic habitat uses. These numeric biological indices shall be derived from measures of the biological integrity of the reference condition for different water body types. In establishing numeric biological indices, the Secretary shall establish procedures that employ standard sampling and analytical methods to characterize the biological integrity of the appropriate reference condition. Characteristic measures of biological integrity include but are not limited to community level measurement such as: species richness, diversity, relative abundance of tolerant and intolerant species, density, and functional composition.
   2. In addition, the Secretary may determine whether there is full support of aquatic biota and aquatic

habitat uses through other appropriate methods of evaluation, including habitat assessments.

Section 3-02 Class A(1) Ecological Waters

B. Water Quality Criteria for Class A(1) Ecological Waters
   3. Aquatic Biota, Wildlife, and Aquatic Habitat - Change from the natural condition limited to minimal impacts from human activity. Measures of biological integrity for aquatic macroinvertebrates and fish assemblages are within the range of the natural condition. Uses related to either the physical, chemical, or biological integrity of the aquatic habitat or the composition or life cycle functions of aquatic biota or wildlife are fully supported. All life cycle functions, including overwintering and reproductive requirements are maintained and protected.

Section 3-03. Class A(2) Public Water Supplies

A. Management Objectives. Waters managed for public water supply purposes to achieve and maintain waters with a uniformly excellent character and a level of water quality that is compatible with the following designated uses:
   1. Aquatic Biota, Wildlife, and Aquatic Habitat - high quality aquatic biota and wildlife sustained by high quality aquatic habitat necessary to support their life-cycle and reproductive requirements.
B. Water Quality Criteria for Class A(2) Public Water Supplies. The following water quality criteria shall be achieved in all Class A(2) public water supplies.
   3. Aquatic Biota, Wildlife and Aquatic Habitat - Biological integrity is maintained, no change from the reference condition that would prevent the full support of aquatic biota, wildlife or aquatic habitat uses. Change from the reference condition for aquatic macroinvertebrates and fish assemblages shall not exceed moderate changes in the relative proportions of taxonomic, functional, tolerant and intolerant components. All expected functional groups are present in a high quality habitat and none shall be eliminated. All life cycle functions, including overwintering and reproductive requirements are maintained and protected. Changes in the aquatic habitat shall not exceed moderate differences from the reference condition consistent with the full support of all aquatic biota and wildlife uses.

Section 3-04. Class B Waters

A. Management Objectives. Class B waters shall be managed to achieve and maintain a level of quality that fully supports the following designated uses:
   1. Aquatic Biota, Wildlife, and Aquatic Habitat - aquatic biota and wildlife sustained by high quality aquatic habitat with additional protection in those waters where these uses are sustainable at a higher level based on Water Management Type designation.
B. Water Quality Criteria for Class B waters. In addition to the criteria specified in §3-01 of these rules, the following criteria shall be met in all Class B waters:
   4. Aquatic Biota, Wildlife and Aquatic Habitat - No change from the reference condition that would prevent the full support of aquatic biota, wildlife, or aquatic habitat uses. Biological integrity is maintained and all expected functional groups are present in a high quality habitat. All life-cycle functions, including overwintering and reproductive requirements are maintained and protected. In addition, the following criteria shall be achieved:
      a. In Water Management Type One waters - change from the reference condition for aquatic macroinvertebrate and fish assemblages shall be limited to minor changes in the relative proportions of taxonomic and functional components; relative proportions of tolerant and intolerant components are within the range of the reference condition. Changes in the aquatic habitat shall be limited to minimal differences from the reference condition consistent with the full support of all aquatic biota and wildlife uses.
      b. In Water Management Type Two waters - change from the reference condition for aquatic macroinvertebrate and fish assemblages shall be limited to moderate changes in the relative proportions of tolerant, intolerant, taxonomic, and functional components. Changes in the aquatic habitat shall be limited to minor differences from the reference condition consistent with the full support of all aquatic biota and wildlife uses.
      c. In Water Management Type Three waters - change from the reference condition for aquatic macroinvertebrate and fish assemblages shall be limited to moderate changes in the relative proportions of tolerant, intolerant, taxonomic, and functional components. Changes in the aquatic habitat shall be limited to moderate differences from the reference condition consistent with the full support of all aquatic biota and wildlife uses. When such habitat changes are a result of hydrological modification or water level fluctuation, compliance may be determined on the basis

of aquatic habitat studies.

d. In all other Class B waters - no change from reference conditions that would have an undue adverse effect on the composition of the aquatic biota, the physical or chemical nature of the substrate or the species composition or propagation of fishes.

Section 3-05 Fish Habitat Designation

To provide for the protection and management of fisheries, the waters of the State are designated in Appendix A as being either a cold or a warm water fish habitat. Where appropriate, such designations may be seasonal.

Virginia

SOURCE: State Water Control Board, Virginia Administrative Code (9 VAC 25-260-5 et seq. Water Quality Standards). Statutory Authority: § 62.1-44.15(3a) of the Code of Virginia. Effective Date: December 10, 1997: http://www.deq.state.va.us/wqs/

PART I
SURFACE WATER STANDARDS WITH GENERAL, STATEWIDE APPLICATION

9 VAC 25-260-10. Designation of uses.

A. All state waters, including wetlands, are designated for the following uses: recreational uses, e.g., swimming and boating; the propagation and growth of a balanced, indigenous population of aquatic life, including game fish, which might reasonably be expected to inhabit them; wildlife; and the production of edible and marketable natural resources, e.g., fish and shellfish.

9 VAC 25-260-20. General standard.

A. All state waters, including wetlands, shall be free from substances attributable to sewage, industrial waste, or other waste in concentrations, amounts, or combinations which contravene established standards or interfere directly or indirectly with designated uses of such water or which are inimical or harmful to human, animal, plant, or aquatic life.

9 VAC 25-260-370. Classification column.

B. DGIF trout waters. The Department of Game and Inland Fisheries (DGIF) has established a classification system for trout waters based on aesthetics, productivity, resident fish population and stream structure. Classes i through iv rate wild trout habitat; Classes v through vii rate cold water habitat not suitable for wild trout but adequate for year-round hold-over of stocked trout. The DGIF classification system is included in this publication with the board's trout water classes (Class V - Stockable trout waters and Class VI - Natural trout waters) in the class column of the River Basin Section Tables 9 VAC 25-260-390 et seq.

DGIF trout water classifications which are not consistent with board classifications for stockable trout waters or natural trout waters are shown with a double asterisk (**) in the class column of the River Basin Section Tables 9 VAC 25-260-390 et seq. These trout waters have been identified for reevaluation by the DGIF. Those trout waters which have no DGIF classification are shown with a triple asterisk (***). The DGIF classes are described below. Inclusion of these DGIF classes provides additional information about specific streams for permit writers and other interested persons. Trout waters classified as classes i or ii by the DGIF are also recognized in 9 VAC 25-260-110.

DGIF STREAM CLASS DESCRIPTIONS.

Wild natural trout streams.

Class i. Stream of outstanding natural beauty possessing wilderness or at least remote characteristics, an abundance of large deep pools, and excellent fish cover. Substrate is variable with an abundance of coarse gravel and rubble. Stream contains a good population of wild trout or has the potential for such. Would be considered an exceptional wild trout stream.

Class ii. Stream contains a good wild trout population or the potential for one but is lacking in aesthetic quality, productivity, and/or in some structural characteristic. Stream maintains good water quality and temperature, maintains at least a fair summer flow, and adjacent land is not extensively developed. Stream would be considered a good wild trout stream and would represent a major portion of Virginia's wild trout waters.

Class iii. Stream which contains a fair population of wild trout with carrying capacity depressed by natural factors or more commonly man-related land use practices. Land use activities may result in heavy siltation of the stream, destruction of banks and fish cover, water quality degradation, increased water temperature, etc. Most streams would be considered to be in the active state of degradation or recovery from degradation. Alteration in land use practices would generally improve carrying capacity of the stream.

Class iv. Stream which contains an adequately reproducing wild trout population but has severely reduced summer flow characteristics. Fish are trapped in isolated pools where they are highly susceptible to predators and fishermen. Such streams could quickly be over-exploited and, therefore, provide difficult management problems.

Stockable trout streams.

Class v. Stream does not contain an adequately reproducing wild trout population nor does it have the potential for such. However, water quality is adequate, water temperature is good, and invertebrate productivity is exceptional. Pools are abundant with good size and depth and fish cover is excellent. Stream would be good for stocked trout but may offer more potential for a fingerling stocking program.

Class vi. Stream does not contain a significant number of trout nor a significant population of warmwater gamefish. Water quality is adequate and water temperature good for summer carryover of stocked trout. Summer flow remains fair and adjacent land is not extensively developed. All streams in this class would be considered good trout stocking water.

Class vii. Stream does not contain a significant number of trout nor a significant population of warmwater gamefish. Water quality and temperature are adequate for trout survival but productivity is marginal as are structural characteristics. Streams in this class could be included in a stocking program but they would be considered marginal and generally would not be recommended for stocking.

Class viii. Stream does not contain a significant number of trout nor a significant population of warmwater gamefish. Water quality and temperature are adequate for trout but summer flows are very poor (less than 30% of channel). Streams in this class can provide good trout fishing during spring and early summer but would not be recommended for summer or fall stocking.

Other. Remaining streams would be considered unsuitable for any type of trout fishery. Streams would be considered unsuitable under any of the following conditions:

(a) summer temperatures unsuitable for trout survival;
(b) stream contains a significant population of warmwater gamefish;
(c) insufficient flow; or
(d) intolerable water quality.

Washington

SOURCE: Chapter 173-201A Washington Administrative Code. Water Quality Standards for Surface Waters of the State of Washington, November 18, 1997: http://www.ecy.wa.gov/pubs/wac173201a.pdf

WAC 173-201A-010 Introduction.

(1) The purpose of this chapter is to establish water quality standards for surface waters of the state of Washington consistent with public health and public enjoyment thereof, and the propagation and protection of fish, shellfish, and wildlife, pursuant to the provisions of chapter 90.48 RCW [Revised Code of Washington] and the policies and purposes thereof.

WAC 173-201A-020 Definitions.

"Biological assessment" is an evaluation of the biological condition of a water body using surveys of aquatic community structure and function and other direct measurements of resident biota in surface waters.

"Damage to the ecosystem" means any demonstrated or predicted stress to aquatic or terrestrial organisms or communities of organisms which the department reasonably concludes may interfere in the health or survival success or natural structure of such populations. This stress may be due to, but is not limited to, alteration in habitat or changes in water temperature, chemistry, or turbidity, and shall consider the potential build up of discharge constituents or temporal increases in habitat alteration which may create such stress in the long term.

"Ecoregions" are defined using EPA's *Ecoregions of the Pacific Northwest* Document No. 600/3-86/033 July 1986 by Omernik and Gallant.

"Wildlife habitat" means waters of the state used by, or that directly or indirectly provide food support to, fish, other aquatic life, and wildlife for any life history stage or activity.

WAC 173-201A-030 General water use and criteria classes.
The following criteria shall apply to the various classes of surface waters in the state of Washington:

Class AA (extraordinary), Class A (excellent), and Class B (good). Characteristic uses shall include, but not be limited to, the following:

- (iii) Fish and shellfish: Salmonid migration, rearing, spawning, and harvesting. Other fish migration, rearing, spawning, and harvesting. Clam, oyster, and mussel rearing, spawning, and harvesting. Crustaceans and other shellfish (crabs, shrimp, crayfish, scallops, etc.) rearing, spawning, and harvesting.
- (iv) Wildlife habitat.

Class C (fair). Characteristic uses shall include, but not be limited to, the following:

- (ii) Fish (salmonid and other fish migration).

Lake class. Characteristic uses shall include, but not be limited to, the following:

- (iii) Fish and shellfish: Salmonid migration, rearing, spawning, and harvesting. Other fish migration, rearing, spawning, and harvesting. Clam and mussel rearing, spawning, and harvesting. Crayfish rearing, spawning, and harvesting.
- (iv) Wildlife habitat.

West Virginia

SOURCE: Title 46, West Virginia Secretary of State, Code of State Rules (CSR), Legislative Rule, Environmental Quality Board, Series 1, Requirements Governing Water Quality Standards, effective May 17, 2001: http://www.state.wv.us/csr/verify.asp?TitleSeries=46-01

§46-1-3. Conditions Not Allowable In State Waters.

3.2.i. Any other condition, including radiological exposure, which adversely alters the integrity of the waters of the State including wetlands; no significant adverse impact to the chemical, physical, hydrologic, or biological components of aquatic ecosystems shall be allowed.

§46-1-6. Water Use Categories.

6.3. Category B – Propagation and maintenance of fish and other aquatic life. -- This category includes:

- 6.3.a. Category B1 -- Warm water fishery streams. -- Streams or stream segments which contain populations composed of all warm water aquatic life.
- 6.3.b. Category B2 -- Trout Waters. -- As defined in Section 2.19 (See Appendix A for a representative list.)
- 6.3.c. Category B4 -- Wetlands. -- As defined in section 2.22; certain numeric stream criteria may not be appropriate for application to wetlands (see Appendix E).

6.5. Category D. -- Agriculture and wildlife uses.

- 6.5.c. Category D3 -- Wildlife. -- This category includes all stream segments and wetlands used by wildlife.

Wisconsin

Source: Wisconsin Administrative Code, Department of Natural Resources, Chapter NR 102, Water Quality Standards for Wisconsin Surface Waters, February 1998: http://www.legis.state.wi.us/rsb/code/nr/nr102.pdf

NR 102.04 Categories of standards.

(3) FISH AND OTHER AQUATIC LIFE USES. The department shall classify all surface waters into one of the fish and other aquatic life subcategories described in this subsection. Only those use subcategories identified in pars. (a) to (c) shall be considered suitable for the protection and propagation of a balanced fish and other aquatic life community as provided in the federal water pollution control act amendments of 1972, P.L. 92–500; 33 USC 1251 et seq.

(a) *Cold water communities*. This subcategory includes surface waters capable of supporting a community of cold water fish and other aquatic life, or serving as a spawning area for cold water fish species. This subcategory includes, but is not restricted to, surface waters identified as trout water by the department of natural resources (Wisconsin Trout Streams, publication 6–3600 (80)).

(b) *Warm water sport fish communities*. This subcategory includes surface waters capable of supporting a community of warm water sport fish or serving as a spawning area for warm water sport fish.

(c) *Warm water forage fish communities.* This subcategory includes surface waters capable of supporting an abundant diverse community of forage fish and other aquatic life.

(d) *Limited forage fish communities*. (Intermediate surface waters). This subcategory includes surface waters of limited capacity and naturally poor water quality or habitat. These surface waters are capable of supporting only a limited community of forage fish and other aquatic life.

(e) *Limited aquatic life*. (Marginal surface waters). This sub-category includes surface waters of severely limited capacity and naturally poor water quality or habitat. These surface waters are capable of supporting only a limited community of aquatic life.

(7) STANDARDS FOR WILDLIFE. All surface waters shall be classified for wildlife uses and meet the wildlife criteria specified in or developed pursuant to NR 105.07.

Wyoming

SOURCE: Wyoming Rules and Regulations, Water Quality Rules and Regulations: Chapter 1, Quality Standards for Wyoming Surface Waters Sections 2, 3, and 4, March 7, 2000: http://soswy.state.wy.us/RULES/3925.pdf

Section 2. Definitions. The following definitions supplement those definitions contained in section 35-11-103 of the Wyoming Environmental Quality Act.

(e) "Cold Water Game Fish " means Grayling (Thymallus arcticus), Northern Pike (Esox lucius), Salmon (Oncorhynchus spp.), Sauger (Stizostedion canadense), Tiger muskie (Esox Masquinongy), Trout (Salmo, Oncorhynchus, and Salvelinus spp.), Walleye (Stizostedion vitreum), and Whitefish (Prospium williamsoni).

(p) "Game fish" means Bass (Micropterus spp.), Catfish (Ictalurus punctatus), Crappie (Pomoxis spp.), Grayling (Thymallus arcticus), Ling (Lota lota), Northern Pike (Esox lucius), Perch (Perca flavescens), Salmon (Oncorhynchus spp.), Sauger (Stizostedion canadense), Sunfish (Lepomis spp.), Tiger Muskie (Esox Masquinongy), Trout (Salmo, Oncorhynchus, and Salvelinus spp.), Walleye (Stizostedion vitreum), White Bass (Morone chrysops), and Whitefish (Prospium williamsoni).

(w) "Natural" means that condition which would exist without the measurable effects or measurable influence of man's activities.

(x) "Natural biotic community" means the population structures which were historically or normally present under a given set of chemical and physical conditions or which would potentially exist had not the habitat been degraded.

(y) "Natural water quality" means that quality of water which would exist without the measurable effects or measurable influence of man's activities.

(ll) "Undesirable aquatic life" means organisms generally associated with degraded or eutrophic conditions. These may include the following organisms where they have replaced members of the natural biotic community: nongame fish, bluegreen algae, certain diatoms, fungi, tubificid worms, and certain syrphid flies.

(mm) "Warm water game fish" means Bass (Micropterus spp.), Catfish (Ictalurus punctatus), Crappie (Pomoxis spp.), Ling (Lota lota), Perch (Perca flavescens), Sunfish (Lepomis spp.), and White Bass (Morone Chrysops).

Section 3. Water Uses.
(b) Protection and propagation of fish and wildlife;...and to achieve the goal of the federal act, which is to achieve, wherever attainable, surface water quality which provides for the protection and propagation of fish, shellfish, wildlife, and recreation in and on the water.

Section 4. Surface Water Classes and Uses. There are four classes of surface water in Wyoming:
(a) Class 1 - Those surface waters in which no further water quality degradation by point source discharges other than from dams will be allowed. Nonpoint sources of pollution shall be controlled through implementation of appropriate best management practices. In designating Class 1 waters, the Environmental Quality Council shall consider water quality, aesthetic, scenic, recreational, ecological, agricultural, botanical, zoological, municipal, industrial, historical, geological, cultural, archaeological, fish and wildlife, the presence of significant quantities of developable water and other values of present and future benefit to the people.
(b) Class 2 - Those surface waters, other than those classified as Class 1, which are determined to:
  (i) Be presently supporting game fish; or
  (ii) Have the hydrologic and natural water quality potential to support game fish; or
  (iii) Include nursery areas or food sources for game fish.
(c) Class 3 - Those surface waters, other than those classified as Class 1, which are determined to:
  (i) Be presently supporting nongame fish only; or
  (ii) Have the hydrologic and natural water quality potential to support nongame fish only; or
  (iii) Include nursery areas or food sources for nongame fish only.
(d) Class 4 - Those surface waters, other than those classified as Class 1, which are determined to not have the hydrologic or natural water quality potential to support fish and include all intermittent and ephemeral streams. Class 4 waters shall receive protection for agriculture uses and wildlife watering.

TERRITORIES

American Samoa

SOURCE: American Samoa Water Quality Standards (1999 Revision provided by ASEPA), Sections 24.0205 and 24.0206:

§24.0205 Water Classifications-Protected and Prohibited Uses
(1) Class 1 Fresh Surface Waters
  (A) Class 1 waters are to remain in as near their natural state as possible with a minimum of pollution from any human activity. Protected uses of these waters are: potable water supplies, support and propagation indigenous aquatic and terrestrial life and compatible recreation and aesthetic enjoyment.
  (B) Prohibited uses and activities include, but are not limited to:
    (i) Point source discharges of pollutants
    (ii) Dredging and filling activities
    (iii) Bathing, including washing clothes and dishes
    (iv) Animal pens over or within 100 feet of the water body
    (v) Siting of septic tanks or cesspools within 200 feet of the water body

(vi) Land disturbing (e.g., grading, tillage) activities within 100 feet of the water body
(vii) Wood cutting or clearing within 100 feet of the water body

(2) Class 2 Fresh Surface Waters
(A) Class 2 waters shall be protected for the support and propagation of indigenous aquatic life, recreation in and on the water, and aesthetic enjoyment.
(B) Prohibited uses and activities include, but are not limited to:
(i) No zones of mixing will be granted
(ii) Dredging or filling activities, except as approved by EQC
(iii) Animal pens over or immediately adjacent to the water body

§24.0206 Standards of Water Quality

(i) There shall be no changes in basin geometry or freshwater inflow that will alter current patterns in such a way as to adversely affect existing biological populations or sediment distribution. To protect estuarine organisms, no change in channels, basin geometry, or freshwater influx shall be made which would cause permanent changes in existing isohaline patterns of more than 10 percent.

Commonwealth of Northern Mariana Islands

Source: http://www.epa.gov/ost/standards/wqslibrary/ and http://www.deq.gov.mp/

PART 5 CLASSIFICATION OF WATER USES

5.1 Marine Waters

(a) CLASS AA - It is the objective of this class that these waters remain in their natural pristine state as nearly as possible with an absolute minimum of pollution or alteration of water quality from any human-related source or actions. To the extent practicable, the wilderness character of such areas shall be protected. No zones of mixing shall be permitted. The uses to be protected in this class of waters are the support and propagation of shellfish and other marine life, conservation of coral reefs and wilderness areas, oceanographic research, and aesthetic enjoyment and compatible recreation inclusive of whole body contact and related activities. / The classification of any water area as Class AA shall not preclude other uses of such waters compatible with these objectives and in conformance with the criteria applicable to them.

(b) CLASS A - It is the objective of this class of waters that their use for recreational purposes and aesthetic enjoyment be protected. Any other use shall be allowed as long as it is compatible with the protection and propagation of fish, shellfish, and wildlife, and with recreation in and on these waters of a limited body contact nature. Such waters shall be kept clean of solid waste, oil and grease, and shall not act as receiving waters for any effluent which has not received the best degree of treatment of control practicable under existing technology and economic conditions and compatible with standards established for this class. A zone of mixing is [approvable] in such waters.

5.2 Fresh Surface Waters

(a) Class 1 - It is the objective of this class that these waters remain in their natural state as nearly as possible with an absolute minimum Of pollution from any human-caused source. To the extent possible, the wilderness character of such areas shall be protected. Wastewater discharges and zone of mixing into these waters are prohibited. The uses to be protected in this class of water are for domestic water supplies, food processing, the support and propagation of aquatic life, compatible recreation and aesthetic enjoyment including water contact recreation.

(b) Class 2 - It is the objective of this class of waters that their use for recreational purposes, propagation of fish and other aquatic life, and agricultural and industrial water supply not be limited in any way. The uses to be protected in this class of waters are all uses compatible with the protection and propagation of fish and other aquatic life, and with recreation in and on these waters. Compatible recreation may include limited body contact activities. Such waters shall not act as receiving waters for any discharge which has not received the best degree of treatment or control practical under technological and economic conditions and compatible with the standards established for this class. A zone of mixing is permissible in these waters.

5.3 Protection of wetlands

Wetlands are waters of the State and are subject to the provisions of this rule. Point or nonpoint sources of pollution shall not cause destruction or impairment of wetlands. The general application of the Water Quality Standards shall apply to all wetlands unless replaced by site specific standards for wetlands based on their function are adopted by the Commonwealth and approved by EPA.

7.6 Salinity

Marine Waters (applicable to Class A, Class AA): No alterations of the marine environment shall occur that would: (1) alter the salinity of marine or estuarine waters more than 10% of the ambient conditions, or (2) which would otherwise adversely affect the sedimentary patterns and indigenous biota, except when due to natural causes.

7.10 Oil and Petroleum Products

The concentration of oil or petroleum products shall not:

(b) Cause tainting of fish or other aquatic life, be injurious to the indigenous biota or cause objectionable taste in drinking water.

7.12 General Considerations

(d) The health and life history characteristics of aquatic organisms in waters affected by controllable water quality factors shall not differ substantially from those for the same waters in areas unaffected by controllable water quality factors. Also, controllable water quality factors shall not cause a detrimental increase in concentrations of toxic substances found in bottom sediments or aquatic life.

Guam*

*This language has not been reviewed for accuracy by state/tribal agency.

SOURCE: Section II, Guam STATEMENT OF POLICY, amended 1986:
http://www.epa.gov/ost/standards/wqslibrary/

It shall be the public policy of the Territory of Guam to:

1. conserve, protect, maintain, and improve the quality of the Guam's waters for (drinking and food processing) human consumption, for the growth and propagation of aquatic life, for marine research and for the preservation of coral reefs and wilderness areas, and for domestic, agricultural, commercial, industrial, recreational and other legitimate uses;
4. maintain and improve the chemical, physical, and biological integrity of wetlands water quality as necessary to meet the Clean Water Act Section 101(a), and to protect wetlands...

SECTION I: CATEGORIES OF WATERS

A. **MARINE WATERS.** This category includes all coastal waters off-shore from the mean high water mark, including estuarine waters, lagoons and bays, brackish areas, wetlands and other special aquatic sites, and other inland Waters that are subject to ebb and flow of the tides. Refer to Water Classification Map.

CATEGORY M-1 EXCELLENT: Waters in this category must be of high enough quality to ensure preservation and protection of marine life, including corals and reef dwelling organisms, fish and related fisheries resources, and enable the pursuit of marine scientific research as well as aesthetic enjoyment. This category of water shall remain substantially free from pollution attributed to domestic, commercial and industrial discharges, shipping and boating, or agriculture, construction and other activities which can reduce the waters' quality. Furthermore, there shall be no zones of mixing within this category water.

CATEGORY M-2 GOOD: Water in this category must be of sufficient quality to allow for the propagation and survival of marine organisms, particularly shellfish, corals and other reef related resources. Other important and intended uses include mariculture activities, aesthetic enjoyment and compatible recreation inclusive of whole body contact and related activities.

CATEGORY M-3 FAIR: Water in this category is intended for general, commercial and industrial use. Specific intended uses include the following: shipping, boating and berthing, industrial cooling water, marinas, while allowing for protection of aquatic life, aesthetic enjoyment and compatible recreation with limited body contact.

B. **MIXING ZONES IN RECEIVING WATERS**. ...The following criteria apply to all mixing zones:
3. Biologically important areas, including spawning and nursery areas, shall be protected.

CHAPTER IV DEFINITIONS

BIOTA: The animal, plant and microbial life of a region.

COMMUNITY: An association of living organisms in a given area or region in which the various species are more or less interdependent upon each other.

HABITAT: The environment occupied by individuals of a particular species, population or community.

SPECIAL AQUATIC SITES: Sites possessing special ecological characteristics and values including wetlands, wildlife sanctuaries and refuges, mud flats, vegetated shallows, coral reefs, riffle and pool complexes.

WETLANDS: Means areas of land where the water table is at, near or above the land surface long enough each year to result in the formation of characteristically wet (hydric) soil types, and support the growth of water dependent (hydrophytic) vegetation. Wetlands include, but are not limited to, marshes, swamps, mangroves, natural ponds, surface springs, estuaries, bogs, and other such low-lying or similar areas. Inland wetlands will include all wetlands meeting the following conditions.
1) Wetlands greater than one hectare in size with less than 0.5% (ocean derived) salinity; and
2) Palustrine, Riverine and Lacustrine wetlands with greater than 30% wetland vegetation cover.

WETLAND FUNCTIONS: The beneficial uses of wetlands which are protected by these Water Quality Standards including but not limited to groundwater recharge/discharge, flood water retention, sediment stabilization, nutrient removal/transformation, wildlife diversity/ abundance, aquatic diversity/abundance, and recreation.

Puerto Rico

SOURCE: Commonwealth of Puerto Rico, Office of the Governor, Environmental Quality Board, Puerto Rico Water Quality Standards, amended November 1987: http://www.epa.gov/ost/standards/wqslibrary/

Article I. Definitions

Benthic Species. Organisms that inhabit on, over, or in the bottom of the water body.;live adhered to the bottom or crawl over the bottom.

Biota. All living organisms.

Desirable Species. Species indigenous to the area or introduced to the area because of ecological or commercial value.

Ecological Community. Group of organisms dominated by one species or a specific group of species. The ecological community derives its name from that of the dominant species, such as coral reefs and mangroves.

Ecological Value. Refers to the existing interrelations between water body, fauna and flora that result in the continuity, stability and permanence of the ecological community.

Pelagic Species. Organisms that have the ability of self locomotion and can overcome the currents. These organisms can be found anywhere in the water column, near the surface, the bottom or at any point between the surface and the bottom.

Planktonic Species. Marine organisms that mainly inhabit the surface of the receiving body of water. Their main characteristic is that they cannot overcome the currents even if they have self locomotion.

Propagation and Preservation of Desirable Species. This refers to the reproduction and continuance of flora and fauna associated with water bodies and which have ecologic importance and/or commercial value, whether individually or as part of an ecological community.

Wetlands. Areas inundated or saturated by coastal, surface cr ground water at a frequency and duration sufficient to support, and under normal circumstances do support a prevalence of vegetation typically adapted for life in saturated soil conditions.

ARTICLE 2. CLASSIFICATION OF THE WATERS OF PUERTO RICO ACCORDING TO THE DESIGNATED USES TO BE PROTECTED

3.2 Use Classifications and Water Quality Standards for Specific Classifications:

- 3.2.1 Class SA:
  - (A) Usages and Description: Coastal waters and estuarine waters of high quality and/or exceptional ecological or recreational value whose existing characteristics shall not be altered, except by natural causes, in order to preserve the existing natural phenomena.
- 3.2.2 Class SB:
  - (A) Usages and Description. Coastal waters and estuarine waters for use in primary and secondary contact recreation, and for propagation and preservation of desirable species.
- 3.2.3 Class SC:
  - (A) Usages and Description: Coastal waters intended ...for use in propagation and preservation of desirable species.
- 3.2.4 Class SD:
  - (A) Usages and Description: Surface waters intended for ... propagation and preservation of desirable species as well as primary and secondary contact recreation...
- 3.2.5 Class SE:
  - (A) Usages and Description: Surface waters and wetlands of exceptional ecological value, whose existing characteristics should not be altered in order to preserve the existing natural phenomena.

U.S. Virgin Islands

SOURCE: T.12 Subchapter 186. Water Quality Standards for Coastal Waters of the Virgin Islands Ch. 7 WATER POLLUTION CONTROL §186-2 - 186.4: http://www.epa.gov/ost/standards/wqslibrary

§ 186-2. Class A

(a) Best usage of waters: Preservation of natural phenomena requiring special conditions, such as the Natural Barrier Reef at Buck Island, St. Croix and the Under Water Trail at Trunk Bay, St. John.

(b) Quality criteria: Existing natural conditions shall not be changed.

§ 186-3. Class B

(a) Best usage of waters: For propagation of desirable species of marine life...

§ 186-4. Class C

(a) Best usage of waters: For the propagation of desirable species of marine life...

TRIBES

Confederated Tribes of the Colville Reservation

SOURCE: Source: 40 CFR 131.35, July 1, 2000 edition:
http://www.epa.gov/ost/standards/wqslibrary/tribes/131.35.pdf

<u>§ 131.35</u>

(f) General water use and criteria classes. The following criteria shall apply to the various classes of surface waters on the Colville Indian Reservation:

(1) *Class I (Extraordinary)—(i) Designated uses.* The designated uses include, but are not limited to, the following:

(C) Fish and shellfish: Salmonid migration, rearing, spawning, and harvesting; other fish migration, rearing, spawning, and harvesting.

(D) Wildlife habitat.

(2) *Class II (Excellent)*—(i) *Designated uses.* The designated uses include but are not limited to, the following:

(C) Fish and shellfish: Salmonid migration, rearing, spawning, and harvesting; other fish migration, rearing, spawning, and harvesting; crayfish rearing, spawning, and harvesting.

(D) Wildlife habitat.

(3) *Class III (Good)*—(i) *Designated uses.* The designated uses include but are not limited to, the following:

(C) Fish and shellfish: Salmonid migration, rearing, spawning, and harvesting; other fish migration, rearing, spawning, and harvesting; crayfish rearing, spawning, and harvesting.

(D) Wildlife habitat.

(4) *Class IV (Fair)*—(i) *Designated uses.* The designated uses include but are not limited to, the following:

(C) Fish (salmonid and other fish migration).

Nez Perce Tribe

WQS under development. Currently collecting chemical and physical habitat data to eventually establish WQS for the reservation area. No website available.

Oneida Nation of Wisconsin

(WQS were federally approved in 1996 and then rescinded after a lawsuit.)
SOURCE: Oneida Nation Water Quality Standards, hard copy provided by contact

<u>Article VII. Narrative Criteria</u>

7-1. Narrative criteria shall be used to guide water management decisions and activities that affect the Waters of the Reservation, and to protect and enhance water quality. The following narrative criteria shall apply to all Waters of the Reservations provided, however, where more stringent criteria exist, the stricter standards shall supersede.

7-2. All Waters of the Reservation shall be free from:

a. pollutants in quantities that, either alone or as a result of interaction with other pollutants, cause any designated use to become impaired.

b. pollutants in quantities that produce or contribute to the production of nuisance aquatic life.

c. pollutants in quantities that produce objectionable color, odor, taste or turbidity.

d. hazardous substances, toxic corrosive, nonconventional materials concentrations, or other deleterious substances, chemicals, and materials, which alone or in combination with other substances or in combination with other components of discharges, or their breakdown products, are acutely or chronically toxic, carcinogenic, teratogenic, and injure, or bioaccumulate, biomagnify, bioconcentrate, or produce adverse physiological responses in human beings and/or fish and aquatic life, or which interfere directly or indirectly with designated, existing, or other uses.

e. exotic nuisance species, e.g. purple loosestrife, zebra mussels, etc.

f. toxic pollutants in quantities that result bioaccumulation in aquatic organisms leading to toxicity to consumers of the aquatic organisms.

g. excess nutrients that may cause a condition harmful to human health, decrease fish habitat, cause nuisance aquatic growths, or that in any way impair designated uses. Nitrogen and phosphorous concentrations shall not exceed the levels stated in Article XIII of this document.

h. microorganisms at levels that make recreation in and on Reservation waters unsafe.

i. floating debris, oil, scum and other floating materials as a result of human activity in amounts sufficient to be unsightly, cause degradation or impair designated uses.

j. materials entering the waters as a result of human activity producing color, odor, taste or other conditions in amounts sufficient to be unsightly, cause degradation or in any way impair designated uses.

k. substances other than from natural causes that may settle to form objectionable deposits or adversely impact designated uses.

l. contaminants, from other than natural causes, that may settle or remain suspended that have a deleterious effect on the aquatic life or that will significantly alter the physical or chemical properties of the water body or that in any way impairs designated uses.

7-3. All wetlands shall be protected to maintain and restore their natural physical, biological, and chemical characteristics, including substrate, vegetative and hydrological conditions necessary to support natural amounts of native vegetation, maintain natural hydrodynamics and maintain natural water temperature variations that are necessary to protect and support all existing and designated uses.

7-4. All naturally occuring biological communities and the habitat needed to support them shall be maintained and protected in all waters and wetlands of the Reservation at all times.

7-5. Concentrations of radioactive materials shall not exceed concentrations caused by local naturally occuring materials.

7-6. All Waters of the Reservation shall be free from unauthorized discharges at all places at all times.

7-7. Any activity that allows storm discharges or base flow conditions to significantly degrade stream morphology or result in a waterway's inability to maintain existing aquatic life shall be prohibited. Cumulative impacts of any such activity shall be considered.

7-8. Waters contained in intermittent and ephemeral streams shall meet all water quality criteria applicable to any perennial streams to which they are tributaries.

7-9. All criteria should be met at all times and all locations, including low flow rates. However, allowance may be made for mixing, on a case by case basis, where compliance with the chronic criteria is not technically feasible. In such cases mixing zones shall be established consistent with 40 C. F. R. Pt. 132, Appendix F, Procedure 3. In no case will mixing be permitted in biologically or recreationally sensitive areas. In no case may the acute criteria be exceeded.

7-10. Natural native biological/ecological communities associated with Waters of the Reservation and their biotic and abiotic components and relationships shall be protected.

7-11. Waters of the Reservation shall not be degraded below their present water quality nor shall new or increased discharges be permitted unless it is determined by the Environmental Department that the accompanying water quality degradation from such discharges will provide unique benefits in accordance with Section 6-7 and Section 6-8. All existing and designated uses shall be protected at all times.

7-12. Any activities that degrade the aesthetic quality, stability and/or ecological integrity of the Waters of the Reservation shall be prohibited unless authorized in a manner consistent with the water quality standards contained herein.

7-13. The discharge of toxicants into the Waters of Reservations that are known or found to be synergistic with other pollutants shall be addresses on a case by case basis.

7-14. For substances where numeric criteria have not yet been adopted by the Oneida Nation, the numeric criteria and methodologies in 40 C. F. R. Pt. 132, Appendices A-D shall be used and are incorporated into these standards by reference.

Article IX. Designated Uses

9-1. All of the following categories of designated uses shall apply to all Waters of the reservation except where noted.

9-2. *Public Water Supply*. Waters specifically designated as suitable or intended to become suitable for providing an adequate supply of drinking water for the continuation of the health, safety and welfare of the Nation's members and residents of the Oneida Reservation.

9-3. *Wildlife.* All surface waters capable of providing a water supply and vegetative habitat for the support and propagation of all wildlife located within the exterior boundaries of the Oneida Nation Reservation.

9-4. *Aquatic Life.* Waters of the Reservation shall be categorized as one the following:

1. *Cold Water Ecosystems*: Waters of the Reservation where water temperature, habitat and other characteristics are suitable or intended to be suitable for the support and propagation of cold water fish and other aquatic life, or serving as a spawning or nursery area for cold water fish species. Examples of cold water fish include brook trout and rainbow trout. Trout Creek, Lancaster Brook and associated tributaries are hereby designated as cold water ecosystems.
2. *Warm Water Ecosystems:* Waters of the Reservation where water temperature, habitat and other characteristics are suitable or intended to be suitable for support and propagation of warm water fish and other aquatic life, or serving as a spawning or nursery area for warm water fish species. Examples of warm water fish species include large mouth bass and bluegills. All Waters of the Reservation are hereby designated as warm water ecosystems except those mentioned in Section 9-4(a).

9-5. *Subsistence Fishing.* Water of the Reservation where spearing, netting or bow fishing is allowed as stated in the Oneida Conservation Hunting and Fishing Law.

9-6. *Cultural.* Waters that are suitable or intended to be suitable for traditional, cultural, historic and modern ceremonial uses which uses which may include, but are not limited to the harvest and use of medical plants and wildlife associated with aquatic, wetland and riparian habitats; cultural educational uses including but not limited to ethnohydrological learning experiences that are passed from one generation to the next regarding the harvest of plants, fish, and animals; subsistence fishing; and activities that may require the protection of sensitive and valuable aquatic plant and wildlife, and aquatic, wetland and riparian habitat.

9-7. Recreation.

1. *Primary Contact Recreational:* Waters that are suitable for activities involving prolonged human contact where the risk of ingesting small quantities of water is likely; examples of this type of activity include, but are not limited to, swimming, tubing, rafting, skin diving, etc. The Norbert Hill Pond is hereby designated as a primary contact recreational area.
2. *Secondary Contact Recreational:* Waters that are suitable for activities in which human contact with the water may, but need not occur and in which the probability of ingesting raw water is unlikely. Examples of this type of activity include, but are not limited to, fishing, wading, boating, etc. All Waters of the Reservation are hereby designated as secondary contact recreational

areas except for those mentioned in Section 9-5(a).

9-8. *Agricultural.* Waters that are suitable for crop irrigation and livestock ingestion.

9-9. *Navigational.* Waters that are suitable for navigation in and on the water.

9-10. *Industrial.* Waters that are suitable for manufacturing and/or production enterprises.

Passamaquoddy Tribe, Pleasant Point Reservation

[WQS currently awaiting approval by EPA Region 9]

Pyramid Lake Paiute Tribe

[WQS currently awaiting approval by EPA Region 9]

INTERSTATE COMMISSIONS

Delaware River Basin Commission

SOURCE: Delaware River Basin Commission West Trenton, New Jersey. Administrative Manual — Part III, Water Quality Regulations, Revised to Include Amendments Through October 23, 1996, Article 3 Water Quality Standards for the Delaware River Basin [Comprehensive Plan, Section X]:
http://www.state.nj.us/drbc/regs/wq-regs.pdf

3.10 BASINWIDE SURFACE WATER QUALITY STANDARDS

3.10.2 Water Uses

B. Uses to be Protected. The quality of Basin waters, except intermittent streams, shall be maintained in a safe and satisfactory condition of the following uses:

2. wildlife, fish and other aquatic life;

3.10.3 Stream Quality Objectives

A. Antidegradation of Waters

2. Special Protection Waters. It is the policy of the Commission that there be no measurable change in existing water quality except towards natural conditions in waters considered by the Commission to have exceptionally high scenic, recreational, ecological, and/or water supply values. Waters with exceptional values could be classified by the Commission as Outstanding Basin Waters or Significant Resource Waters.

In determining waters suitable for classification as Special Protection Waters, the Commission will consider nomination petitions from local, state and federal agencies and governing bodies, and the public for waters potentially meeting the definition of Outstanding Basin Waters and Significant Resource Waters as described in 3.10.3A.2.a.

The following policies shall apply to waters classified by the Commission as Outstanding Basin Waters or Significant Resource Waters and their drainage areas:

a. Definitions

1) "Outstanding Basin Waters" are interstate and contiguous intrastate waters that are contained within the established boundaries of national parks; national wild, scenic and recreational rivers systems; and/or national wildlife refuges that are classified by the Commission under Subsection 2.g.1). hereof as having exceptionally high scenic,

recreational, and ecological values that require special protection.

2) "Significant Resource Waters" are interstate waters classified by the Commission under Subsection 2.g.2). hereof as having exceptionally high scenic, recreational, ecological, and/or water supply uses that require special protection.

3) "Existing Water Quality" is defined as the actual concentration of a water constituent at an in-stream site or sites, as determined through field measurements and laboratory analysis of data collected over a time period determined by the Commission to adequately reflect the natural range of the hydraulic and climatologic factors which affect water quality. Existing water quality shall be described in terms of (a) an annual or seasonal mean of the available water quality data, (b) two-tailed upper and lower 95 percent confidence limits around the mean, and (c) the 10th and 90th percentiles of the data set from which the mean was calculated. Where available data are insufficient to determine existing water quality, existing water quality may be estimated from data obtained from sites within the same ecoregion or from best scientific judgment.

4) "Measurable Change" is defined as an actual or estimated change in a mean (annual or seasonal) in-stream pollutant concentration that is outside the range of the two-tailed upper and lower 95 percent confidence limits that define existing water quality. In the absence of adequate available data, background concentrations will be assumed to be zero and "measurable change" will be based on in-stream concentrations greater than the detection limit for each parameter, based on the lowest limit of the most sensitive technique specified in 40 CFR Part 136.

Excerpted from Table 1: Definition of Existing Water Quality in the Delaware River Between Hancock, NY and the Delaware Water Gap:

Part A: Upper Delaware Scenic & Recreational River

Parameter	Mean	95 Percent Confidence Limits of Mean	10^{th} and 90^{th} Percentiles	Additional
....	....	....	...	....
Biocriteria: Shannon-Weiner	3.6	3.4 to 3.8	2.7 and 4.3	May - Sept; reachwide
Biocriteria: Equitability	0.8	0.7 to 0.9	0.5 and 1.1	May - Sept; reachwide
Biocriteria:: EPT	15.5	13.8 to 17.2	8.0 and 24.0	May - Sept; reachwide

Part B: Delaware River from Millrift through the Delaware Water Gap Including the Middle Delaware Scenic and Recreational River

Parameter	Mean	95 Percent Confidence Limits of Mean	10^{th} and 90^{th} Percentiles	Additional
....	....	....	...	....
Biocriteria: Shannon-Weiner	3.6	3.4 to 3.7	3.2 and4.1	May - Sept; reachwide
Biocriteria: Equitability	0.8	0.7 to 0.9	0.5 and 1.1	May - Sept; reachwide

Biocriteria: EPT	13.9	12.8 to 15.1	8.0 and 20.0	May - Sept; reachwide

Ohio River Valley Water Sanitation Commission

SOURCE: Ohio River Valley Water Sanitation Commission Pollution Control Standards for discharges to the Ohio River, 2000 Revision: http://www.orsanco.org/watqual/standards/PollutionControl.pdf and http://www.orsanco.org/

II. Definitions

B. "Biological integrity" means the ability of an aquatic ecosystem to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to those best attainable given ecoregional attributes and the modified habitat types of the river.

H. "Early Life Stages" of fish means the pre-hatch embryonic period, the post-hatch free embryo or yolk-sac fry, and the larval period, during which the organism feeds. Juvenile fish, which are anatomically rather similar to adults, are not considered an early life stage.

R. "Representative Aquatic Species" means those species of aquatic life whose protection and propagation will assure the sustained presence of a balanced indigenous community. Such species are representative in the sense that maintenance of suitable water quality conditions will assure the overall protection and sustain propagation of the balanced, indigenous community.

IV. Water Quality Criteria

B. Aquatic Life Protection. To provide protection of warm water aquatic life habitats, the following criteria shall be met outside the mixing zone:
   1. BIOLOGICAL: The biological integrity of the Ohio River shall be protected and preserved.

5. LIST OF ACRONYMS AND DEFINITION OF TERMS

5.1 Acronyms

AL	Aquatic Life
ALU	Aquatic Life Use
ALUS	Aquatic Life Use Support
ANOVA	Analysis of Variance
BMP	Best Management Practice
CALM	Consolidated Assessment Listing Methodology
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CWA	Clean Water Act
DO	Dissolved Oxygen
DQO	Data Quality Objectives
EDAS	Ecological Data Application System
EMAP	Environmental Monitoring and Assessment Program
EPT	Ephemeroptera, Plecoptera, Trichoptera
FTE	Full Time Employees
GIS	Geographic Information System
GPS	Global Positioning System
HBI	Hilsenhoff Biotic Index
IBI	Index of Biological/Biotic Integrity
MACS	Mid-Atlantic Coastal Streams
NAWQA	National Water Quality Assessment Program
NCBI	North Carolina Biotic Index
NHD	National Hydrography Database
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
PAHs	Polycyclic Aromatic Hydrocarbons
PCBs	Polychlorinated Biphenyls
POTW	Publicly Owned Treatment Works
QA	Quality Assurance

QAPP	Quality Assurance Project Plan
QC	Quality Control
QHEI	Qualitative Habitat Evaluation Index
QMP	Quality Management Plan
RBP	Rapid Bioassessment Protocols
RCRA	Resource Conservation and Recovery Act
REMAP	Regional Environmental Monitoring and Assessment Program
RIVPACS	River Invertebrate Prediction and Classification System
RF3	River Reach File 3
SOP	Standard Operating Procedures
STORET	Data Storage and Retrieval System
TMDL	Total Maximum Daily Load
UAA	Use Attainability Analyses
USEPA	United States Environmental Protection Agency
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WQ	Water Quality
WQS	Water Quality Standards
WWTP	Waste Water Treatment Plant

5.2 Definition of Terms

Accuracy	the degree of agreement between an observed value and an accepted reference value.
Ambient Monitoring	sampling and evaluation of receiving waters not necessarily associated with episodic perturbations.
Analysis of Variance	a general statistical method for comparing the mean response to different treatments using the ratio of among-group to between-group variance. The method has also been applied to estimating precision and quantifying sources of variance.
Antidegradation Statement	statement that protects existing designated uses and prevents high-quality waterbodies from deteriorating below the water quality necessary to maintain existing or anticipated designated beneficial uses.

Aquatic Assemblage	an association of interacting populations of organisms in a given waterbody, for example, fish assemblage or a benthic macroinvertebrate assemblage.
Aquatic Community	an association of interacting assemblages in a given waterbody, the biotic component of an ecosystem.
Aquatic Life Use	a beneficial use designation in which the waterbody provides suitable habitat for survival and reproduction of desirable fish, shellfish, and other aquatic organisms; classifications specified in state water quality standards relating to the level of protection afforded to the resident biological community by the state agency.
Beneficial Uses	desirable uses that water quality should support. Examples are drinking water supply, primary contact recreation (such as swimming), and aquatic life support.
Benthic Macroinvertebrates	animals without backbones, living in or on the sediments, of a size large enough to be seen by the unaided eye and which can be retained by a U.S. Standard No. 30 sieve (28 meshes per inch, 0.595 mm openings). Also referred to as benthos, infauna, or macrobenthos.
Benthos	see Benthic Macroinvertebrates.
Best Management Practice	an engineered structure or management activity, or combination of these, that eliminates or reduces an adverse environmental effect of a pollutant.
Bias	the systematic or persistent distortion of a measurement process which deprives the result of representativeness (i.e., the expected sample measurement is different than the sample's true value).
Biological Assessment or Bioassessment	an evaluation of the biological condition of a waterbody using surveys of the structure and function of the community of resident biota.
Biological Criteria or Biocriteria	narrative expressions or numerical values that describe the reference biological condition (structure and function) of aquatic communities inhabiting waters of a given designated aquatic life use. Biocriteria are based on the numbers and kinds of organisms present and are regulatory-based biological measurements.
Biological Diversity or Biodiversity	refers to the variety and variability among living organisms and the ecological complexes in which they occur. Diversity can be defined as the number of different items and their relative frequencies. For biological diversity, these items are organized at many levels, ranging from complete ecosystems to the biochemical structures that are the molecular basis of heredity. Thus, the term encompasses different ecosystems, species, and genes.
Biological Indicator or Bioindicator	an organism, species, assemblage, or community characteristic of a particular habitat, or indicative of a particular set of environmental conditions.

Biological Integrity	the ability of an aquatic ecosystem to support and maintain a balanced, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitats within a region.
Biological Monitoring or Biomonitoring	use of a biological entity as a detector and its response as a measure to determine environmental conditions. Ambient biological surveys and toxicity tests are common biological monitoring methods.
Biological Survey or Biosurvey	collecting, processing, and analyzing a representative portion of the resident aquatic community to determine its structural and/or functional characteristics.
Bioregion	any geographical region characterized by a distinctive flora and/or fauna.
Clean Water Act	an act passed by the U.S. Congress to control water pollution (formerly referred to as the Federal Water Pollution Control Act of 1972). Public Law 92-500, as amended. 33 U.S.C. 1251 et seq.
Clean Water Act 303(d)	This section of the Act requires States, territories, and authorized tribes to develop lists of impaired waters for which water quality standards are not being met, even after point sources of pollution have installed the minimum required levels of pollution control technology. The law requires that these jurisdictions establish priority rankings for waters on the lists and develop TMDLs for these waters. States, territories, and authorized tribes are to submit their list of waters on April 1 in every even-numbered year.
Clean Water Act 305(b)	biennial reporting requires description of the quality of the Nation's surface waters, evaluation of progress made in maintaining and restoring water quality, and description of the extent of remaining problems.
Criteria	limits on a particular pollutant or condition of a waterbody presumed to support or protect the designated use or uses of a waterbody. Criteria may be narrative or numeric.
Data Quality Objectives	qualitative and quantitative statements developed by data users to specify the quality of data needed to support specific decisions; statements about the level of uncertainty that a decision maker is willing to accept in data used to support a particular decision.
Data Storage and Retrieval System (STORET)	EPA's largest computerized environmental data system; repository for biological, chemical, and physical data used by state environmental agencies, EPA and other federal agencies, universities, private citizens, and many others.
Designated Use	classification specified in water quality standards for each waterbody or segment describing the level of protection from perturbation afforded by the regulatory programs. The designated aquatic life uses established by the state or authorized tribes set forth the goals for the restoration and/or baseline conditions for maintenance and prevention from further degradation of the aquatic life in specific waterbodies.

Ecological Data Application System (EDAS)	relational database system that allows the user to input, compile, and analyze complex ecological data to make assessments of ecosystem condition.
Ecological Integrity	the condition of an unimpaired ecosystem as measured by combined chemical, physical (including habitat), and biological attributes.
Ecoregion	a relatively homogeneous ecological area defined by similarity of climate, landform, soil, potential natural vegetation, hydrology, or other ecologically relevant variables.
Environmental Monitoring and Assessment Program	a US EPA research program to develop the tools necessary to monitor and assess the status and trends of national ecological resources. EMAP's goal is to develop the scientific understanding for translating environmental monitoring data from multiple spatial and temporal scales into assessments of ecological condition and forecasts of the future risks to the sustainability of our natural resources.
Eutrophication	enrichment of a waterbody with nutrients, resulting in high levels of primary production, often leading to depletion of dissolved oxygen.
Habitat	a place where the physical and biological elements of ecosystems provide a suitable environment including the food, cover, and space resources needed for plant and animal livelihood.
Historical Data	data sets from previous studies, which can range from handwritten field notes to published journal articles.
Index of Biological/Biotic Integrity	an integrative expression of site condition across multiple metrics. An index of biological integrity is often composed of at least seven metrics.
Least Disturbed/Impaired	the physical, chemical and biological conditions of a site, reach, segment, or water body that has the least amount of human disturbance in comparison to others within the water body, class, region, or basin. Least disturbed conditions change over time as land use and management practices change and, therefore, are not a "target" or upper bound of water quality potential (Best available current condition).
Macroinvertebrates	see Benthic Macroinvertebrates.
Macrophytes	large aquatic plants that may be rooted, unrooted, vascular, or algiform (such as kelp); includes submerged aquatic vegetation, emergent aquatic vegetation, and floating aquatic vegetation.
Metric	a calculated term or enumeration representing some aspect of biological assemblage, function, or other measurable aspect and is a characteristic of the biota that changes in some predictable way with increased human influence.

Minimally Disturbed/Impaired	the physical, chemical and biological conditions of a site, reach, segment, or water body in the absence of significant, or with minimal, human disturbance. Historical information or models may be used to help describe the minimally disturbed condition. Minimally disturbed conditions change little over time mostly due to natural processes and, therefore, provide a "target" or upper bound of water quality potential (Best potential condition).
Multimetric Index	an index that combines indicators, or metrics, into a single index value. Each metric is tested and calibrated to a scale and transformed into a unitless score prior to being aggregated into a multimetric index. Both the index, and metrics, are useful in assessing and diagnosing ecological condition. See Index of Biotic Integrity.
Multivariate Analysis	statistical methods (e.g. ordination or discriminant analysis) for analyzing physical and biological community data using multiple variables.
Narrative Biocriteria	general statements of attainable or attained conditions of biological integrity and water quality for a given designated aquatic life use.
Nonpoint Source Pollution	pollution that occurs when rainfall, snowmelt, or irrigation water runs over land or through the ground, picks up pollutants, and deposits them into rivers, lakes, and coastal waters or introduces them into ground water.
Numeric Biocriteria	specific quantitative measures (metrics) of desired level of biological condition.
Perennial Streams	permanently inundated surface stream courses. Surface water flows throughout the year except in years of drought.
Periphyton	a broad organismal assemblage composed of attached algae, bacteria, their secretions, associated detritus, and various species of microinvertebrates.
Point Source	an origin of pollutant discharge that is known and specific, usually thought of as effluent from the end of a pipe.
Precision	the degree of variation among individual measurements of the same property, usually obtained under similar conditions.
Quality Assurance	includes quality control functions and involves a totally integrated program for ensuring the reliability of monitoring and measurement data; the process of management review and oversight at the planning, implementation, and completion stages of environmental data collection activities. Its goal is to assure that the data provided are of the quality needed and claimed.

Quality Assurance Plan	a written document that describes the quality assurance procedures, quality control requirements, and other technical activities that must be implemented to ensure that the results of the project or task to be performed will meet project requirements; contains several important guidelines for a program to follow such as objectives and milestones for achieving those objectives, lines of responsibility, accountability of staff for meeting data quality objectives, and accountability for ensuring precision, accuracy, completeness of the data collection activities, and documentation of the sample custody process.
Quality Control	refers to the routine application of procedures for obtaining prescribed standards of performance in the monitoring and measurements process; focuses on the detailed technical activities needed to achieve data of the quality specified by data quality objectives. Quality control is implemented at the bench or field level.
Quality Management Plan	a document that describes an organization's quality system. It identifies the organizational structure, policy and procedures, functional responsibilities of management and staff, lines of authority, and its processes for planning, implementing, documenting, and assessing all activities conducted under the organization's quality system.
Rapid Bioassessment Protocols	cost-effective techniques used to survey and evaluate the aquatic community to detect aquatic life impairments and their relative severity.
Reference Condition	the set of selected measurements or conditions of unimpaired or minimally impaired waterbodies characteristic of a waterbody type in a region.
Reference Site	a specific locality on a waterbody which is unimpaired or minimally impaired and is representative of the expected ecological integrity of other localities on the same waterbody or nearby waterbodies.
Regional Environmental Monitoring and Assessment Program	a US EPA program initiated to assess the applicability of the EMAP approach to answer questions about ecological conditions at regional and local scales. REMAP conducts projects at smaller geographic scales and in shorter time frames than the national EMAP program.
Regional Reference Condition	a description of the chemical, physical, or biological condition based on an aggregation of data from minimally impaired sites that are representative of a waterbody type in an ecoregion, subecoregion, watershed, or political unit.
River Invertebrate Prediction and Classification System	a predictive method developed for use in the United Kingdom to assess water quality using a comparison of observed biological species distributions to those expected to occur based on a model derived from reference data.

River Reach File 3	a national database of 1:100,000 scale Digital Line Graph (DLG) hydrography data in a processed, edgematched, hydrologically networked format. RF3 data are a "directed network" dataset meaning that all stream segments, or reaches, are ordered in a uniform direction.
Sensitivity	capability of a method or instrument to discriminate between measurement responses of a variable of interest.
Standard Operating Procedures	a set of written instructions that document a routine or repetitive activity. SOPs describe both technical and administrative operational elements of an organization that would be managed under a Quality Assurance Project Plan and under an organization's Quality Management Plan.
Stressors	physical, chemical, and biological factors that adversely affect aquatic organisms.
Taxa	a grouping of organisms given a formal taxonomic name such as species, genus, family, etc.
Total Maximum Daily Load	calculation of the maximum amount of a pollutant a waterbody can receive and still meet water quality standards and an allocation of that amount to the pollutant's source.
Use Attainability Analysis	structured scientific assessment of the physical, chemical, biological and economic factors affecting attainment of the uses of waterbodies.
Water Quality Standards	a law or regulation that consists of the beneficial designated use or uses of a waterbody, the narrative or numerical water quality criteria (including biocriteria) that are necessary to protect the use or uses of that particular waterbody, and an antidegradation statement.
Water Resource Management (Non-Regulatory)	decisions on management activities relevant to a water resource such as problem identification, need for and placement of best management practices, pollution abatement actions, and effectiveness of program activity.
Zooplankton	refers to animals which are unable to maintain their position or distribution independent of the movement of water or air.

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6.2 Additional Resources

More information and guidance on biological assessments and criteria can be found in the documents and websites listed below.

Federal Water Pollution Control Act, as amended by the Clean Water Act of 1977: [Commonly Referred to as Clean Water Act] [Enacted by Public Law 92-500, October 18, 1972, 86 Stat. 816; 33 U.S.C. 1251 et seq.; Amended by PL 93-207, December 28, 1973, and PL 93-243, January 2, 1974; PL 93-592, January 2, 1975; PL 94-238, March 23, 1976; PL 94-273, April 21, 1976; PL 94-558, October 19, 1976; PL 95-217, December 28, 1977; PL 95-576, November 2, 1978; PL 96-148, December 16, 1979; PL 96-478, PL 96-483, October 21, 1980; PL 96-510, December 11, 1980; PL 96-561, December 22, 1980; PL 97-35, August 13, 1981; PL 97-117, December 29, 1981; PL 97-164, April 2, 1982; PL 97-440, January 8, 1983; Amended by PL 100-4, February 4, 1987]

Intergovernmental Task Force on Monitoring Water Quality [ITFM]. 1995. *The strategy for improving water-quality monitoring in the United States: Final report of the Intergovernmental Task Force on Monitoring Water Quality. Technical Appendixes.* U.S. Geological Survey, Reston, VA.

USEPA 1983. *Technical support manual: Waterbody surveys and assessments for conducting use attainability analyses*. U.S. Environmental Protection Agency, Office of Water Regulations and Standards, Criteria and Standards Division, Washington, DC.

USEPA. 1989. *Regionalization as a tool for managing environmental resources*. EPA/600/3-89/060. U.S. Environmental Protection Agency, Environmental Research Laboratory, Corvallis, OR.

USEPA. 1989. *Standard operating procedures for the collection of and laboratory identification of freshwater benthic macroinvertebrates*. U.S. Environmental Protection Agency, Region 5, Chicago, IL.

USEPA. 1990. *Macroinvertebrate field and laboratory methods for evaluating the biological integrity of surface waters*. EPA/600/4-90/030. U.S. Environmental Agency, Office of Water, Washington, DC.

USEPA. 1991. *Biological criteria: Guide to technical literature*. EPA/5-91-004. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

USEPA. 1991. *Biological criteria: Research and regulation – Proceedings of a symposium*. EPA-440/5-91-005. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

USEPA. 1991. *Biological criteria: State development and implementation efforts*. EPA-440/5-91-003. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

USEPA. 1991. Transmittal of Final Policy on Biological Assessments and Criteria (Memorandum). From Tudor T. Davies, Director, Office of Science and Technology to Waste Management Division Directors, Regions I-X. June 19, 1991. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

USEPA. 1994. *Water Quality Standards Handbook, Second Edition*. EPA 823-B-94-005. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

USEPA. 1995. *Generic quality assurance project plan guidance for programs using community level biological assessment in wadeable streams and rivers*. EPA 841-B-95-004. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

USEPA. 1996. *Bioindicators for assessing ecological integrity of prairie wetlands*. EPA/600/R-96/082. U.S. Environmental Protection Agency, Environmental Research Laboratory, Corvallis, OR.

USEPA. 1996. *Biological assessment methods, biocriteria, and biological indicators. Bibliography of selected technical, policy, and regulatory literature.* EPA 230-B-96-001. U.S. Environmental Protection Agency, Office of Policy, Planning and Evaluation, Washington, DC.

USEPA. 1996. *The volunteer monitor's guide to quality assurance project plans*. EPA 841-B-96-003. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

USEPA. 1997. *Volunteer stream monitoring: A methods manual*. EPA 841-B-97-003. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

USEPA. 1998. *Development of biological criteria for coral reef ecosystem assessment*. U.S. Environmental Protection Agency, Office of Science and Technology, Health and Ecological Criteria Division, Washington, DC.

USEPA. 1998. *Wetland bioassessment fact sheets*. EPA 843-F-98-001. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

USEPA. 2000. *Stressor identification guidance document*. EPA 822-B-00-025. U.S. Environmental Protection Agency, Offices of Water and Research and Development, Washington, DC.

USEPA. 2002. *Biological assessment and criteria: Crucial components of water quality programs*. EPA 822-F-02-006. U.S. Environmental Agency, Office of Water, Washington, DC.

USEPA Office of Environmental Information, Biological Indicators of Watershed Health website: http://www.epa.gov/bioindicators/index.html

USEPA Office of Science and Technology, Bioassessment and Biocriteria website: http://www.epa.gov/ost/biocriteria/index.html

USEPA Office of Water, Monitoring and Assessing Water Quality, Biological Assessment website: http://www.epa.gov/owow/monitoring/bioassess.html

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APPENDIX A.

BIOASSESSMENT PROGRAMS FOR STREAMS AND WADEABLE RIVERS (2001)

Appendix A. Bioassessment programs for streams and wadeable rivers (2001)

Entity	Stream/river miles		Number of miles assessed using biology				Assemblages assessed				Habitat assessment	Reference site determination	Characterization of regional reference sites	Data analysis tools & methods	Impairment thresholds	Bioassessment uses		Biocriteria in WQS		Other waterbody types with biological programs
Name	Total miles	Perennial miles	Total miles assessed	fully supporting for 305(b)	partially/non-supporting for 305(b)	listed for 303(d)	Benthos	Fish	Periphyton	Other	VB = visual based; QM = quantitative measurements; HY = hydrogeomorphology; O = other	SS = site specific; PW = paired watersheds; R =regional; PJ = professional judgment; O = other	HC = historical conditions; LD = least disturbed sites; GR = gradient response; PJ = professional judgment; MD = minimally disturbed; O = other	TG = tables & graphs; PA = parametric ANOVAs; MV = multivariate; BM = biological metrics; DG = disturbance gradients; O = other	MM = multimetric; MV = multivariate; CDF = cumulative distribution function; O = other	Water resource management	Aquatic Life Use Support (ALUS) in 305(b) reporting	Narrative	Numeric	LR = large rivers; LK = lakes; RES = reservoirs; ENC = estuaries/ near coastal marine; WL = wetlands
STATES																				
Alabama	77,274	47,077	7,103.5	5,124.4	1,979.1	1,979.1	Y	Y	N	Y	VB	R	LD	TG, BM	MM - O	Y	Y	N	N	LR, WL
Alaska	>3 million	unknown	150 watersheds	140 watersheds	10 watersheds	10 watersheds	Y	N	UD	N	VB, HY	SS, PJ	MD	TG, BM	MM - 1^{st} quartile from the 95^{th} %tile	Y	UD	N	N	LR, LK, ENC, WL
Arizona	127,505	4,980	0	n/a	n/a	n/a	Y	N	Y	N	VB, QM, HY	R	LD, PJ, MD	BM	MM - 25^{th} %tile of ref. pop.	Y	N	UD	N	RES (UD)
Arkansas	87,617	28,408	245 stream segments	n/a	n/a	n/a	Y	Y	N	N	VB, QM, HY, O	SS, PW, R, PJ, O	HC, LD, PJ	TG, MV, BM, DG	MM - O	Y	N	Y	N	LR, LK, RES, WL
California	211,513	64,438	unknown	unknown	unknown	unknown	Y	N	N	N	VB	PJ, O	LD	PA, MV, BM	MV - UD	Y	UD	Y	N	LR, LK, ENC (limited)
Colorado	107,403	31,415	n/a	n/a	n/a	85.1	Y	Y	**UD**	N	VB, HY, O	SS, PJ	HC, LD, PJ, O	TG, BM	MM - UD	Y	N	UD	N	LR, LK, RES

n/a = not applicable; pop. = population; ref. = reference; UD = under development; WQS = water quality standards; – = none or information not reported

Entity	Stream/river miles		Number of miles assessed using biology				Assemblages assessed				Habitat assessment	Reference site determination	Characterization of regional reference sites	Data analysis tools & methods	Impairment thresholds	Bioassessment uses				Other waterbody types with biological programs
																		Biocriteria in WQS		
Name	Total miles	Perennial miles	Total miles assessed	fully supporting for 305(b)	partially/non-supporting for 305(b)	listed for 303(d)	Benthos	Fish	Periphyton	Other	VB = visual based; QM = quantitative measurements; HY = hydrogeomorphology; O = other	SS = site specific; PW = paired watersheds; R =regional; PJ = professional judgment; O = other	HC = historical conditions; LD = least disturbed sites; GR = gradient response; PJ = professional judgment; MD = minimally disturbed; O = other	TG = tables & graphs; PA = parametric ANOVAs; MV = multivariate; BM = biological metrics; DG = disturbance gradients; O = other	MM = multimetric; MV = multivariate; CDF = cumulative distribution function; O = other	Water resource management	Aquatic Life Use Support (ALUS) in 305(b) reporting	Narrative	Numeric	LR = large rivers; LK = lakes; RES = reservoirs; ENC = estuaries/ near coastal marine; WL = wetlands
Connecticut	5,830	5,484	961	764	195	n/a	Y	Y	Y	Y	VB	SS, O	LD	TG, BM	MM - O	Y	Y	Y	N	ENC
Delaware	2,506	1,778	2,506	741	1,765	1,173	Y	N	N	N	VB	R, PJ	LD	BM	MM - 67th %tile of ref. pop.	Y	N	N	UD	WL
District of Columbia	39	–	39	0	39	unknown	Y	Y	N	Y	HY	PJ	–	BM	–	Y	Y	Y	N	LR, WL
Florida	51,858	22,993	4,795	4,365	430	430	Y	N	Y	Y	VB	R, PJ	LD, GR	TG, BM, DG	MM - quadra-section of best score	Y	Y	Y	Y	LR, LK, RES, ENC, WL
Georgia	70,150	44,056	1,416	477	939	–	Y	Y	N	N	VB, O	R	LD	TG, BM	MM - UD, MV - UD	Y	Y	Y	N	LR
Hawai`i	249	249	15	5	10	10	UD	Y	N	N	VB, O	R	LD	TG, BM	MM - UD	Y	UD	UD	UD	–
Idaho	96,200	49,500	16,742	8,434	8,312	8,312	Y	Y	Y	N	VB, O	R, PJ	LD, PJ, MD	TG, PA, MV, BM, DG	MM - 25th %tile of ref. pop.	Y	Y	Y	N	LK, RES
Illinois	86,021	30,246	15,304	9,498	5,806	unknown	Y	Y	N	N	VB, QM	SS, O	HC, LD, PJ	TG, PA, MV, BM, DG, O	MM - O	Y	Y	UD	N	LR
Indiana	35,673	21,094	35,430	23,000	12,430	unknown	Y	Y	Y	Y	VB	R, PJ	HC, LD, GR, O	TG, PA, MV, BM, DG	MM - CDF, O, MV - O	Y	Y	UD	N	LR, LK, RES, WL

n/a = not applicable; pop. = population; ref. = reference; UD = under development; WQS = water quality standards; – = none or information not reported

Entity	Stream/river miles		Number of miles assessed using biology				Assemblages assessed				Habitat assessment	Reference site determination	Characterization of regional reference sites	Data analysis tools & methods	Impairment thresholds	Bioassessment uses				Other waterbody types with biological programs
																		Biocriteria in WQS		
Name	Total miles	Perennial miles	Total miles assessed	fully supporting for 305(b)	partially/non-supporting for 305(b)	listed for 303(d)	Benthos	Fish	Periphyton	Other	VB = visual based; QM = quantitative measurements; HY = hydrogeomorphology; O = other	SS = site specific; PW = paired watersheds; R =regional; PJ = professional judgment; O = other	HC = historical conditions; LD = least disturbed sites; GR = gradient response; PJ = professional judgment; MD = minimally disturbed; O = other	TG = tables & graphs; PA = parametric ANOVAs; MV = multivariate; BM = biological metrics; DG = disturbance gradients; O = other	MM = multimetric; MV = multivariate; CDF = cumulative distribution function; O = other	Water resource management	Aquatic Life Use Support (ALUS) in 305(b) reporting	Narrative	Numeric	LR = large rivers; LK = lakes; RES = reservoirs; ENC = estuaries/ near coastal marine; WL = wetlands
Iowa	71,665	26,630	2,018	1,418	600	n/a	Y	Y	N	N	VB, QM	R, PJ	LD	TG, PA, MV, BM, DG	MM - 25th %tile of ref. pop.	Y	Y	UD	N	LR
Kansas	134,338	23,731	23,731	n/a	n/a	n/a	Y	Y	Y	Y	VB, QM	PJ	HC, LD	TG, BM, O	MM - UD	Y	Y	Y	N	LK, RES, WL
Kentucky	89,431	34,334	~30,000	~20,000	~10,000	7,500	Y	Y	Y	N	VB	R	LD, MD	MV, BM	MM - 25th %tile of ref. pop.	Y	Y	Y	N	LR
Louisiana	66,294	–	–	n/a	n/a	n/a	Y	Y	N	N	VB	SS, PJ	HC, LD, O	TG, MV, BM, O	MM - CDF, O	Y	N	Y	N	–
Maine	31,672	23,879	1,000	858.5	141.5	141.5	Y	N	Y	N	VB	R, PJ	LD, GR, PJ, MD	TG, MV, BM, DG	MV	Y	Y	Y	UD	LR, LK (UD), RES, ENC
Maryland	17,000	12,343	6,142	3,429	2,713.4	178 actual listings	Y	Y	N	Y	VB, QM, O	O	LD	TG, PA, MV, BM, DG, O	MM - 10th %tile	Y	Y	UD	N	ENC
Massachusetts	8,229	7,133	1,344	649	695	695	Y	Y	Y	Y	VB	SS, PW, R, PJ	LD	TG, BM	MM - 83rd %tile of ref. pop.	Y	Y	N	N	LK, RES
Michigan	49,141	27,873	21,469	15,469	6,000	2,600	Y	Y	N	N	VB	SS	n/a	TG, BM	MM - O	Y	Y	N	N	LR
Minnesota	91,944	32,985	2,047	1,575	472	785	Y	Y	N	Y	QM	R, PJ	LD, O	TG, BM, DG	MM - O	Y	Y	Y	N	LR, LK, RES, WL

n/a = not applicable; pop. = population; ref. = reference; UD = under development; WQS = water quality standards; – = none or information not reported

Entity	Stream/river miles		Number of miles assessed using biology				Assemblages assessed				Habitat assessment	Reference site determination	Characterization of regional reference sites	Data analysis tools & methods	Impairment thresholds	Bioassessment uses				Other waterbody types with biological programs
																		Biocriteria in WQS		
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Mississippi	84,003	26,454	1,365	505	860	860	Y	N	N	N	VB, O	R	LD	TG, MV, BM, DG	MM - UD	Y	Y	N	N	LR, LK, ENC
Missouri	52,194	22,194	21,996	11,519	10,477	n/a	Y	Y	N	N	VB, QM, O	SS, R, PJ, O	LD, MD	TG, PA, MV, BM	MM - cumulative score = 81% of ref. condition	Y	Y	Y	UD	LR
Montana	176,750	53,221	9,076	1,340	7,736	7,736	Y	Y	Y	Y	VB, QM, HY, O	SS, R, PJ	HC, LD, PJ, MD	TG, PA, MV, BM, DG	MM - 75% of ref. condition	Y	UD	UD	N	LR, LK, RES
Nebraska	81,573	16,090	16,314	13,867	2,447	0	Y	Y	N	N	VB, QM	SS, R, PJ	LD, O	TG, PA, BM	MM - 25th %tile of ref. pop.	Y	Y	Y	N	LK, RES , WL
Nevada	143,578	14,988	602	0	0	0	Y	N	UD	N	VB, QM, O	SS, PW, R, PJ (all UD)	HC, LD, PJ (all UD)	TG, MV, BM (UD), DG	–	Y	UD	UD	N	RES
New Hampshire	10,881	8,636	400	389	11	0	Y	Y	N	Y	VB	SS, PJ	n/a	TG, BM	–	Y	Y	Y	UD	LK, WL
New Jersey	6,500	–	330	121	209	–	Y	Y	N	N	VB	R, PJ	LD	BM	MM - USEPA RBPs	Y	Y	N	N	LK, ENC (all UD)
New Mexico	110,741	8,682	~5,875	~3,200	~2,675	UD	Y	Y	Y	Y	VB, HY, O	PJ	n/a	TG, BM	MM - 95th %tile of ref. pop.	Y	Y	**N**	N	LR, LK

n/a = not applicable; pop. = population; ref. = reference; UD = under development; WQS = water quality standards; – = none or information not reported

Entity	Stream/river miles		Number of miles assessed using biology				Assemblages assessed				Habitat assessment	Reference site determination	Characterization of regional reference sites	Data analysis tools & methods	Impairment thresholds	Bioassessment uses				Other waterbody types with biological programs
																		Biocriteria in WQS		
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New York	52,337	46,266	16,000	15,430	570	484	Y	Y	Y	N	QM	SS	n/a	TG, BM, O	MM - 75th %tile of all sites	Y	Y	N	N	–
North Carolina	37,662	–	32,072	29,929	2,143	2,143	Y	Y	Y	Y	VB	R	LD	TG, PA, BM, DG	MM - O	Y	Y	Y	N	WL, RES
North Dakota	54,427	unknown	14,426	9,923	4,503	–	Y	Y	Y	N	VB, HY	R	LD	TG, BM, DG	MM - O	Y	Y	Y	N	–
Ohio	29,113	29,113	9,535	5,204	4,331	2,052	Y	Y	N	N	VB	R	LD	TG, BM	MM - 25th & 75th %tile of ref. pop.	Y	Y	Y	Y	LR, LK, RES, WL
Oklahoma	78, 778	22,386	13,313	UD	UD	UD	Y	Y	N	N	QM	R, O	LD	TG, BM	MM - CDF	Y	UD	Y	Y	UD
Oregon	114,823	51,695	40,188	12,056	28,132	unknown	Y	Y	Y	Y	QM	R, PJ, O	LD, MD	TG, PA, MV, BM, DG	MM - CDF, MV	Y	Y	Y	UD	LR, ENC
Pennsylvania	83,000	–	45,000	36,900	8,100	8,100	Y	Y	N	Y	VB	PW, R	MD	TG, PA, MV, BM, DG	MM - UD	Y	Y	N	N	LR, LK, ENC, WL
Rhode Island	1,498	979	272.8	188.1	84.7	78.5	Y	N	N	Y	VB	SS, PJ	HC, MD	TG, BM	MM - 75th %tile of ref. pop.	Y	Y	Y	N	–
South Carolina	35,461	25,729	**678.6**	**563.98**	**114.6**	**114.6**	Y	N	N	N	VB	R	LD	TG, BM	MM - CDF	Y	Y	Y	N	LR
South Dakota	9,937	1,932	3.73	n/a	n/a	n/a	Y	N	Y	N	VB, QM, HY	PJ (UD)	LD (UD)	TG, BM	MM - 25th %tile of ref. pop.	Y	N	Y	N	LR, LK, RES

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Tennessee	60,187	–	24,233	16,693	7,540	14,333	Y	N	N	N	VB	R	LD	TG,PA, MV, BM	MM - 25% of 90th %tile of ref. pop.	Y	Y	Y	UD	–
Texas	191,228	40,194	266.9	196.1	70.8	–	Y	Y	N	N	QM	SS, PW, R, PJ	LD	TG, PA, BM	MM - 50th %tile of ref. pop.	Y	Y	Y	N	LR, ENC, WL
Utah	85,916	14,000+	705	75	630	300	Y	N	UD	N	QM, O	n/a	n/a	TG, BM, O	–	Y	N	N	N	LK, RES
Vermont	7,099	7,099	~800	~650	~150	~150	Y	Y	Y	N	VB, HY, O	SS, R, PJ	HC, PJ, MD	TG, PA, MV, BM	MM - CDF	Y	Y	Y	N	–
Virginia	50,329	50,329	15,540.4	13,321.9	2,218.5	2,218.5	Y	N	N	N	VB	SS, PW, PJ	–	TG	–	Y	Y	N	N	LK
Washington	73,886	39,483	3,275	982.5	2,292.5	0	Y	Y	Y	Y	VB, QM, HY	R, PJ	HC, LD, MD	TG, MV, BM	MM - 25th %tile of ref. pop.	Y	Y	UD	N	–
West Virginia	32,278	21,114	5,745	3,706	2,039	1,315	Y	Y	N	N	VB, QM, O	R, PJ	MD	TG, BM	MM - 5th %tile of ref. pop.	Y	Y	N	N	–
Wisconsin	55,000	32,000	24,422	7,989	12,028	–	Y	Y	Y	N	QM	SS, R	LD, PJ, O	TG, PA, MV, BM, DG	MM - 25th %tile of ref. pop.	Y	Y	N	N	LR, LK, RES, WL
Wyoming	113,422	32,520	2,639	2,124	177	177	Y	N	UD	N	VB, QM, HY,	R, PJ	LD, PJ	MV (UD), TG,	MM - 25th %tile	Y	Y	**Y**	UD	LR, LK,

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Entity	Stream/river miles		Number of miles assessed using biology				Assemblages assessed				Habitat assessment	Reference site determination	Characterization of regional reference sites	Data analysis tools & methods	Impairment thresholds	Bioassessment uses				Other waterbody types with biological programs
																		Biocriteria in WQS		
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TERRITORIES																				
American Samoa	–	–	–	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	N	N	N	N	–
Commonwealth of Northern Mariana Islands (CNMI)	–	–	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	N	N	**N**	N	ENC
Puerto Rico	5,394.2	–	0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	UD	N	N	N	–
U.S. Virgin Islands	–	–	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	N	N	N	N	–
TRIBES																				
Confederated Tribes of the Colville Res.	–	–	–	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	N	N	N	N	–
Nez Perce Tribe	–	–	–	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	UD	n/a	n/a	n/a	–
Oneida Nation of Wisconsin	233	–	–	n/a	n/a	n/a	Y	Y	N	N	VB, QM	PJ	LD	TG, PA, BM	MM	Y	n/a	n/a	n/a	LR, LK, WL

n/a = not applicable; pop. = population; ref. = reference; UD = under development; WQS = water quality standards; – = none or information not reported

Entity	Stream/river miles		Number of miles assessed using biology				Assemblages assessed				Habitat assessment	Reference site determination	Characterization of regional reference sites	Data analysis tools & methods	Impairment thresholds	Bioassessment uses		Biocriteria in WQS		Other waterbody types with biological programs
Name	Total miles	Perennial miles	Total miles assessed	fully supporting for 305(b)	partially/non-supporting for 305(b)	listed for 303(d)	Benthos	Fish	Periphyton	Other	VB = visual based; QM = quantitative measurements; HY = hydrogeomorphology; O = other	SS = site specific; PW = paired watersheds; R =regional; PJ = professional judgment; O = other	HC = historical conditions; LD = least disturbed sites; GR = gradient response; PJ = professional judgment; MD = minimally disturbed; O = other	TG = tables & graphs; PA = parametric ANOVAs; MV = multivariate; BM = biological metrics; DG = disturbance gradients; O = other	MM = multimetric; MV = multivariate; CDF = cumulative distribution function; O = other	Water resource management	Aquatic Life Use Support (ALUS) in 305(b) reporting	Narrative	Numeric	LR = large rivers; LK = lakes; RES = reservoirs; ENC = estuaries/near coastal marine; WL = wetlands
Passamaquoddy Tribe, Pleasant Point Res.	–	–	–	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	N	n/a	n/a	n/a	ENC
Pyramid Lake Paiute Tribe	–	–	31+	–	–	–	Y	Y	Y	N	VB, QM	PJ	HC, PJ	UD	UD	Y	n/a	UD	UD	LK
Seminole Tribe of Florida	–	–	–	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	N	N	N	N	–
INTERSTATE COMMISSIONS																				
DRBC	200	–	200	n/a	n/a	n/a	Y	Y	N	Y	VB, HY, O	R, O	HC, LD	TG, BM	–	Y	n/a	Y	Y	LR
ICPRB	383	–	n/a	n/a	n/a	n/a	Y	Y	N	Y	VB	R	LD, GR	TG, PA, MV, BM	MM - UD	Y	n/a	n/a	n/a	–
ORSANCO	981	–	981	974	7	55	Y	Y	N	N	O	SS, R, PJ	LD	TG, PA, MV, BM, DG	MM - 25th %tile of ref. pop.	Y	Y	Y	UD	LR
SRBC	31,193	–	3,520	2,525	995	n/a	Y	N	N	N	VB	R, PJ	LD	TG, BM	MM - O	Y	Y	n/a	n/a	LR

n/a = not applicable; pop. = population; ref. = reference; UD = under development; WQS = water quality standards; – = none or information not reported

APPENDIX B.

EPA CONTACTS

Appendix B. EPA CONTACTS

Regional Biocriteria Coordinators

REGION 1
(CT, ME, MA, NH, Passamaquoddy Tribe - Pleasant Point Reservation, RI, VT)

Peter Nolan, *Regional Biocriteria Coordinator*
USEPA New England Regional Laboratory
Office of Environmental Measurement and Evaluation
11 Technology Drive
North Chelmsford, MA 01863-2431
Phone 617/918-8343, Fax 617/918-8397
email: nolan.peter@epa.gov

REGION 2
(DRBC, NJ, NY, Puerto Rico and the US Virgin Islands)

James Kurtenbach, *Regional Biocriteria Coordinator*
USEPA - Region 2
Facilities - Mail Code MS220
Raritan Depot, 2890 Woodbridge Avenue
Edison, NJ 08837-3679
Phone 732/321-6695, Fax 732/321-6616
email: kurtenbach.james@epa.gov

REGION 3
(DE, DC, ICPRB, MD, PA, SRBC, VA, WV)

Margaret Passmore, *Regional Biocriteria Coordinator*
USEPA - Region 3
Wheeling Operations Office - Mail Code 3ES31
303 Methodist Building
11th and Chapline Streets
Wheeling, WV 26003
Phone 304/234-0245, Fax 304/234-0259
email: passmore.margaret@epa.gov

REGION 4
(AL, FL, GA, KY, MS, NC, Seminole Tribe, SC, TN)

Jim Harrison, *Regional Biocriteria Coordinator*
USEPA - Region 4
61 Forsyth Street, S.W.
Atlanta, GA 30303-8960
Phone 404/562-9271
email: harrison.jim@epa.gov

REGION 5
(IL, IN, MI, MN, OH, ORSANCO, Oneida Nation of Wisconsin, WI)

Ed Hammer, *Regional Biocriteria Coordinator*
USEPA - Region 5
Mail Code WT-15J
77 West Jackson Boulevard
Chicago, IL 60604-3507
Phone 312/886-3019
email: hammer.edward@epa.gov

REGION 6
(AR, LA, NM, OK, TX)

Philip Crocker, *Regional Biocriteria Coordinator*
USEPA - Region 6
Mail Code 6WQ-EW
1445 Ross Avenue, Suite 1200
Dallas, TX 75202-2733
Phone 214/665-6644, Fax 214/665-7373
email: crocker.philip@epa.gov

Charlie Howell, *Regional Biocriteria Coordinator*
USEPA - Region 6
Mail Code 6WQ-EW
1445 Ross Avenue, Suite 1200
Dallas, TX 75202-2733
Phone 214/665-8354, Fax 214/665-7373
email: howell.charlie@epa.gov

REGION 7
(IA, KS, MO, NE)

Gary Welker, *Regional Biocriteria Coordinator*
USEPA - Region 7
Mail Code ENSVEMWC
901 North Fifth Street
Kansas City, KS 66101
Phone 913/551-7177, Fax 913/551-9177
email: welker.gary@epa.gov

REGION 8
(CO, MT, ND, SD, UT, WY)

Tina Laidlaw, *Regional Biocriteria Coordinator*
USEPA - Region 8
Phone 303/312-6880, Fax 303/312-6071
email: laidlaw.tina@epa.gov

Jill Minter, *Regional Biocriteria Coordinator*
USEPA - Region 8
Phone 303/312-6084, Fax 303/312-6071
email: minter.jill@epa.gov

REGION 9
(American Samoa, AZ, CA, CNMI, HI, NV, Pyramid Lake Paiute Tribe)

Gary Wolinsky, *Regional Biocriteria Coordinator*
USEPA - Region 9
Mail Code WTR-5
75 Hawthorne Street
San Francisco, CA 94105
Phone 415/972-3498, Fax 415/947-3545
email: wolinsky.gary@epa.gov

<u>REGION 10</u>
(AK, Confederated Tribes of the Colville Reservation,
ID, Nez Perce Tribe, OR, WA)

Gretchen Hayslip, *Regional Biocriteria Coordinator*
USEPA - Region 10
1200 Sixth Avenue
Seattle, WA 98101
Phone 206/553-1685
email: hayslip.gretchen@epa.gov

EPA Headquarters

Bill Swietlik, *Program Manager*
USEPA Office of Water
Office of Science and Technology
Health and Ecological Criteria Division (4304T)
1200 Pennsylvania Avenue, N.W.
Washington, D.C. 20460
Phone 202/566-1129, Fax 202/566-1140 or 1139
email: swietlik.william@epa.gov

Questions regarding a specific entity's program should be directed to the contact(s) listed at the top of each entity's program summary in Chapter 3. Questions regarding other sections of this document may be directed to any of the following USEPA Headquarters contacts:

Wayne Davis
USEPA Office of Environmental Information
Environmental Science Center
701 Mapes Road
Ft. Meade, Maryland 20755-5350
410-305-3030 410-305-3096 (fax)
email: davis.wayne@epa.gov

Beth Jackson
USEPA Office of Environmental Information
Environmental Analysis Division
1200 Pennsylvania Avenue (2842T)
Washington, D.C. 20460
Phone 202/566-0626, Fax 202/566-0706
email: jackson.elizabeth@epa.gov

Treda Smith
USEPA Office of Water
Office of Science and Technology
1200 Pennsylvania Ave NW (4304T)
Washington, D.C. 20460-0001
Phone 202/566-1128, Fax 202/566-1139
email: smith.treda@epa.gov

APPENDIX C.

ORIGINAL CHECKLIST TEMPLATE

Appendix C. ORIGINAL CHECKLIST TEMPLATE

Form Approved
OMB Control No. 2040-0049
Approval Expiration: 7/31/02

Survey of State/Tribal Water Quality Programs for Protecting Aquatic Life Through the Use of Bioassessments and Biocriteria

Contact Information:

state	
name	
position	
agency/organization	
mailing address	
phone	
fax	
email	
website	

Briefly describe your professional responsibilities as they relate to water quality standards, conducting bioassessments, and establishing biocriteria.

For each waterbody type below with biological programs, please provide a contact (if different than yourself)

	name	phone	email
non-wadeable rivers			
lakes			
reservoirs			
estuaries/near-coastal marine			
wetlands			

Please attach any ancillary materials that will provide further in insight or background about your program and/or agency. Examples might include an organizational chart, promotional materials, etc. THANK YOU!

State/Tribal WaterQuality Supporting Aquatic Life Use
Designations and Biocriteria Development

1 With respect to your program, which waterbody type categories apply ("X"), and which is being described using this checklist ("XX)"?

	wadeable streams, creeks, rivers
	non-wadeable rivers
	lakes
	reservoirs
	estuaries and near-coastal marine
	wetlands

2 For lotic systems, how are they defined?

	stream order
	drainage area
	other (please describe)

3 With respect to the resource type for this checklist, what is the percentage of information in your state, tribal land, or basin, coming from the following entities?

	state/tribal water quality agency
	state fish & game agency
	USEPA
	other federal agency
	consultants
	volunteer monitoring programs
	local college or university
	regulated entities
	other (please describe)

4 Do you contract out any or all or your bioassessment work?

	Yes
	No

4a If you answered yes to #4, please specify the percentage contracted out to each type of entity for field and lab work.

field	lab	
		consultants
		other state agency
		volunteer monitoring groups
		federal agency
		college or university
		other (please describe)

5 What is the lead agency USING the bioassessment information?

6 In which ways are bioassessments used within the water quality program in your state, tribe, or basin? Please check Yes (Y), No (N), or Unsure (?) for all that apply.

Y	N	?	
			problem identification (screening)
			nonpoint source assessments
			monitoring the effectiveness of BMPs
			aquatic life use determinations/ambient monitoring
			promulgated into state WQ standards as biocriteria
			support of antidegradation
			evaluation of discharge permit conditions
			TMDL assessment & monitoring
			other (please describe)

7 Which of the following monitoring designs are used (please check all that apply)?

	targeted (i.e., sites selected for a specific purpose)
	fixed station (i.e., WQ monitoring stations)
	probabalistic by stream order/catchment area
	probalistic by ecoregion, or statewide
	rotating basin
	other (please describe)

7a For each monitoring design checked in #7, please indicate how it is implemented (check all that apply for each design).

special projects only	specific river basins or watersheds	comprehensive use throughout jurisdiction

8 Indicate the extent of resources assessed using biology (e.g., miles, acres, etc.)

- [ ] extent of resource assessed for biology (total)
- [ ] extent of resource fully supporting for 305b
- [ ] extent of resource partially supporting/non supporting for 305b
- [ ] extent of resource listed for 303d
- [ ] number of sites sampled
- [ ] extent of resource per site (if predetermined)

8a Please indicate which of the following units of measure you used to answer #8

- [ ] watersheds
- [ ] acreage
- [ ] miles
- [ ] other (please describe)

9 What is the basis for determining the extent of the resource?

- [ ] RF3
- [ ] National Hydrography Database
- [ ] state based
- [ ] other (please describe)

10 Please use this space to add any additional information you'd like about programmatic elements.

11 What are your Aquatic Life Use Support (ALUS) designations based on?

- [ ] Single Aquatic Life Use
- [ ] Class System (A,B,C)
- [ ] Fishery Based Uses
- [ ] Warm Water vs. Cold Water

11a How many different aquatic life use designations are contained in your water quality standards (WQS)? Please describe.

11b Does your state plan to further refine its AL designated uses in the next triennial WQS review?

- [ ] Yes
- [ ] No

12 If you have narrative biocriteria in your WQS. Is the attached description accurate?

- [ ] Yes
- [ ] No

12a If you answered no to #12, please correct below

13 For your narrative biocriteria, do you have formal/informal numeric procedures to support your decisions?

- [ ] Yes
- [ ] No

*If you answered yes to #13, where are these procedures located (e.g., in the WQS)?

13a If you answered no to #13, do you use a qualitative and/or narrative scale of condition?

- [ ] Yes
- [ ] No

*Where are the scale(s) located?

14 Do you have numeric biocriteria?

- [ ] Yes
- [ ] No

*If you answered yes to #14, where are they located?

14a If you have numeric biocriteria, please describe or attach separate description.

15 Are bioassessment data used in an integrated assessment with other environmental data (e.g., toxicity testing and chemical specific criteria)? Please check Yes (Y), No (N), or Unsure (?) for all that apply.

Y	N	?	
			for assessment of aquatic resources
			for cause and effect determinations
			for permitted discharges
			for monitoring (e.g., improvements after mitigation)
			for watershed based management

15a For each box you answered yes to in #15, do you use

- [ ] independent application (IA)
- [ ] weight-of-evidence
- [ ] combination
- [ ] other (explain)

16 Do you know where bioassessments/biocriteria have been used in making management decisions regarding restoration of the aquatic resources to its designated ALUS?

☐ Yes
☐ No

16a If you answered yes to #16, please elaborate.

☐

17 How many full time employees were devoted to

☐ developing the bioassessment/biocriteria program
☐ maintaining the bioassessment/biocriteria program

18 Please use this space to add any additional information you'd like about your ALUS descision making process

☐

Field & Lab Methods for Determining Existing Uses, Designated Uses & Collecting Data for Biocriteria Development

19 How are your reference sites determined?

- [ ] site-specific
- [ ] paired watersheds
- [ ] regional (aggregate of sites)
- [ ] professional judgement
- [ ] other (please describe)

19a How do you define a reference site?

19b Do you have reference site criteria?

- [ ] No
- [ ] Yes (If so, please describe in space below.)

20 If you use regional reference conditions, how do you characterize those sites?

- [ ] historical conditions
- [ ] least-disturbed sites
- [ ] gradient response
- [ ] judgement prescription
- [ ] other (please describe)

21 If you use regional reference sites, how do you characterize (stratify) your streams?

- [ ] ecoregions (or some aggregate)
- [ ] elevation
- [ ] stream type
- [ ] multivariate grouping
- [ ] jurisdictional (i.e., statewide)
- [ ] other (please describe)

22 Please indicate how many reference sites you have

- [ ] by strata
- [ ] total

23 What are your criteria for defining reference sites and, if applicable, disturbed sites (e.g., D.O., sulfates, habitat)?

23a Are your reference sites linked to your aquatic life designated uses?

- [ ] Yes
- [ ] No

23b Are your reference sites/conditions identified or referenced in your WQS?

- [ ] Yes (provide citation________________________)
- [ ] No

23c Do any of your reference sites represent acceptable man-induced conditions?

- [ ] Yes
- [ ] No

24 Which of the following assemblages are assessed by your program? Please check Yes (Y), No (N), or Unsure (?) for all that apply.

Y	N	?	
			phytoplankton
			periphyton
			macrophytes
			zooplankton
			benthos
			fish
			amphibians/reptiles
			waterfowl

24a For each assemblaged assessed in #24, please indicate the range of samples processed per year

< 100	100-500	> 500

24b For each assemblaged assessed in #24, please indicate the level of rigor by choosing A, B, C, D, or E

- [ ] phytoplankton
- [ ] periphyton
- [ ] macrophytes
- [ ] zooplankton
- [ ] benthos
- [ ] fish
- [ ] amphibians/reptiles
- [ ] waterfowl

A single observation (no discrete season), limited sampling (e.g., 1-2 sites)
B single season, multiple sites (not at watershed level)
C single season, multiple sites (watershed level)
D single season, multiple sites (broad coverage)
E multiple seasons, multiple sites (broad coverage for watershed level)

25 Do you perform habitat assessments at your sites?

- [ ] Yes
- [ ] No

25a If you answered yes to #25, how are they conducted?

- [ ] with bioassessments
- [ ] independent of bioassessments

25b If you answered yes to #25, what type of habitat assessment is used?

- [ ] visual based (e.g., QHEI, RBP, etc.)
- [ ] quantitative measurements (e.g., EMAP)
- [ ] hydrogeomorphology (e.g., Rosgen)
- [ ] other quantitative parameters (e.g., pebble counts, sediment index, etc.) (please describe)

25c Are these habitat reference conditions cited or mentioned in your WQS?

- [ ] Yes (provide citation________________________)
- [ ] No

26 Do you use biological information to facilitate public participation in setting WQS?

- [ ] Yes (please describe in space below)
- [ ] No

27 Which of the following are part of your quality assurance (QA) program? Please check Yes (Y), No (N), or Unsure (?) for all that apply.

Y	N	?	
			standard operating procedures (SOPs)
			quality assurance plan (QAP)
			periodic meetings, training for biologists
			sorting proficiency checks
			taxonomic proficiency checks
			specimen archival
			other (please describe)

28 Do you have a certification program for bioassessment?

- [ ] Yes
- [ ] No

If yes, briefly describe:

Questions 29 -33 deal with field issues specific to BENTHOS. Please describe your program by checking all that apply. If your program does not assess this assemblage, please skip these questions.

29 Sampling gear-- please check all that apply to your program

- [ ] Surber
- [ ] Hess
- [ ] Slack (0.5 m)
- [ ] D-frame
- [ ] dipnet
- [ ] kick net (1 m)
- [ ] multiplate
- [ ] rock baskets
- [ ] collect by hand
- [ ] other (please describe)

29a Indicate the mesh size used by your program (in microns)

- [ ] 200 - 400
- [ ] 500 - 600
- [ ] > 800
- [ ] other (please describe)

29b Indicate the area sampled

- [ ] < 1 m^2
- [ ] 1 - 3 m2
- [ ] 3 - 6 m
- [ ] other (please describe)

30 Reach length

- [ ] selected habitat
- [ ] habitat sequences or cycles
- [ ] fixed distance
- [ ] stream width formula
- [ ] time
- [ ] other (please describe)

31 Habitat selection

- [ ] richest habitat
- [ ] riffle/run (cobble)
- [ ] multihabitat
- [ ] artificial substrate
- [ ] woody debris
- [ ] other (please describe)

32 Where are samples processed?

- [ ] field
- [ ] lab

32a What is the target subsample size?

- [ ] 100 count
- [ ] 200 count
- [ ] 300 count
- [ ] 500 count
- [ ] proportional/volume
- [ ] entire sample
- [ ] other (please describe)

33 What level of taxonomy do you use?

- [ ] order
- [ ] family
- [ ] genus
- [ ] species
- [ ] combination
- [ ] other (please describe)

Questions 34 - 38 deal with field issues specific to FISH/AMPHIBIANS. Please describe your program by checking all that apply. If your program does not assess these assemblages, please skip these questions.

34 Sampling gear-- please check all that apply to your program

- [ ] seine
- [ ] backpack electrofisher
- [ ] boat electrofisher
- [ ] pram unit (tote barge)
- [ ] other (please describe)

34a Seine and/or dipnet mesh size (in inches)

- [ ] 1/8"
- [ ] 3/16"
- [ ] 1/4"
- [ ] 3/8"
- [ ] 1/2"

35 Reach length

- [ ] selected habitat
- [ ] habitat sequences or cycles
- [ ] fixed distance
- [ ] stream width formula
- [ ] time
- [ ] other (please describe)

36 Habitat selection

- [ ] pool/glide
- [ ] riffle/run (cobble)
- [ ] multihabitat
- [ ] other (please describe)

37 Where are the samples processed?

- [ ] field
- [ ] lab

37a How are the samples processed?

- [ ] length measurement
- [ ] biomass--individual
- [ ] biomass--batch
- [ ] anomalies

37b How are samples subsampled?

- [ ] selected species
- [ ] batch
- [ ] selected size
- [ ] none
- [ ] other (please describe)

38 What level of taxonomy do you use

- [ ] species
- [ ] subspecies
- [ ] life stage
- [ ] other (please describe)

Questions 39 -43 deal with field issues specific to PERIPHYTON. Please describe your program by checking all that apply. If your program does not assess this assemblage, please skip these questions.

39 Sampling gear-- natural substrate

- [ ] suction device
- [ ] bar clamp sample
- [ ] brushing/scraping device (razor, toothbrush, etc.)
- [ ] collect by hand
- [ ] other (please describe)

39a Sampling gear-- artificial substrate

- [ ] periphytometer
- [ ] microslides or other suitable substratum
- [ ] collect by hand
- [ ] other (please describe)

40 Reach length

- [ ] selected habitat
- [ ] habitat sequences or cycles
- [ ] fixed distance
- [ ] stream width formula
- [ ] time
- [ ] other (please describe)

41 Habitat selection

- [ ] richest habitat
- [ ] riffle/run (cobble)
- [ ] multihabitat
- [ ] artificial substrate
- [ ] other (please describe)

42 How are samples processed?

- [ ] chlorophyll *a*/ phaeophytin
- [ ] biomass
- [ ] taxonomic identification
- [ ] other (please describe)

43 What level of taxonomy do you use?

- [ ] diatoms only
- [ ] all algae
- [ ] division level
- [ ] genus level
- [ ] species level
- [ ] other (please describe)

44 Please use this space to add any additional information you'd like about your field and lab methods.

Data Analysis and Interpretation for Determining Biological Condition of Aquatic Life Uses and Deriving Biocriteria

45 Which data analysis tools and methods do you use (check all that apply)?

- [ ] summary tables, illustrative graphs
- [ ] parametric ANOVAs
- [ ] multivariate analysis
- [ ] biological metrics
- [ ] disturbance gradients
- [ ] other (please describe)

46 If you use biological gradients, how are the metrics selected and tested?

- [ ] selected by consensus
- [ ] tested for sensitivity, ecological value
- [ ] calibrated for natural gradients (and covariates)

46a Please describe your response to #46

47 If you use biological metrics, how is the threshold determined for transforming metrics into unitless scores?

- [ ] 25th %tile of reference population
- [ ] 50th %tile of reference population
- [ ] 75th %tile of reference population
- [ ] 95th %tile of reference population
- [ ] 95th %tile of all sites
- [ ] cumulative distribution function
- [ ] other (please describe)

48 If you use biological metrics do you

- [ ] aggregate metrics into an index
- [ ] return single metrics (use endpoint for each single metric)

49 If you use a multimetric index, how do you define the impairment threshold?

- [ ] 25th %tile of reference population
- [ ] 50th %tile of reference population
- [ ] 75th %tile of reference population
- [ ] 95th %tile of reference population
- [ ] 95th %tile of all sites
- [ ] cumulative distribution function
- [ ] other (please describe)

50 If you use a multivariate technique, how do you define the impairment threshold?

- [ ] 5th %tile of reference population
- [ ] 10th %tile of reference population
- [ ] Significant departure from mean of reference population
- [ ] other (please describe)

51 Have you evaluated the performance characteristics of your bioassessment results?

- [ ] Yes
- [ ] No

51a If you answered yes to #51, please describe. Please check Yes (Y), No (N), or Unsure (?) for all that apply.

Y	N	?		
			repeat sampling (please describe)	
			precision (please describe)	
			sensitivity (please describe)	
			bias (please describe)	
			accuracy (please describe)	

52 Please use this space to add any additional information you'd like about your data analysis and interpretation methods.

53 Identify where your biological data are stored. Please check Yes (Y), No (N), or Unsure (?) for all that apply.

Y	N	?	
			STORET
			other database (what program/application)
			spreadsheets (what program/application)
			paper files only
			other (please describe)

54 Please describe how data are retrieved and analyzed. Please check Yes (Y), No (N), or Unsure (?) for all that apply.

Y	N	?	
			SAS
			Systat
			Statistica
			EDAS
			other (please describe)

55 Please list any website URLs for all relevant data.

56 Please list all documents and references used to provide this information (e.g., SOPs, 305(b) reports, etc.)any website URLs for all relevant data.

57 Please use this space to add any additional information you'd like about your information management.

APPENDIX D.

PROGRAM SUMMARY TEMPLATE

Appendix D. PROGRAM SUMMARY TEMPLATE

The numbers of relevant checklist questions (see Appendix C) are colored black and found within each corresponding program summary section.

ENTITY NAME

Contact Information

Contact name, title
Agency
Street ■ city/state/zip
Phone ■ Fax
email:

Program Description

Documentation and Further Information

#55, 56

ENTITY NAME

Contact Information

Contact name, title
Agency
Street ■ city/state/zip
Phone ■ Fax
email:

Programmatic Elements

Uses of bioassessment within overall water quality program **#6**	☐	problem identification (screening)
	☐	nonpoint source assessments
	☐	monitoring the effectiveness of BMPs
	☐	ALU determinations/ambient monitoring
	☐	promulgated into state water quality standards as biocriteria
	☐	support of antidegradation
	☐	evaluation of discharge permit conditions
	☐	TMDL assessment and monitoring
	☐	other:
Applicable monitoring designs ***#7, (7a)***	☐	targeted (i.e., sites selected for specific purpose)
	☐	fixed station (i.e., water quality monitoring stations)
	☐	probabilistic by stream order/catchment area
	☐	probabilistic by ecoregion, or statewide
	☐	rotating basin
	☐	other:

Stream Miles

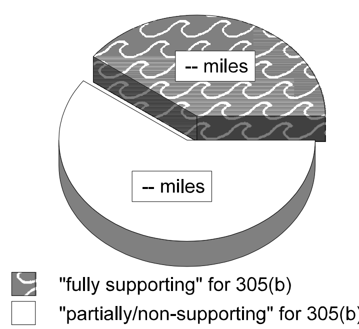
Total miles
(determined using... **#8b**)

Total perennial miles

Total miles assessed for biology **#8**

- fully supporting for 305(b)
- partially/non-supporting for 305(b)
- listed for 303(d)
- number of sites sampled
- number of miles assessed per site

Miles Assessed for Biology



Aquatic Life Use (ALU) Designations and Decision-Making

ALU designation basis	**#11**	
ALU designations in state water quality standards	**#11a**	
Narrative Biocriteria in WQS	**#12 to 13a**	
Numeric Biocriteria in WQS	**#14, 14a**	
Uses of bioassessment data in integrated assessments with other environmental data (e.g., toxicity testing and chemical specific criteria) **#15**	☐	assessment of aquatic resources
	☐	cause and effect determinations
	☐	permitted discharges
	☐	monitoring (e.g., improvements after mitigation)
	☐	watershed based management
Uses of bioassessment/ biocriteria in making management decisions regarding restoration of aquatic resources to a designated ALU	**#16, 16a**	

Reference Site/Condition Development

Number of reference sites	**#22**		
Reference site determinations **#19**	☐	site-specific	
	☐	paired watershed	
	☐	regional (aggregate of sites)	
	☐	professional judgment	
	☐	other:	
Reference site criteria	**#19b, 23**		
Characterization of reference sites within a regional context **#20**	☐	historical conditions	
	☐	least disturbed sites	
	☐	gradient response	
	☐	professional judgment	
	☐	other:	
Stream stratification within regional reference conditions **#21**	☐	ecoregions (or some aggregate)	
	☐	elevation	
	☐	stream type	
	☐	multivariate grouping	
	☐	jurisdictional (i.e., statewide)	
	☐	other:	
Additional information	☐	reference sites linked to ALU	**#23a**
	☐	reference sites/condition referenced in water quality standards	**#23b**
	☐	some reference sites represent acceptable human-induced conditions	**#23c**

Field and Lab Methods

Assemblages assessed #24, (24a, 24b)	☐ benthos *(# samples/year; level of rigor)* ☐ fish ☐ periphyton ☐ other:
Benthos	
sampling gear	#29, 29a
habitat selection	#31
subsample size	#32a
taxonomy	#33
Fish	
sampling gear	#34, 34a
habitat selection	#36
sample processing	#37a
subsample	#37b
taxonomy	#38
Periphyton	
sampling gear	natural substrate #39; artificial substrate #39a
habitat selection	#41
sample processing	#42
taxonomy	#43
Habitat assessments	#25 to 25c
Quality assurance program elements	#27, 28

Data Analysis and Interpretation

Data analysis tools and methods #45	☐ summary tables, illustrative graphs ☐ parametric ANOVAs ☐ multivariate analysis ☐ biological metrics (#48) ☐ disturbance gradients ☐ other:
Multimetric thresholds	
transforming metrics into unitless scores	#47
defining impairment in a multimetric index	#49
Multivariate thresholds	
defining impairment in a multivariate index	#50
Evaluation of performance characteristics #51, 51a	☐ repeat sampling ☐ precision ☐ sensitivity ☐ bias ☐ accuracy
Biological data	
Storage	#53
Retrieval and analysis	#54

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