Condition of Rivers and Streams in the St. Croix River Basin of Minnesota

Minnesota Pollution Control Agency
Biological Monitoring Program

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Executive Summary

In 1996, the MPCA began a monitoring program designed to assess the condition of rivers and streams in each of the 10 major river basins of Minnesota. To obtain an unbiased estimate of stream condition, the MPCA program used a random site selection process developed by the Environmental Protection Agency, Environmental Monitoring and Assessment Program (EPA/EMAP). The random sampling design allowed for the extrapolation of the monitoring results from approximately 50 sites to the entire population of rivers and streams in the geographical area of interest – in this case, the St. Croix River Basin in Minnesota. Longitudinal surveys were also conducted at targeted locations on the St. Croix River, Kettle River, Snake River, and Rush Creek to further document their condition.

Coordinates for 60 randomly selected sites were provided by EPA/EMAP, and an initial site reconnaissance was conducted by MPCA to determine if the selected sites could be considered part of the target population of streams. The 10 additional sites were requested because the EMAP site selection procedure was based on mapping information that was not always accurate. Therefore, it was necessary to visit each site in advance to ensure that the chosen location was, in fact, an accessible flowing stream. Sites that were dry, inaccessible, had no defined channel, or where a landowner denied permission to access the stream, were not considered part of the target stream population. Other sampling limitations restricted interpretation of the results for some parameters to a subset of the target population.

An integrated monitoring approach that combined measures of habitat, water chemistry, and fish and/or invertebrate community structure was used to assess each site. In addition to the field measurements, GIS technology was used to derive land use percentages for each upstream watershed to quantify human disturbance. A habitat index score was calculated using key variables from the habitat assessment. Water chemistry variables were compared to state water quality standards or ecoregion expectations. Index of biological integrity (IBI) scores were calculated using both fish and invertebrate community data. The IBI scores for fish and invertebrates were used to assess whether or not the site was supporting or non-supporting (i.e. impaired) of its aquatic life uses.

The entire dataset was analyzed using S-plus statistical software and statistical routines provided by EPA/EMAP. The dataset was also divided into two ecoregion groups (Northern Lakes and Forests and North Central Hardwood Forests), stream size groups (1st and 2nd order, and 3rd through 6th order), and watershed disturbance groups (<40% disturbance and >40% disturbance) to determine if any of these factors influenced the estimates. Cumulative distribution functions (CDF's) were created for each continuous variable. The CDF's graphically illustrate the cumulative stream miles for every level of the variable. For example, a CDF may show the cumulative percent of stream miles for all possible IBI scores, which may then be used to find the percent of stream miles in the basin with IBI scores equal to or less than a biologically based impairment threshold. Bar charts were created to view the results of categorical variables.

The majority of land in the St. Croix River Basin is forested with many wetlands and lakes interspersed throughout. Most headwater streams in the basin, particularly in the northern portion of the basin, emanate from these wetland complexes. The connection of most streams to the surrounding wetlands, along with the relatively small amount of watershed disturbance and in-stream habitat alteration, makes streams in this basin some of the most scenic in the state.

The primary form of land use in the basin is from light agricultural practices such as pasturing cattle and hay fields. Other more intensive types of land use, such as row crop agriculture and residential/urban development, are not as common but are intensifying with an expanding human population. The southern portion of the basin, primarily the North Central Hardwood Forests ecoregion, is relatively more developed than the northern portion, due in part to rapid development in and around the Minneapolis/St. Paul metropolitan area.

The habitat assessment results indicated that approximately 74% of all streams in the basin had habitat index scores in the fair to good range (i.e. habitat index scores of at least 4 out of 12). Ecoregional differences were not related to the quality of habitat. However, streams in the NCHF ecoregion tended to have substrates that were dominated by fine material (i.e. sands and silts). Watershed disturbance (i.e. summation of agriculture, urban, residential, pasture, and mining land use percentages) had was strongly related to habitat quality, with the poorer habitat occurring in streams with higher disturbance. In highly disturbed watersheds the riparian zone within 30 meters of the stream bank tended to be more disturbed, the bottom substrates tended to be smaller, there were fewer riffle/run/pool sequences, bends, and log jams, and the contour of the stream bottom was not as variable.

Water quality in the basin was found to be generally good from a chemical perspective. However, single-visit water quality samples from 31% of the streams failed to meet the applicable state water quality standard for at least one chemical parameter. The vast majority of these exceedances were attributed to naturally low dissolved oxygen or pH concentrations in headwater streams influenced by riparian wetlands. Similarly, ecoregion expectations for turbidity, conductivity, TSS, total phosphorus, and nitrogen were often exceeded, even in streams with low watershed disturbance. A reexamination of ecoregion expectations may be warranted, particularly for small streams, given that many of the exceedances occurred in streams that had watersheds with very little disturbance and that the ecoregion expectations were developed using data from larger streams only.

The biological surveys documented the occurrence of a diverse assemblage of fish and invertebrates. Seventy one of the 110 fish species known to occur in the basin were collected during the study. Over 380 invertebrate taxa were collected during the study. The structure of the fish and invertebrate varied by ecoregion, watershed disturbance level and stream size. Three fish species on the state list of special concern species were collected during the survey and were estimated to occur in 11% of the streams in the basin. Several federal- or state-listed mussels and other invertebrates occur in the basin, but no attempt was made to document the distribution of these species during this survey.

The fish and invertebrate IBI scores indicated that streams in the St. Croix River Basin were generally in fair to excellent condition with only a small percentage of streams in poor or very poor condition. The highest quality streams were in the NLF ecoregion (i.e. northern portion of the basin) in watersheds with a lower level of disturbance. On the other hand, nearly all of the poor quality streams were in the NCHF ecoregion in watersheds with a relatively high level of disturbance. Nearly 36% (690 km) of all streams in the basin were estimated to be biologically impaired for fish, invertebrates, or both assemblages. Individually, the assessments based on each assemblage agreed with each other most (72%) of the time. The impaired streams were not evenly distributed throughout the basin. Only 13% of the streams in the NLF ecoregion were impaired, compared to 89% of the streams in the NCHF ecoregion. Likewise, only 11% of the streams with low watershed disturbance were impaired, compared with 100% of the streams with high watershed disturbance.

The results of the longitudinal stream surveys tend to corroborate the results of the random survey. Fair to excellent IBI scores were obtained for every site on the St. Croix, Snake, and Kettle Rivers. Each of these streams are either wholly confined to the NLF ecoregion or have a significant portion of their watersheds in this ecoregion. Rush Creek, located in the NCHF ecoregion, was in poor condition, particularly in the headwater reaches.

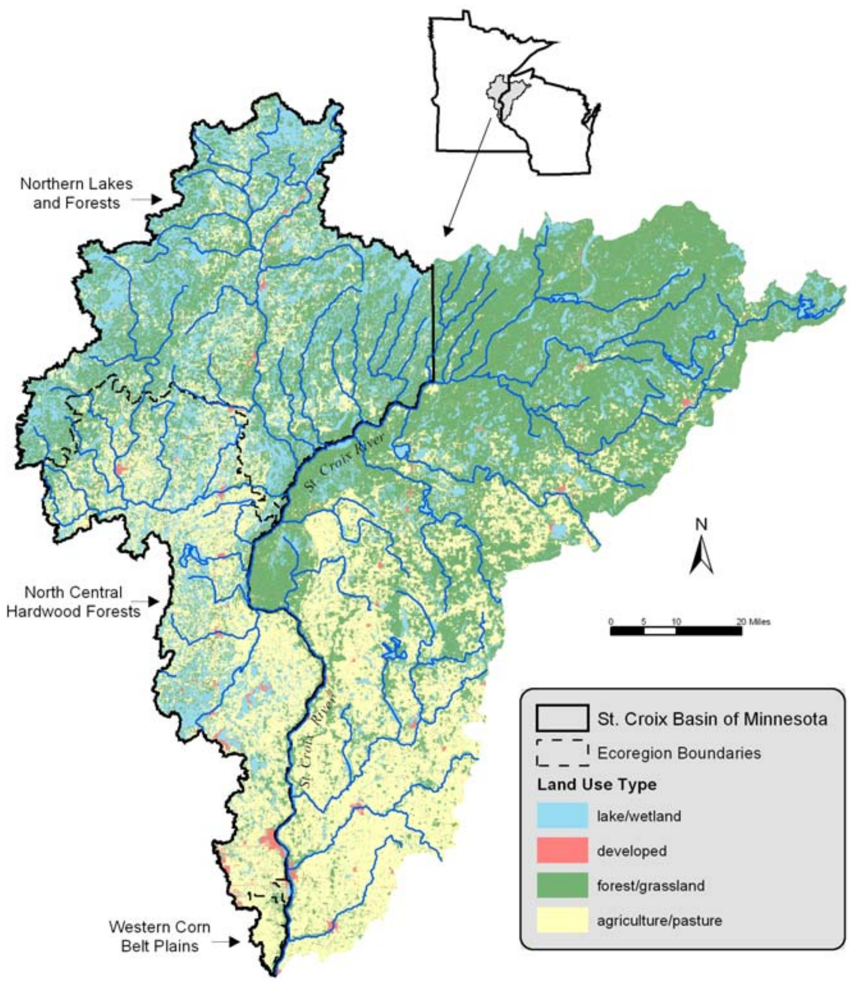
While the St. Croix River does not at this time appear to be negatively affected by the impaired tributary streams in the southern portion of the basin, developmental pressures are sure to increase and place even more pressure on this susceptible river. Further monitoring of rivers and streams throughout the basin, particularly the southern portion of the basin, is warranted to help prevent further degradation of the tributary streams and to maintain the excellent condition of the St. Croix River, a most valuable resource. The inclusion of additional biological indicators (e.g. stream periphyton) may help to identify stressors that fish and invertebrates are not particularly sensitive to.

Condition of Rivers and Streams in the St. Croix River Basin of Minnesota

Introduction and Background

The St. Croix River originates at St. Croix Lake near Solon Springs, Wisconsin. The length of the St. Croix River from the Gordon Dam in Wisconsin is approximately 150 miles with the last 125 miles (80%) forming the border between Minnesota and Wisconsin (Waters 1977). This report focuses exclusively on the portion of the St Croix River Basin that is within Minnesota (Fig. 1). Approximately half (3532 mi^2 of 7707 mi^2) of the watershed is in Minnesota.

Figure 1. Land use in the St. Croix River Basin in Minnesota (outlined) and Wisconsin. Dashed lines represent ecoregion boundaries within the Minnesota portion of the basin.



Rivers and streams within the St. Croix River Basin are arguably some of the most scenic in Minnesota. These waterways support a wide variety of recreational activities including fishing, hunting, canoeing, and site seeing. Recognition of the St. Croix River as a unique water body of exceptional quality that is being threatened by human development has led to federal and state protection status. The upper St. Croix River (above Taylors Falls) was one of the first eight rivers to be included in the original National Wild and Scenic Rivers Act of 1968 (Public Law 90-542; 16 U.S.C. 1271-1287) The lower St. Croix River was included in 1972. In addition, Minnesota has designated the St. Croix and Kettle Rivers as an Outstanding Resource Value Water (Minnesota Rule Chapter 7050.0180). This special designation carries with it regulations intended to control the spread of development within the stream corridor and control point source emissions in the St. Croix River itself and its tributaries.

The basin topography was shaped by the advance and retreat of glaciers that scoured some areas and deposited glacial materials in others to form the flat to gently rolling landscape that is present today. The glacial deposits in the northern portion of the basin are generally thin and coarse, resulting in the formation of soils that were agriculturally unproductive. In many places in the northern portion of the basin and close to the major rivers, bedrock is exposed or lies close to the land surface (MPCA 2000). The relatively thick and fine glacial deposits of the southern portion of the basin have produced soil conditions that are more amenable to cultivation.

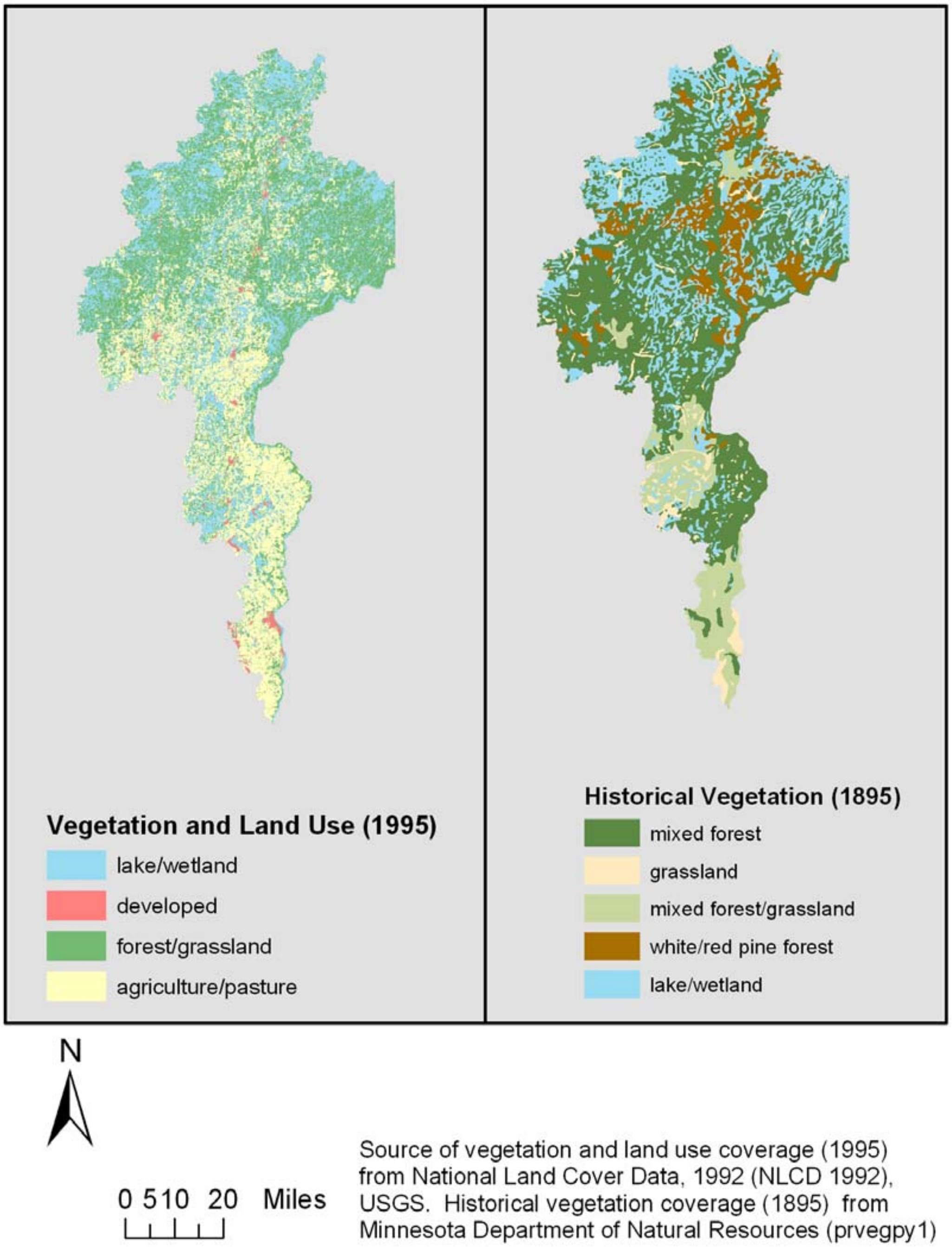
In 1929-1930 Francis J. Marschner, a research assistant in the USDA Bureau of Agricultural Economics, constructed a map of historical vegetation based on the notes of the Public Land Survey, 1847-1907 (Brady 2003, Fig. 2). Marschner's map indicated that over 11% of the basin vegetation was once dominated by white and red pine stands. Most of the remaining vegetation was dominated by mixed forest types (aspen, maple, basswood, oak, etc). While the map gives the most complete information regarding historical vegetative cover in the basin, the data probably reflects changes in vegetative cover that were already underway due to logging practices.

Today, logging and agricultural land use practices have almost entirely eliminated the large pine stands. A diverse mixture of second-growth mixed-hardwood forests, open fields, and cropland now dominates in the basin (Figs. 2 and 3). Logging in the basin began with the opening of the first sawmill in Stillwater in 1844. The Snake and Kettle Rivers were among the first major watersheds to be exploited for their abundance of virgin white pines (Waters 1977). By the 1890's logging in the St. Croix River Basin was at its peak. Over 3.5 million logs were floated down the river in 1890 (Waters 1977). Around 1914, when almost all of the virgin timber within the basin had been harvested, logging operations ceased.

Agriculture supported the early settlers and loggers during the logging era and intensified as the harvestable timber was depleted and the logging industry collapsed. However, in many cases farms were abandoned because of poor soil conditions, particularly in the northern portion of the basin where soils were marginal at best. The farming practices that survived included a mix of row-crop agriculture, small-grain farming, and beef, dairy, and poultry operations. In the latter half of the 1900's, residential and commercial development began to transform the landscape once again, particularly in the southern portion of the basin, where the Twin Cities metropolitan area emerged as a major regional economic center.

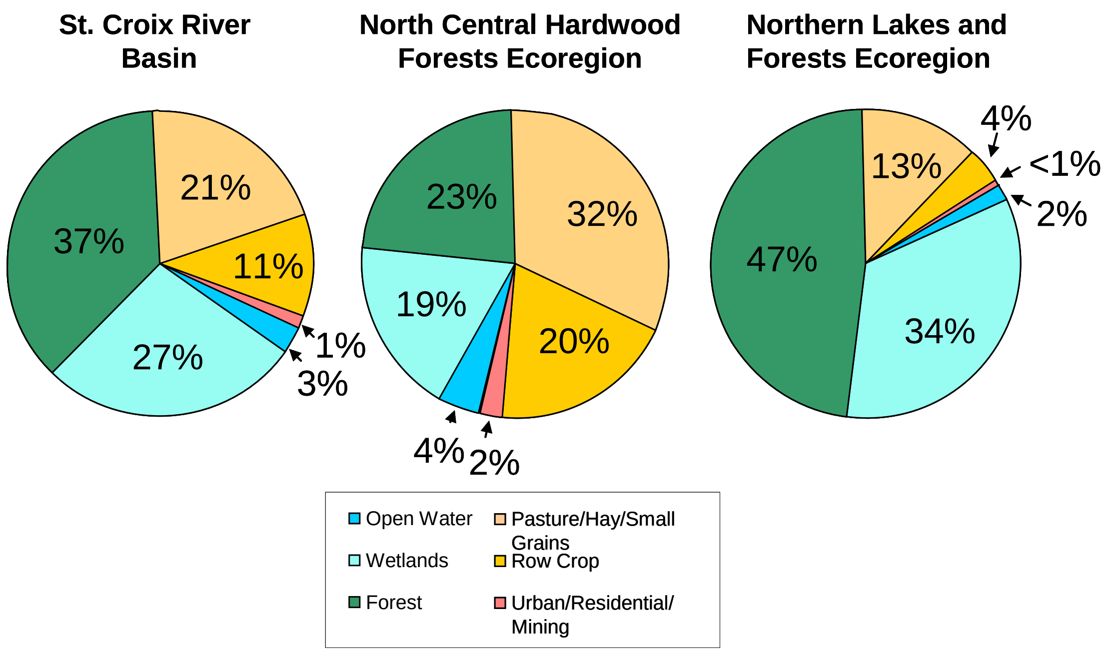
The majority of agricultural land occurs in the southern half of the basin, coinciding with an ecoregional divide that runs roughly through the center of the basin in an east-west direction (Fig. 1). Ecoregions are areas of land that have similar land-surface form, soils, potential natural vegetation, and land use patterns (Omernik 1987). The divide separates the two major ecoregions of the basin: the Northern Lakes and Forests (NLF) ecoregion in the north and the North Central Hardwood Forests (NCHF) ecoregion in the south. Two other ecoregions, the Western Corn Belt Plains and Driftless Area, comprise a very small portion of the southern tip of the basin.

Figure 2. Current and historical vegetation and land use patterns in the St. Croix River Basin of Minnesota.



The ecoregion framework was developed, in part, to help classify streams for more effective water quality management and has been shown to correspond to observed regional patterns in water quality (Hughes et al. 1994). In the St. Croix River Basin, the forested landscape of the NLF ecoregion contrasts sharply with the more agricultural landscape of the more southern NCHF ecoregion. The amount of forest cover within the entire basin is currently approximately 44%, but the majority of the remaining forest is confined to the northern half of the basin in the NLF ecoregion.

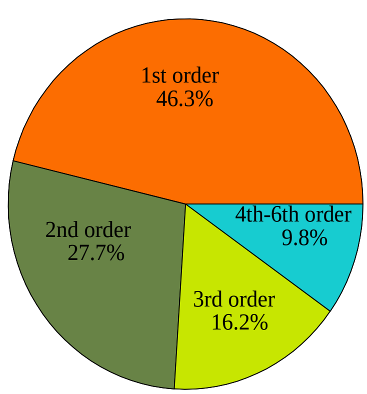
Figure 3. Vegetation and land use types for the Minnesota portion of the St. Croix River Basin as well as the NCHF and NLF ecoregions within the basin.



Rivers and Streams of the St. Croix River Basin

There are approximately 2770 km of streams in the Minnesota portion of the basin. Almost half (46%) of the streams are 1st order and approximately 74% are 2nd order or less (Fig. 4). Stream order is a general way of describing the size of a stream or river. The smallest permanent streams are called "first order." Two 1st order streams join to form a larger, 2nd order stream; two 2nd order streams join to form a 3rd order, and so on. The lower portion of the St. Croix River below the confluence with the Kettle is a 6th order stream.

Figure 4. Stream order in the St. Croix River Basin in Minnesota.



The dark, tea-colored water found in many St. Croix River Basin streams results from the decomposition of plant material from surrounding wetlands. Because of the wetland influence, headwater streams in the basin have low turbidity or muddiness. They also tend to be sinuous, low-gradient, have few riffles, and have mucky bottoms consisting of fine silts and detritus (Fig. 5).

Figure 5. (A) A wetland-influenced headwater stream (Gillespie Brook) and (B) a moderate sized stream (Upper Tamarack River) in the St Croix River Basin.

A B

Although the larger streams (4th order and above) account for a small percentage of the total stream kilometers, their watersheds encompass a large percentage of the basin. Two such streams, the Snake and Kettle Rivers, have watersheds that have a combined drainage area of 2080 mi^2, or approximately 59% of the area of Minnesota's portion of the basin. The other two major watersheds are comprised of smaller streams that enter the St. Croix along its upper and lower reaches. The middle and lower sections of the Snake and Kettle, like other moderate to large streams in the basin, have many riffles, a variety of substrate types, and a natural riparian zone consisting of woods, shrubs, and meadow. Many of these larger streams alternate between slow, sandy-bottomed pools and turbulent, boulder-strewn riffles (Fig. 5). The Kettle River Rapids on the St. Croix River and the Kettle River Gorge area on the Kettle River are two of the more spectacular examples of high-gradient reaches.

Water Quality Issues

Development in the basin has raised many issues related to the quality of rivers and streams. Water quality concerns in the St. Croix River Basin include:

Population growth and development: A high percentage of the population in the St. Croix River Basin is located in the southern portion of the basin in and around the Twin Cities metropolitan area. Half of the counties in the basin are projected to grow from 2 to 20% by 2025. The most growth is predicted to occur in Washington and Chisago Counties, both directly adjacent to the lower St. Croix mainstem, with 41% to 57% population increases predicted (Minnesota Planning 1998). Development within these highly populated areas results in impacts to rivers and streams from habitat destruction, increased point source discharges, and nonpoint run-off. Increased levels of impervious surfaces in urbanized areas exacerbate nonpoint source run-off. Impervious surface levels of 7 to 10% have been linked to significant changes in the diversity and integrity of aquatic systems (Wang et al. 2000).

Wastewater treatment: There are 40 permitted wastewater dischargers in the basin. Most of these are municipal sources that discharge treated effluent directly to surface waters (MPCA basin information document, in draft). Each permitted discharger is assigned effluent limitations, monitoring requirements, and other conditions intended to protect water resources. In addition there are 12 unincorporated and 57 incorporated communities in the basin which are considered inadequately sewered. These communities have inadequate centralized systems or rely on individual sewage treatment systems (i.e. septic systems). While these communities are not necessarily out of compliance with current regulations, their wastewater systems are not permitted through the National Pollution Discharge Elimination System (NPDES) process.

Soil erosion and sediment impacts: Soil loss from poorly managed land and inadequate riparian buffers impairs habitat for aquatic life. In many areas of the basin, the natural riparian zone along the stream has been eliminated and converted to cropland or pasture. Intact riparian buffers reduce soil loss from fields by providing a barrier between the open fields and the stream. Some soil conservation practices (e.g. conservation tillage, riparian buffer strips) are gaining acceptance within the farming community, but these gains have been slow and soil loss from farm fields continues to be a problem.

Nutrient loading from agricultural run-off: The impact of tributary nutrient loads is considered to pose a top threat to the entire St. Croix River Basin's water quality (NPS 1997). Nitrogen and phosphorus generally enter streams through run-off of fertilizers, livestock wastes, and soil erosion; direct discharges from municipal and industrial wastewater treatment facilities and livestock feedlots; precipitation; and from ground-water inflow. Excessive nutrients from these sources can lead to increased algae and plant growth, oxygen depletion, toxicity, and the presence of disease-causing organisms (MPCA 2000).

Drainage and channelization: Ditching and stream channelization compromise habitat and water quality. These drainage techniques are used throughout the basin but are much more prevalent in the southern half. Alteration of natural drainage pathways fundamentally alters the natural hydrologic cycle of streams causing changes in the flow regime and loss of habitat. Water that was once slowed by bends, pools, and woody debris in the water column is encouraged to move through the system faster by straightening the stream and removing obstructions. The faster flowing water erodes stream banks and carries with it sediment and nutrients, some of which is deposited in the downstream reaches.

The MPCA Biological Monitoring Program

Pollution control efforts have been largely successful in reducing point source pollution to rivers and streams. However, the consequences of landscape alteration and non-point source pollution on the quality of rivers and streams have been much less successfully addressed. Watershed disturbances from urban, residential, and agricultural development (e.g. road building, stream channelization, alteration of the stream’s riparian zone, and many others) contribute to an overall decrease in the physical, chemical, and biological quality of rivers and streams.

The MPCA biological monitoring program is designed to measure physical, chemical, and biological conditions in rivers and streams using an integrated approach that combines measures of fish and invertebrate community characteristics along with physical habitat assessments and water chemistry analyses. Fish and invertebrate communities are particularly useful indicators of water quality because they reside in the stream and respond directly to physical, chemical, and biological stressors (Ohio EPA 1987a, Barbour et al. 1999). Additional biological indicators (e.g. stream periphyton) may help to identify stressors that fish and invertebrates are not particularly sensitive to. Unlike traditional water chemistry indicators that can provide information about the quality of the resource at the time of sample collection, the presence of a healthy and diverse aquatic community suggests that the community has withstood and recovered from any short-term stresses that may have occurred previously.

The MPCA quantifies the results of biological surveys by developing a biological index commonly referred to as an index of biological integrity or IBI (Karr 1981). The IBI provides a framework to interpret biological data to assess water quality. Attributes (termed metrics) of fish and invertebrate communities that demonstrate a response to stress are used to calculate the IBI score. A typical IBI will include seven to 12 metrics. Metrics used to calculate an IBI vary greatly, depending on the type of aquatic community being used (e.g. fish, invertebrates, plants, etc.) and the type of water body being assessed (e.g. small streams, rivers, lakes, wetlands). A typical fish IBI may include metrics that address species richness, the abundance of different types of feeding and reproductive groups, or the condition of individual fish in the sample. Each metric value is assigned a unitless score based on how far the value deviates from a range of reference values. The term “reference” denotes sites that are least impacted by human influence. Metric values closer to the reference condition receive a higher score. When the metrics are summed the resulting IBI score characterizes the biological integrity or “health” of a site (Karr et al. 1986).

The MPCA uses the integrated approach to assess the condition of each major river basin in the state by randomly sampling a subset of the rivers and streams within the basin. The random sampling locations are provided by the U.S. EPA Environmental Monitoring and Assessment Program (EMAP). The MPCA uses a random site-selection process because a representative sample allows for the extrapolation of results from a relatively small number of sites to the entire population of rivers and streams within the basin. The same concept is used in political polling, where the results of a small number of randomly selected interviews can represent the opinions of a much larger population.

Because the results are based on a sub-sample of all streams in the basin, it is necessary to incorporate an error term when reporting the results. The error term, often expressed as a 95% confidence limit, indicates the reliability of a reported result. For example, we may conclude that the average water temperature that was measured in streams of the St. Croix River Basin was 21^{o}C $\pm$ 4^{o}C. This means that we are 95% confident that the true average temperature of all streams in the basin will fall within 4^{o}C of the average measured temperature, between 17^{o}C and 25^{o}C.

The results of this survey provide, for the first time, a statistically valid picture of the overall condition of the rivers and streams in the St. Croix River basin, showing what portion of the total waters are impaired. Future surveys will focus on other basins of the state. The first assessment in each basin will provide a baseline of current conditions; future rounds will allow the analysis of basin-wide and state-wide water quality trends, providing a picture of long-term problems as well as of the effectiveness of water quality programs.

In addition to the randomly selected sites, the MPCA conducted longitudinal surveys (i.e. a series of surveys at different locations on a stream) on three major rivers – the St. Croix, Snake, Kettle Rivers, as well as Rush Creek to develop an understanding of the longitudinal trends in water quality within each stream. Because these sites were not selected randomly the data was not used in the basin assessment.

Methods

Upstream land use in the watershed served as an indicator of potential human disturbance. Watersheds with a high degree of land use disturbance were assumed to have an increased level of environmental stressors. Upstream land use in the watershed of each site was characterized using the most recent GIS land use coverages. The land use coverage was overlaid on a watershed drainage area coverage to produce a land use coverage identical in shape and size to the watershed drainage area coverage. Land uses were then summed across the entire drainage area and divided by the total area to produce percentages for each land use. The percent watershed disturbance was calculated by adding together the percentages that were agricultural, urban or residential, grassland associated with pastured areas, and mines.

A quantitative habitat assessment was completed at each site following procedures modified from Simonson et al. (1994). The assessment provided information concerning flow, morphology, substrate, cover, and riparian land use. A habitat score was calculated for each wadeable site using a modified version of a habitat index developed as described by Niemela and Feist (2000). Because, for reference sites, both the IBI scores and the variables used to calculate the habitat index scores were correlated with stream size, regression residuals, rather than the raw values of the variables themselves, were used to calculate the habitat index scores. The residuals were taken from LOWESS (locally-weighted scatterplot smoothing) regressions of the habitat variables against (log of) mean stream width. The residuals were used for number of stream features per 100 meters, number of substrate types, percent coarse substrates, coefficient of variation of depth, and sinuosity. Residuals were not used for percent disturbed land use within 30 meters because, for reference sites, the variable should not be affected by stream size. The resulting habitat index scores range from 0 (very poor habitat) to 12 (excellent habitat).

During each site visit, grab samples of stream water were taken for chemical analysis. Water chemistry parameters included dissolved oxygen, turbidity, conductivity, temperature, pH, total suspended solids, nitrite/nitrate, total phosphorus, and total ammonia. Water chemistry results were compared to the applicable state water quality standard or ecoregion expectation (McCollor and Heiskary 1993)

Fish were collected using electrofishing techniques following procedures described in Niemela and Feist (2000) and invertebrates were collected following procedures described in Chirhart (2003). IBI scores for fish and invertebrates were calculated for each sampling event using IBI's developed specifically for streams in the St. Croix River Basin (Niemela and Feist 2000, Chirhart 2003). IBI scores ranged from 0 to

100 points. The IBI scores were divided equally into five 20-point groups and assigned a narrative rating of excellent, 80-100; good, 60-79; fair, 40-59; poor, 20-39; and very poor, 0-19. These narrative ratings were intended to provide a context for interpretation of the IBI score.

The impairment status of each stream was based on thresholds that were established by examining the range of scores at reference sites in each stream class. The biological impairment thresholds used in the assessment process were based on a common set of reference sites for streams throughout the St. Croix River Basin (TMDL guidance 2003). The reference sites were chosen by reviewing disturbed land use percentages, point source discharges, feedlots, and the prevalence of ditching throughout each watershed, as well as habitat conditions within each sampled reach. The bottom of the range in IBI scores for the reference sites was used as the impairment threshold. The impairment thresholds do not necessarily correspond to the narrative integrity classes that were described earlier. For example, the impairment threshold for streams with watershed drainage areas between 0 and 35 mi^2 using the fish IBI is 47 which corresponds to a narrative rating of fair, whereas streams with drainage areas of 35-200 mi^2 have an impairment threshold of 68 which corresponds to a narrative rating of good.

S-Plus statistical software and statistical routines developed by USEPA/EMAP were used to provide basin-wide estimates for each variable. Estimates were also made for subsets of the data based on ecoregion, stream size, and watershed disturbance level. Due to low sample sizes within these subsets, however, confidence limits surrounding the estimates were wide, and only large differences between the subsets were statistically significant. Cumulative distribution functions (CDF's) were created for each continuous variable. The CDF's graphically illustrate the cumulative stream miles at every level of the variable. For example, a CDF may show the cumulative percent of stream miles at all possible IBI scores; this may then be used to find the percent of stream miles in the basin with IBI scores equal to or less than a biologically based impairment threshold. Mean-Eigenvalue-Corrected CDF Tests were used to compare CDF's for the different data subsets. Categorical results were illustrated using bar charts.

Figure 6. (A) Target sites and (B) sites sampled for fish and invertebrates. Dashed lines represent ecoregion boundaries.

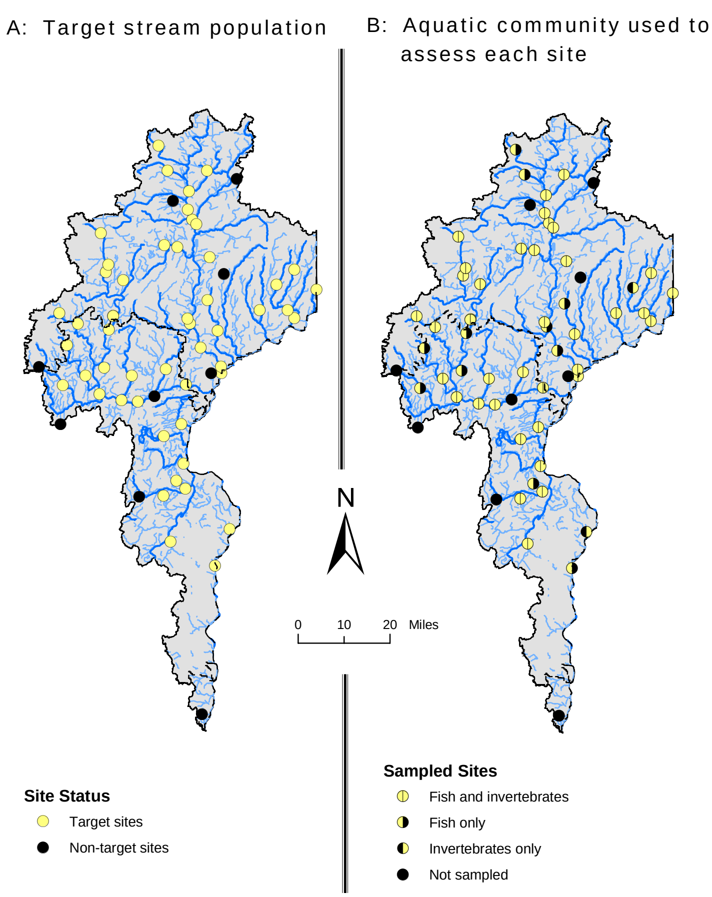
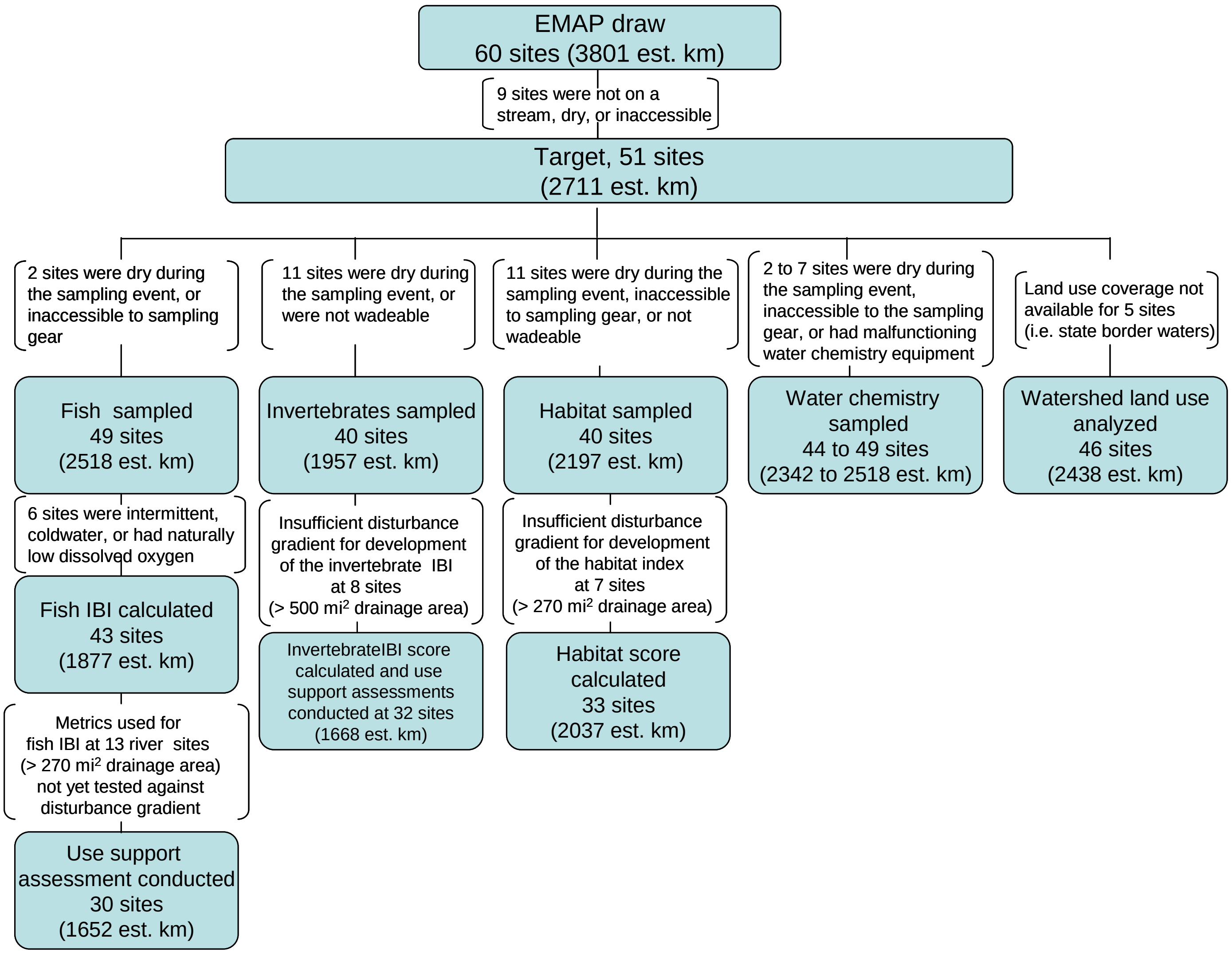


Figure 7. Flow chart showing the number of sites and estimated number of stream kilometers at different analysis levels, from the original 60 candidate sites provided by EMAP to the number of sites and estimated stream kilometers that were able to be sampled and assessed for fish, invertebrates, habitat, water chemistry, and watershed land use. Reasons for eliminating sites are provided in parentheses between each step.



Results and Discussion

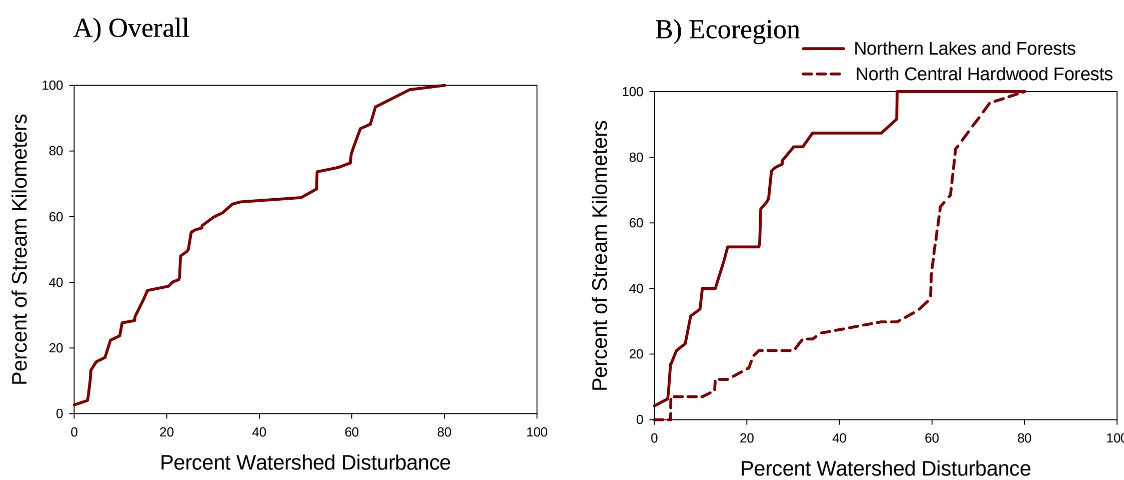
MPCA requested and received from USEPA/EMAP a list of 60 random sites within the St. Croix River Basin (Appendix 1). An initial site reconnaissance conducted in the spring of 1996 indicated that eight of the initial 60 sites were non-target (Figs. 6 and 7). That is, the intended sampling locations did not have a defined channel or flowing water and were therefore considered unsampleable. Examples of non-target sites include wetlands with undefined channels, streams with man-made impoundments or beaver dams, or dry washes or gullies. An additional site, located on private property, was considered a non-target site because the landowner denied the field crew permission to access the stream across his property.

The omission of the nine non-target sites left 51 sites from which conclusions about the water quality in the basin could be made. The 51 sites represented a total of 2711 km of rivers and streams. However, target sites were often omitted from the analysis for a variety of reasons (Fig. 7). The omission of target sites from the analysis affects how the data is interpreted. For example, invertebrate sampling was limited to sites that were wadeable. This restriction limited sampling for invertebrates to 40 of the 51 target locations and interpretation of the data to 1957 km out of a possible 2711 km target streams in the basin (Figs. 6 and 7). Likewise the fish sampling occurred at a subset of the target population: 49 sites representing 2518 stream km. The two target sites were omitted from the analysis because one was inaccessible with the required sampling gear and the other contained no water during the summer index period. Fish IBI scores were not calculated for target sites on coldwater or intermittent streams. Thus, IBI scores for fish were calculated for 43 sites representing 1876 km (Figs. 6 and 7). Similar sampling restrictions affected the land use, habitat, and water chemistry results.

Land Use in the Watershed

The basin-wide median proportion of watershed disturbance was 25%. However, the distributions of

Figure 8. CDF's of percent of watershed disturbance (i.e. land being used for agriculture, urban and residential development, and mining activities) for the basin (A) and for each major ecoregion (B).



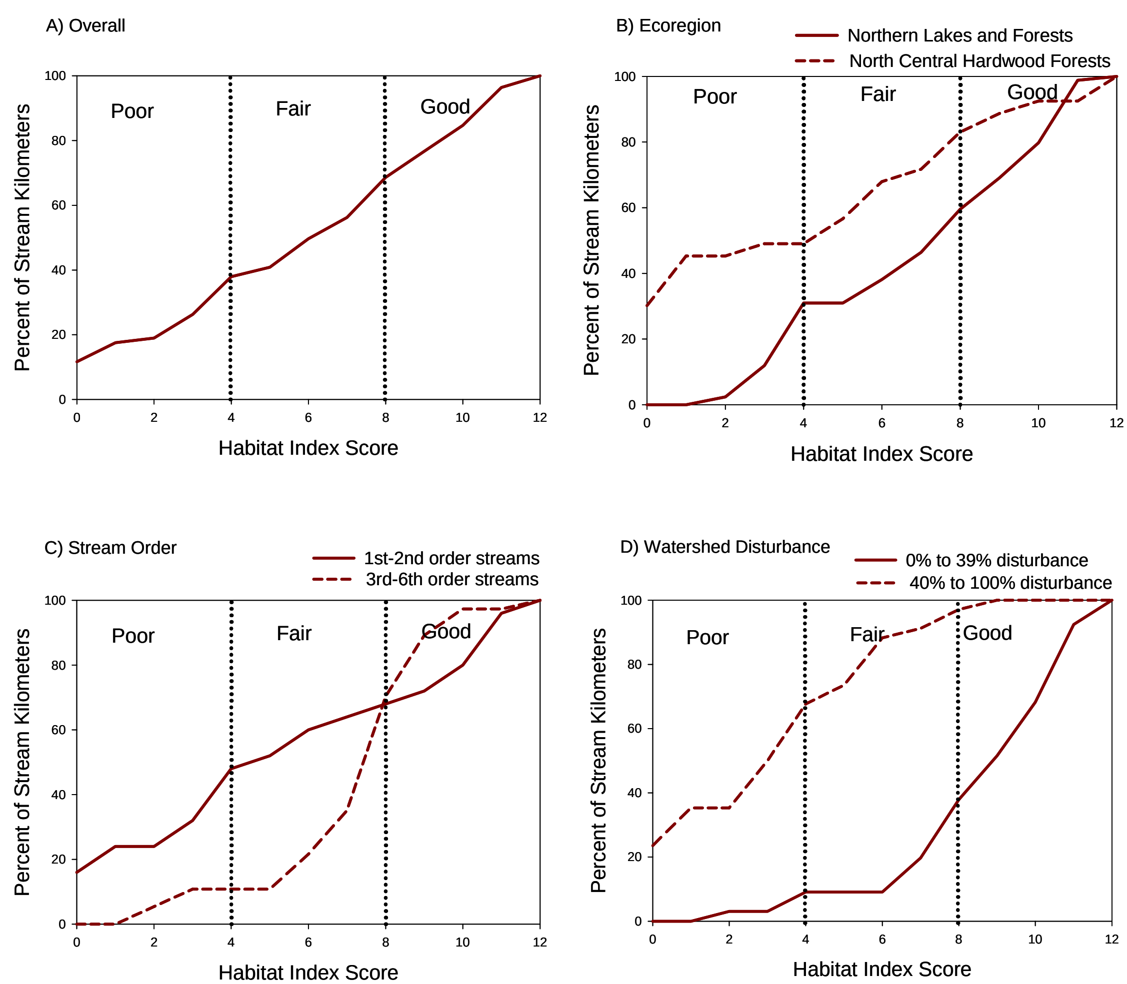
A cumulative distribution function (CDF) shows how a specific variable varies across an entire population. Each point on the curve shows the probability that the variable is no larger than a certain magnitude. In the case of figure 8A, the population is the streams in the St. Croix Basin and the variable is the percent of watershed disturbance. Since no streams were found with more than 80% of their watershed developed, the graph shows that the probability is 100% that any particular stream's watershed is 80% or less disturbed. Likewise, half of the streams in the basin were found to have more and half were found to have less than 25% of their watershed developed, and the graph shows that the probability associated with this (median) value is 50%.

watershed disturbance differed significantly between ecoregions (Mean-Eigenvalue-Corrected CDF Test, $p<0.05$, Fig. 8). Approximately 34% of stream kilometers in the basin had watersheds with over 50% watershed disturbance; however, no watershed in the basin was over 80% disturbed. Most of the disturbed land was rangeland (median value = 18%) that was used for low-intensity farming (i.e. pastures, hay fields, etc.). Intensive farming practices such as row-crop agriculture and sod farms comprised less than 7% of the basin area. These farming practices were even less common in the NLF, where 36% of watersheds did not have any intensive agriculture and no watershed had more than 5% land in intensive agriculture. With the exception of the development surrounding the Twin Cities metropolitan area, urban and residential land use occurred sporadically, if not infrequently, throughout the basin. Nearly all of the watersheds in the NLF ecoregion had less than 1% urban and residential land use. Urban and residential land use was somewhat more common in the NCHF, in some instances approaching 4%.

Habitat

The median basin-wide habitat index score was approximately six (out of a possible 12). A score of eight or above is considered good. Approximately 74% of all streams in the basin had fair to good habitat conditions (i.e. a habitat index score of at least four; Fig. 9). A typical 100-meter stream reach had four major changes in stream character (e.g. a shift from riffle to pool, a pronounced stream bend, or a large accumulation of woody debris), four substrate types with 23% being coarse substrate, a sinuous channel structure, a wide variation in stream depth, and very little disturbance in the stream corridor (Fig. 10).

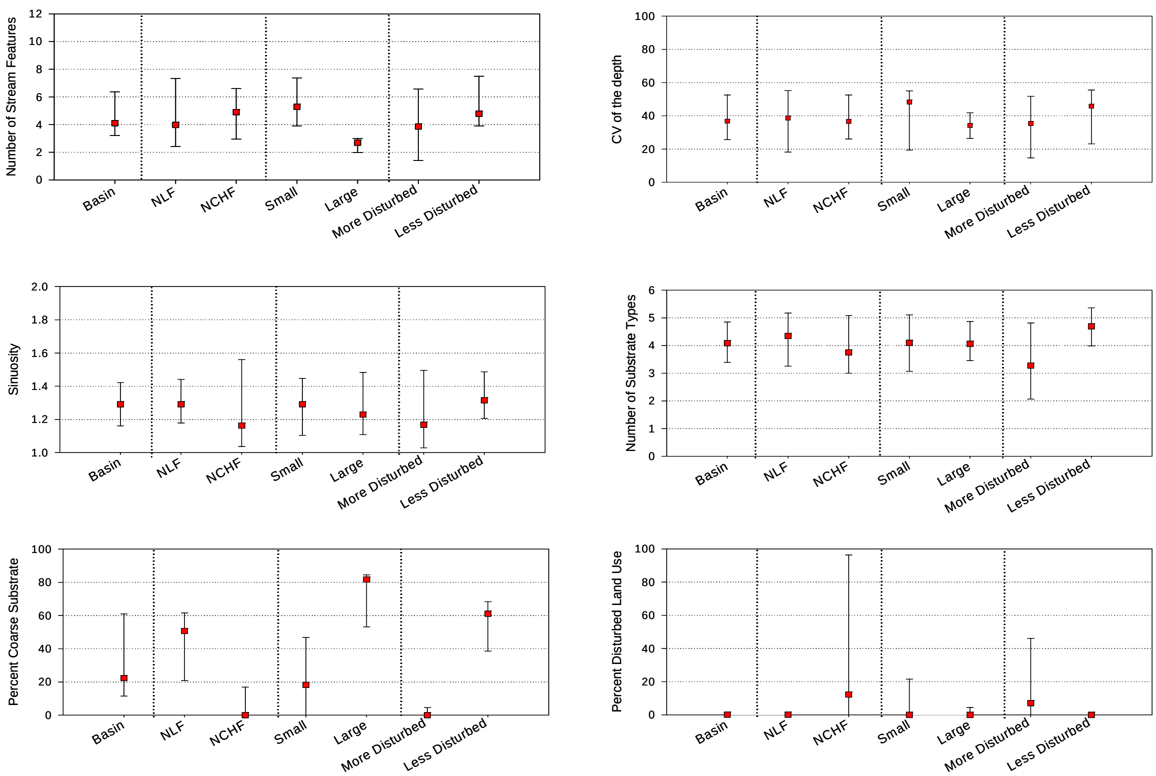
Figure 9. CDF's of habitat index score for the basin, each major ecoregion, two stream size classes, and two watershed disturbance levels.



Streams in the NCHF had substrates that consisted primarily of fine material (e.g. sands, silts) while NLF streams had more coarse material (e.g. gravel, cobble, boulder). The differences in substrates may be due to the composition of the parent material. In a large portion of the NCHF, receding glacial melt waters formed a large sandy plain known as the Anoka Sand Plain. This large area of glacial outwash originated from a large glacial lake (Glacial Lake Grantsburg) which covered a large portion of the lower St. Croix River Basin. The glacially derived parent material in the NLF tends to be considerably coarser. The difference in substrate sizes between ecoregions may also be related to disturbance within the 30-meter riparian zone. Natural stream riparian corridors protect the stream from bank erosion and overland run-off of fine sediments. Most of the streams in the NLF maintain an intact riparian buffer close to the stream, whereas in the NCHF development within the stream corridor is more common (Fig. 10).

The CDF of the habitat index scores for 1st and 2nd order streams was significantly different from that for 3rd through 6th order streams (Mean-Eigenvalue-Corrected CDF Test, $p<0.05$, Fig. 9). Habitat variables

Figure 10. Median values, with lower and upper 95% confidence limits, for each variable used to calculate the habitat index score. Values are provided for the basin, each major ecoregion, two stream size classes, and two watershed disturbance levels.



with medians that differed significantly ($p<0.05$) by stream size were the number of stream features per 100 meters and the percent coarse substrates (Fig. 10). Coarse substrates occurred more often in large streams (median = 82%) than in small streams (median = 18%). Also, large streams had significantly less stream features (median = 2.7) than small streams (median = 5.3). . However, this was not unexpected because larger streams generally have a greater distance between major morphological shifts.

Watershed land use was related to stream habitat. The CDF of the habitat index score differed significantly in streams that had less than 40% disturbance in the upstream watershed versus streams that had greater than 40% disturbance (Mean-Eigenvalue-Corrected CDF Test, $p<0.05$, Fig. 9). Likewise, the CDF's of three of the six habitat variables (or their residuals) used to calculate the habitat index score differed significantly by level of watershed disturbance. Streams with more-disturbed watersheds had fewer coarse substrates and stream features and less bottom contour variability.

These habitat differences suggest that stressors associated with a higher level of watershed disturbance are influencing stream habitat by decreasing the abundance of key habitat parameters thought to be important to fish populations. The lack of habitat heterogeneity in more-disturbed watersheds may also have a negative influence on other aquatic organisms that are sensitive to habitat changes or that have more specific habitat requirements.

Relationships between habitat index and IBI scores in the St. Croix River Basin were statistically significant for fish (Spearman's Rank Correlation, $p<.05$, Appendix 2) and nearly significant for invertebrates. For the individual variables used to compute the habitat index scores, (the residuals for) number of stream features per 100 meters, percent coarse substrates, and coefficient of variation of depth had statistically significant correlations with fish IBI's; the latter two individual variables had statistically significant correlations with invertebrate IBI's. The number of substrate types, sinuosity, and percent disturbed land use within 30 meters were not statistically correlated with the fish or invertebrate IBI score. The lack of relationships for some of the habitat factors may reflect a need for further development of the habitat index.

Water Chemistry

Approximately 31% of all streams (770 km) did show exceedances of a water chemistry standard, meaning that they had at least one single-sample chemical measurement that failed to meet the water quality standard for at least one of the four measured parameters – dissolved oxygen, pH, un-ionized ammonia, or turbidity – for which standards exist (Fig. 11). The large majority of these exceedances, however, were on small, low-gradient, wetland-influenced streams with fine substrates and no riffles, where low dissolved-oxygen and pH levels are likely the result of natural conditions rather than human-induced changes.

With regard to ecoregions, water chemistry measurements were generally better in the NLF than in the NCHF, with statistically significant differences in CDF's found for conductivity, ammonia, and turbidity (Mean-Eigenvalue-Corrected CDF Test, $p<0.05$, Fig. 12). However, the one-time water chemistry samples of most streams – approximately 73% in the NCHF and 88% in the NLF – failed to meet ecoregion expectations (McCollor and Heiskary 1993) for least-impacted streams for at least one of the measured parameters. The fact that 82% of the streams in the basin with low (<40%) watershed disturbance levels exceeded ecoregion expectations, yet had generally good water quality as evidenced by the basin-wide fish and invertebrate IBI scores, suggests that NCHF and NLF ecoregion expectations may merit reexamination.

With regard to stream order, water chemistry measurements were generally better in larger streams than in smaller streams, with statistically significant differences in CDF's found for dissolved oxygen, ammonia, turbidity, and total suspended solids (Mean-Eigenvalue-Corrected CDF Test, $p<0.05$, Fig. 13). Again, the low dissolved oxygen levels observed in smaller order streams may reflect the fact that many of the basin's headwater streams are low-gradient and wetland-influenced, with fine substrates and few riffles.

With regard to watershed disturbance, water chemistry measurements were generally better in streams with less-disturbed watersheds. There were significant differences in CDF's for turbidity and dissolved oxygen, (Mean-Eigenvalue-Corrected CDF Test, $p<0.05$, Fig. 14). Conductivity and phosphorus concentrations were generally lower in watersheds with a lower level of disturbance, but these differences were not statistically significant.

Relationships between water chemistry and IBI's in the St. Croix River Basin were not particularly strong (Appendix 2). Weak but statistically significant correlations were found between fish IBI scores and turbidity, total suspended solids, conductivity, and total phosphorus (Spearman's Rank Correlation, $p<0.05$). Significant correlations were found between invertebrate IBI scores and conductivity. The lack of strong relationships probably reflects the generally good water quality found in the basin. A greater range of chemistry measurements would likely show greater correlation.

Figure 11. CDF's of the water chemistry variables for the St. Croix River Basin. Vertical dotted lines represent the applicable Minnesota water quality standard.

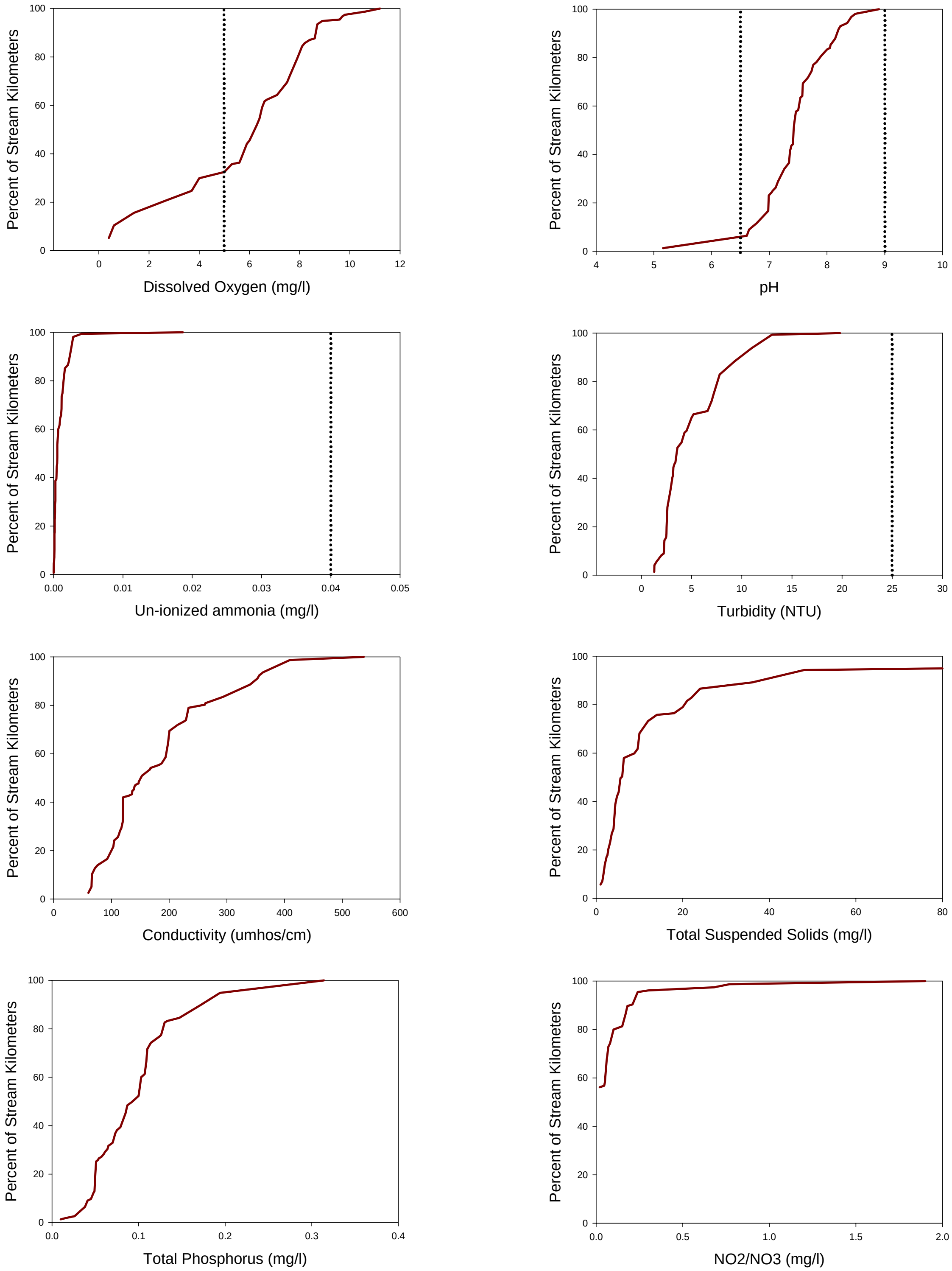


Figure 12. CDF's of the water chemistry variables for the two major ecoregions in the St. Croix River Basin. The vertical dotted lines represent the applicable Minnesota water quality standard. The vertical solid line represents the ecoregion expectation for the NLF ecoregion and the vertical dashed line represents the ecoregion expectation for the NCHF ecoregion.

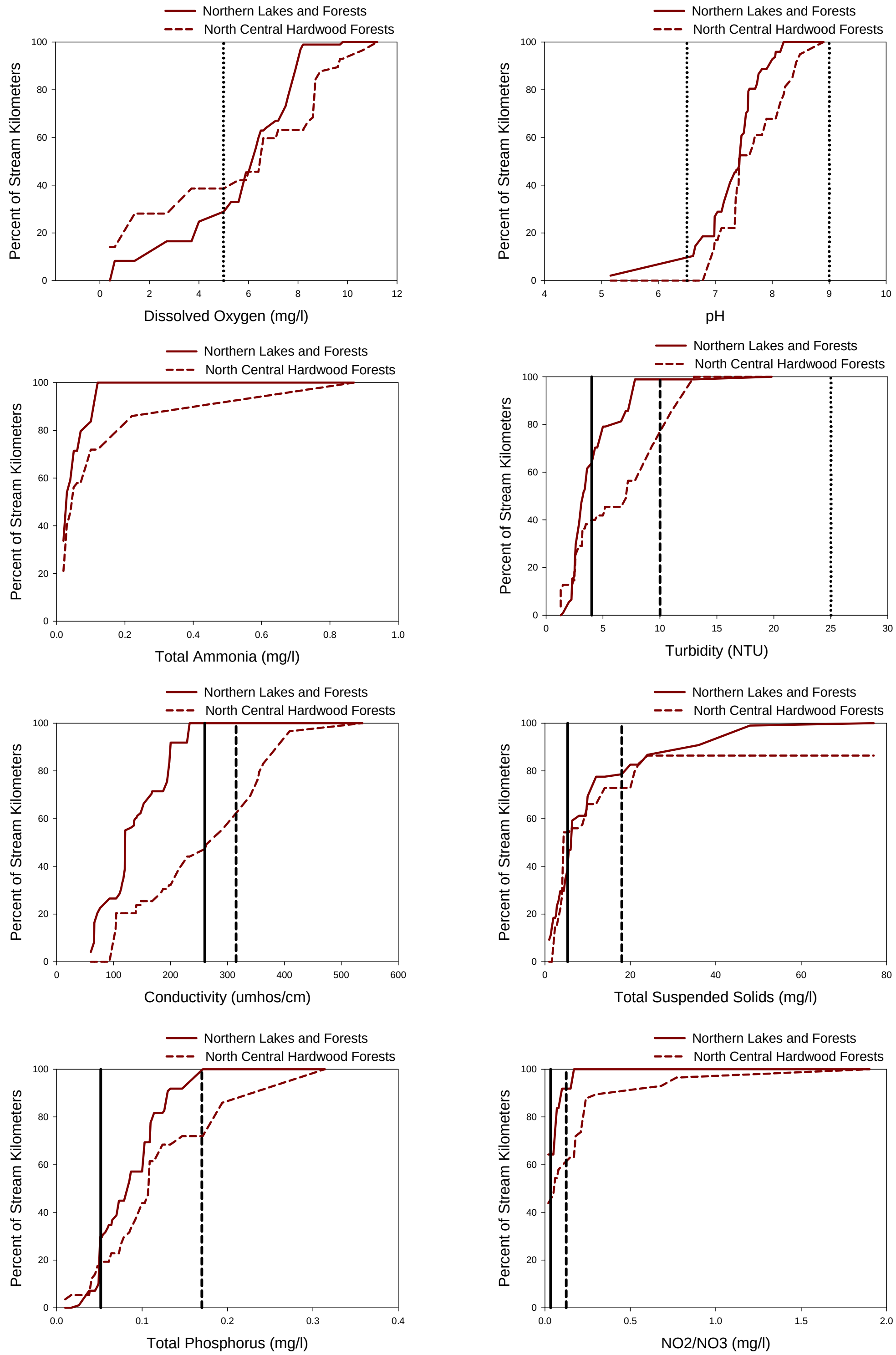


Figure 13. CDF's of the water chemistry variables for two stream size classes in the St. Croix River Basin. The vertical dotted lines represent the applicable Minnesota water quality standard.

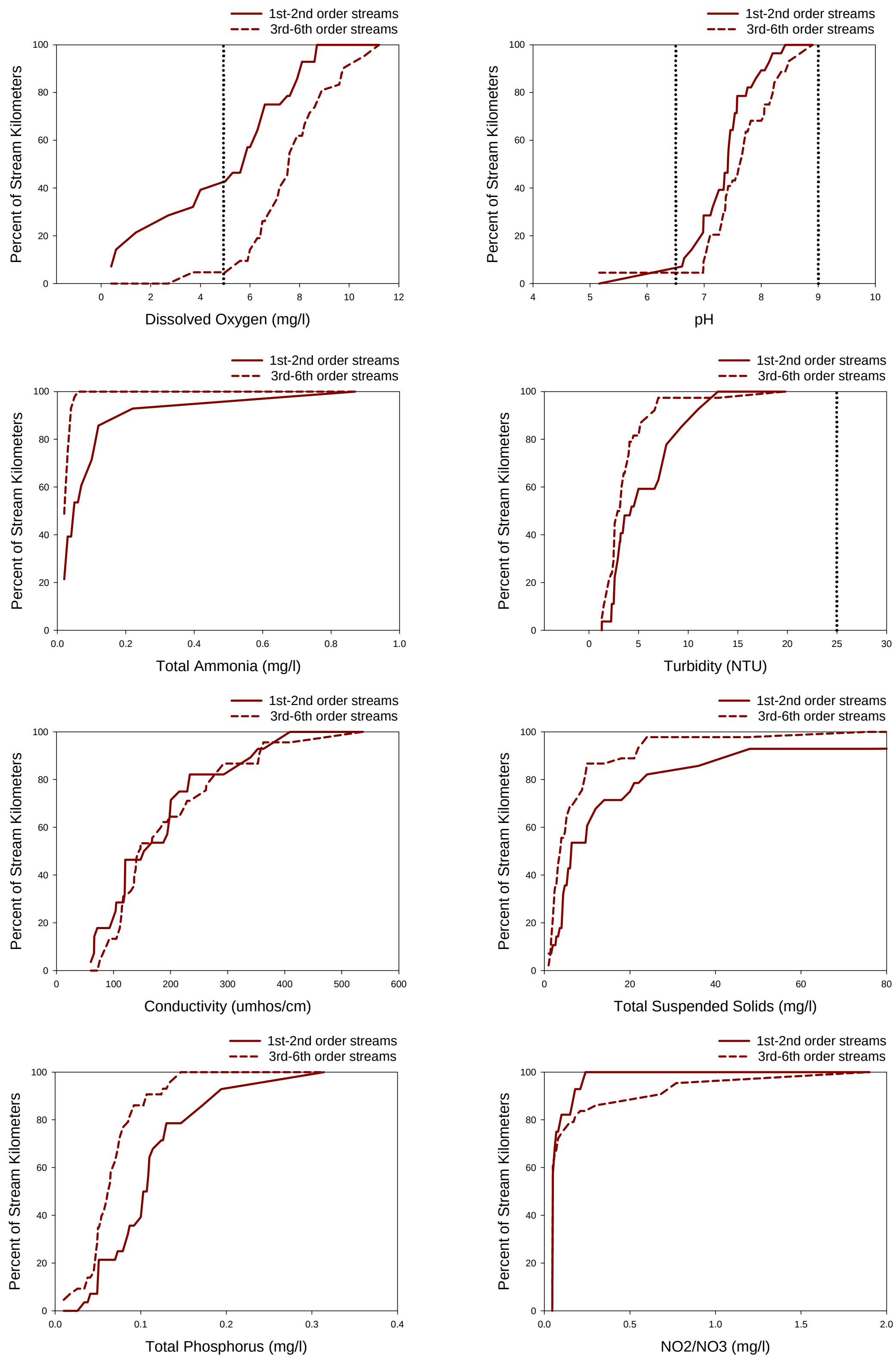
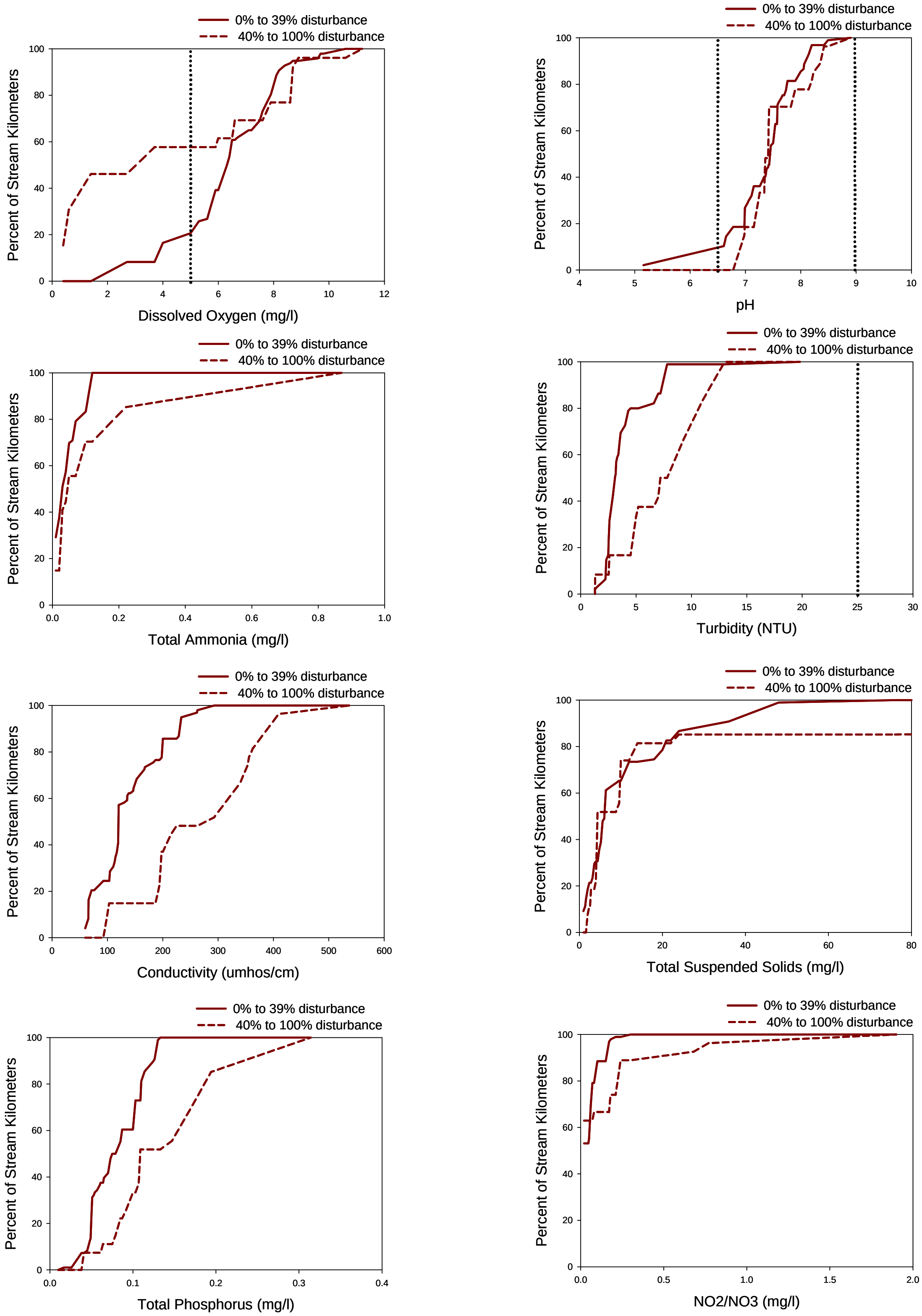


Figure 14. CDF's of the water chemistry variables for two watershed disturbance levels in the St. Croix River Basin. The vertical dotted lines represent the applicable Minnesota water quality standard.



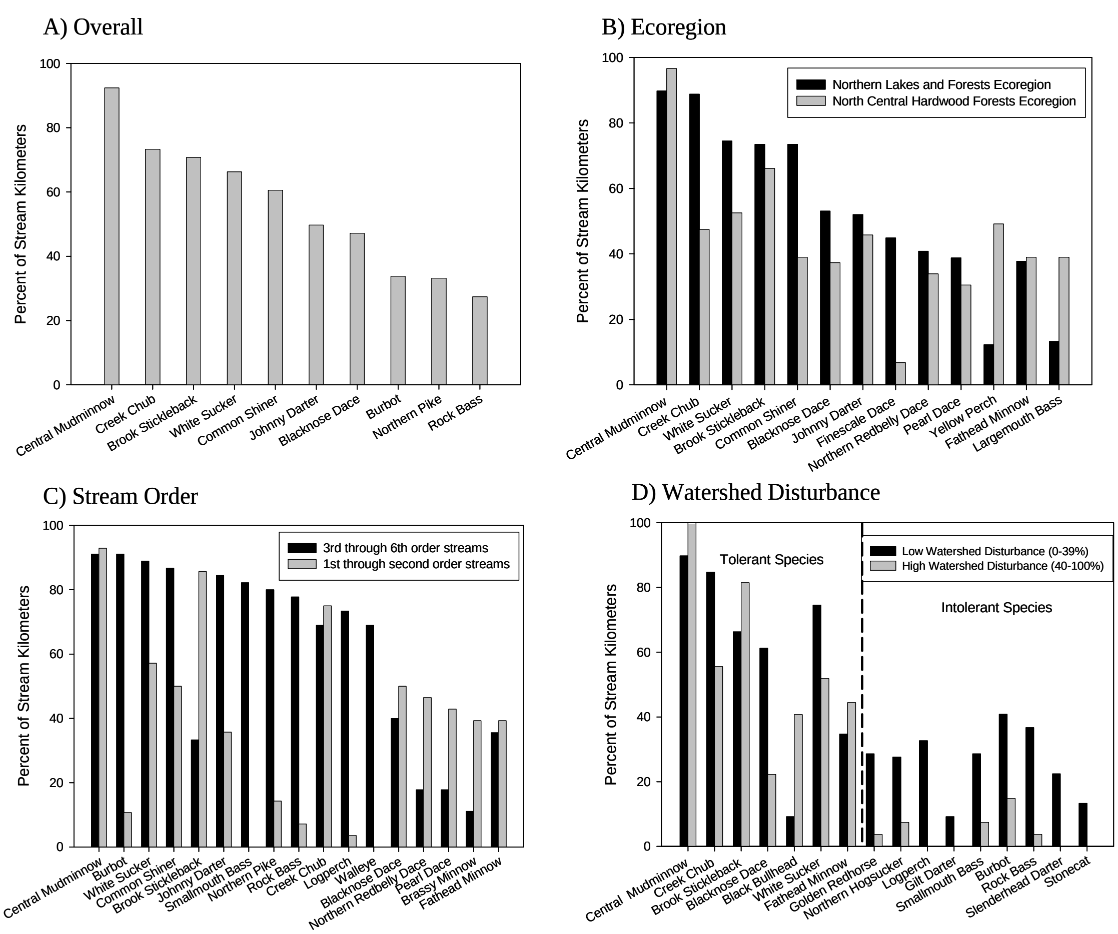
The Fish Community

General Characteristics

The St. Croix River Basin supports a diverse fish assemblage. Fago and Hatch (1993) list 110 species of fish representing 24 families occurring in the (entire) St. Croix River Basin (Appendix 3). A dam at St. Croix Falls has been a barrier to fish migration for over 80 years. One hundred and three fish species have been reported from the lower portion of the basin below the falls, compared to 84 above St. Croix Falls dam (Fago and Hatch 1993). Fago and Hatch (1993) list seven species that have not been collected within the basin since 1974.

Seventy one fish species were collected during the study period. The four most prevalent species encountered in the basin were the central mudminnow (*Umbra limi*), creek chub (*Semotilus atromaculatus*), brook stickleback (*Culaea inconstans*), and the white sucker (*Catastomus commersoni*) (Fig. 15). These species are considered tolerant of pollution, but their prevalence in the St. Croix River Basin is more likely due to their ability to inhabit streams of all sizes as well as of all qualities. These four species were nearly equally as prevalent in streams with high watershed disturbance as in streams with low watershed disturbance. The rock bass (*Ambloplites rupestris*), the only intolerant species present in the top 10 most common species, was present in 27% of the streams.

Figure 15. Fish species occurrence for the St. Croix River Basin (A), each major ecoregion (B), two stream size classes (C), and two watershed disturbance levels (D).



There was only a moderate difference on the most dominant species between ecoregions (Fig. 15). Creek chubs, common shiners, and finescale dace (*Phoxinus neogaeus*) were relatively more common in the NLF ecoregion, while yellow perch (*Perca flavescens*) and largemouth bass (*Micropterus salmoides*) were found relatively more often in the NCHF ecoregion.

Fish species composition was influenced significantly by stream size (Fig. 15). The most prevalent fish species in 1st and 2nd order streams were similar to those for the basin as a whole. Of the most prevalent species, however, the burbot (*Lota lota*), white sucker (*Catostomas commersoni*), and common shiner (*Luxilus cornutus*) were more common in 3rd through 6th order streams than in 1st and 2nd order streams. Game fish species such as the northern pike (*Esox lucius*), smallmouth bass (*Micropterus dolomieui*), walleye (*Sander vitreus*), and rock bass were found infrequently throughout the basin but were much more common in 3rd through 6th order streams. The lack of game fish in small streams should not be considered evidence that small streams are unimportant to game fish species. Small streams are well known to be critical spawning areas for many game fish species, and provide critical habitat for smaller fish species that game fish are dependent on for food.

The level of disturbance in the watershed influenced the composition of the fish community. Intolerant species such as the logperch (*Percina caprodes*), gilt darter (*Percina evides*), slenderhead darter (*Percina phoxocephala*), and stonecat (*Noturus flavus*) disappeared completely from streams with a high level of disturbance and species such as the golden redhorse (*Moxostoma erythrurum*), smallmouth bass (*Micropterus dolomieui*), northern hogsucker (*Hypentelium nigricans*), Burbot (*Lota lota*), and rock bass occurred much less frequently. Tolerant species tended to be pervasive throughout the basin regardless of the level of disturbance. Exceptions included the black bullhead (*Ameiurus melas*) which occurred in only 9% of streams with a low level of disturbance and the blacknose dace which occurred in only 22% of streams with a higher level of watershed disturbance.

Species Richness and Composition

The basin-wide median number of fish species per sample was 9.6 (Table 1). As expected, the median number of fish species in 1st and 2nd order streams (median = 7.0) was significantly lower than in 3rd through 6th order streams (median = 18.5). Species richness was not significantly influenced by ecoregion but nearly significant (p=0.057) with watershed disturbance level (as measured using GIS-based land use coverages). There was a difference in the median species richness values of 4 species (10.6 versus 6.6) between highly developed watersheds ($\geq$40%) and less developed watersheds (<40%).

Others have demonstrated that fish species richness typically decreases as environmental degradation becomes more severe (Leonard and Orth 1986). Similarly, this data suggests that stressors associates with land use development within watersheds of the St. Croix River Basin are having an effect on species richness even though intensive agricultural practices (i.e. row crops) and urban development comprise only 17% of the basin area. Differences in species richness due to watershed land use may have been greater had this study been specifically designed for that purpose. While EMAP study designs are an appropriate design for estimating the conditions within a large watershed or basin, biological responses to disturbance may be less apparent because the extreme conditions on either end are not as likely to be sampled.

Darters prefer fast water that flows over sediment-free, coarse substrates (Appendix 3). Eight darter species were collected during the survey (Appendix 3). The specific habitat requirements of darters make this group of fishes a sensitive indicator of water quality degradation. Darters tend to disappear in streams that have been affected by siltation or channelization. The median number of darter species encountered throughout the St. Croix River Basin was 0.2 (Table 1). Darter species were significantly less prevalent in small streams and in streams with a higher level of watershed disturbance (Table 1, p<0.05).

Minnows are an important and diverse component of the fish community in most warm or cool water streams throughout the Midwest. Because minnows exhibit a wide range of food and habitat preferences this group of fish is sensitive to a wide range of environmental degradation. Twenty one minnow species were collected during the survey (Appendix 3). The median number of minnow species was 2.3 (Table 1).

The number of minnow species was not significantly different between the two ecoregion, stream size, and watershed disturbance groups (Table 1, $p>0.05$).

Fish species such as the northern redbelly dace and finescale dace are commonly found in headwater streams that have retained their connection to riparian wetlands. Riparian wetlands are effective stream buffers, filtering contaminants, trapping sediment, and mitigating flow extremes. Removal of riparian wetlands, ditching, and tiling will eliminate or destabilize these systems and reduce the amount of available fish habitat. Four headwater species were collected during the survey (Appendix 3). Stream size and ecoregion had a significant influence on the occurrence of headwater species (Table 1, $p<0.05$).

Tolerance and Dominance

The presence of intolerant fish species in a stream is an indication of a high quality resource (Appendix 3). Intolerant fish species are often the first species to disappear following a disturbance. As a result, most intolerant fish species have experienced a reduction in their distribution (i.e. range) coinciding with human development. Twenty intolerant species were encountered in the St. Croix River Basin (Appendix 3). Intolerant species were much more common in large streams (median = 4.9) than in small streams (median = 0, Table 1, $p<0.05$)). Significantly more intolerant fish species were present in streams in watersheds with a low level of disturbance (Table 1, $p<0.05$). There was no relationship with ecoregion and the number of intolerant species (Table 1, $p>0.05$).

Some fish species are better able to adapt to a change in environmental conditions brought about by natural or human-induced disturbance. These tolerant species often become dominant in streams that have been physically altered by channelization, siltation, or other hydrologic modifications, or chemically altered by chronically low dissolved oxygen levels, high levels of ammonia, other toxic substances, or high turbidity (Lyons 1992). Most tolerant species have expanded their ranges as a result of human influence. Ten tolerant fish species were collected during the survey (Appendix 3). The proportion of tolerant species ranged from 0% to 99% with a basin-wide median of 76% (Table 1). The median percent tolerant species in small streams was statistically greater (88%) in small streams than in large streams (17%, $p<0.05$). Tolerant species naturally tend to be much more common in small streams because they are more able to adapt to these inherently more stressful environments. There was also a relationship with watershed disturbance and the proportion of tolerant species (Table 1, $p<0.05$). The median proportion of tolerant species in streams with a low level of watershed disturbance was 68% compared with 94% in streams with a high level of watershed disturbance.

In degraded streams there are often a few fish species that will tend to dominate the community, out-competing other less adaptive species. In the St. Croix River Basin the dominant two species comprised a median of 63% of the total number of individuals in the fish samples (Table 1). The fish community in the NCHF ecoregion, small streams, and streams with a higher level of watershed disturbance tended to have a higher degree of dominance by two species (Table 1, $p<0.05$).

Trophic Composition and Reproductive Function

Invertivores and benthic invertivores are specialized feeders that are dependent upon a stable invertebrate food base, the latter acquiring its food near the substrate (Appendix 3). Disruptions in the food base through human disturbance can lead to a decrease in the number of these species. For benthic invertivores, degradation of the substrate (e.g. channelization, siltation) can be particularly harmful. Thirty seven invertivore species and 19 benthic invertivore species were collected during the survey (Appendix 3). There were statistically more invertivore and benthic invertivore species in large streams and in streams with a low level of watershed disturbance (Table 1, $p<0.05$).

Omnivorous fish species consume both plants and animals. The ability to utilize multiple food sources allows omnivorous species to switch to another food source when one type of food is disrupted. A fish community dominated by omnivorous species indicates that there is an unstable food base. Seven omnivorous species were collected during the survey. The number of omnivore species was not influenced by ecoregion, size class, and watershed disturbance level (Table 1, $p>0.05$).

The diet of piscivorous species is primarily composed of other fish. The majority of fish that are considered game fish, such as the northern pike (*Esox lucius*), walleye (*Sander vitreus*), and smallmouth bass, are piscivores. The position of piscivores at the top of the food chain makes them excellent indicators of disturbances that occur at the lower trophic levels (Karr et al. 1986). Nine piscivorous species were collected during the survey. The proportion of piscivorous fish species ranged from 0% to 48%. The number of gamefish species ranged from 0 to 9. Both the proportion of piscivore species and the number of gamefish species were significantly greater in large streams compared to small streams ($p<0.05$). There were no statistically significant differences due to ecoregion or watershed disturbance level ($p>0.05$).

Some fish species broadcast their eggs over coarse substrates and exhibit no parental care of the developing embryos. These species have been identified as simple lithophilic spawners (Balon 1975, Appendix 3). Their developing embryos require a continuous flow of clean, well-oxygenated water. Thus, reproduction of these species can be impacted when silt and other fine particulates fill in the interstitial spaces of the coarse substrates, reducing the amount of available habitat for spawning and smothering the developing embryos (Berkman and Rabeni 1987). Nineteen simple lithophilic fish species were collected during the survey (Appendix 3). The proportion of simple lithophilic fish ranged from 0% to 81% (median = 20%, Table 1). Simple lithophilic spawning fish tended to occur more often in the NLF ecoregion, larger streams, and streams with low watershed disturbance, although the comparison was not statistically significant for ecoregion ($p>0.05$)

Fish Abundance and Condition

Very low numbers of fish within a reach can be an indication of water quality or habitat problems. The median number of fish captured in a 100-meter stream reach was 40 (Table 1). There were more fish captured per meter in large streams than in small streams ($p<0.05$) but there was not a statistically significant relationship between ecoregion or watershed disturbance and the number of fish per meter ($p>0.05$).

External anomalies such as deformities, eroded fins, lesions, or tumors are often indicative of exposure to industrial pollutants. These anomalies were found very infrequently throughout the St. Croix River Basin (median = 0%, Table 1) but were somewhat more common in the larger streams ($p<0.05$).

Special Concern Species

Minnesota does not currently list any of the fish species in the St. Croix River Basin as endangered. However, the paddlefish (*Polydon spathula*) is listed as threatened and nine other species known to occur within the basin are listed as special concern (Appendix 3). Three special concern species were collected during the survey: the gilt darter (*Percina evides*), the southern brook lamprey (*Ichthyomyzon gagei*), and the lake sturgeon (*Acipenser fulvescens*). These species occurred in only 11% of the streams. Most of the sites (37 out of 49) did not have any special concern fish species and only four sites contained more than one. The MDNR has determined that special concern species deserve careful monitoring because they are extremely uncommon in Minnesota and often have unique or highly specific habitat requirements. Streams harboring special concern fish species tended to be larger and in better condition than streams that did not have special concern species. The gilt darter, a large river species that requires clear, continuously flowing water and coarse substrates, was collected in four rivers in the basin: the St. Croix, Snake, Kettle, and Lower Tamarack. The southern brook lamprey was collected from the St. Croix, Snake, Pine, and East Fork Crooked Creek. The adult southern brook lamprey inhabits clear, moderate size to large rivers over coarse substrates; however the larval lamprey (i.e. ammocoetes) inhabits slack water areas with accumulations of leaves and other woody debris. The lake sturgeon, collected from the St. Croix and Snake Rivers, occupies the deep pool areas of large rivers. Recent declines in lake sturgeon populations nationwide are likely due to poor water quality and migration barriers (locks and dams).

Table 1. Median values for the fish IBI and its metrics. Values in bold indicate that the CDF's (for the two categories of ecoregion or stream order or disturbance level) are statistically significantly different ($p<0.05$).

IBI Score and Fish Community Attributes	**All Streams**		**Ecoregion**				**Stream Order**				**Watershed Disturbance Level**			
			Northern Lakes and Forests		**North Central Hardwood Forests**		**1st and 2nd**		**3rd through 6th**		**Low (0-39%)**		**High (40-100%)**	
	median	95% CI	median	95% CI	median	95% CI	median	95% CI	median	95% CI	median	95% CI	median	95% CI
IBI Score	63.5	57.4-69.3	65.9	58.3-71.7	52.5	40.1-64.1	59.0	52.1-70.5	68.2	61.9-73.9	**66.8**	**59.9-72.1**	**41.8**	**11.3-59.7**
Fish IBI Metrics														
Number of fish taxa	9.6	6.8-15.2	9.6	7.2-13.2	6.9	2.0-16.9	**7.0**	**4.4-9.9**	**18.5**	**16.9-21.7**	10.6	7.4-16.3	6.6	2.0-15.3
Number of headwater fish taxa w/o tolerant taxa	0.0	0.0-1.1	**0.5**	**0.0-1.8**	**0.0**	**0.0-1.0**	**1**	**0.0-2.0**	**0.0**	**0.0-0.0**	0.0	0.0-1.3	0.2	0.0-2.1
Number of minnow taxa w/o tolerant taxa	2.3	1.4-2.8	2.5	1.7-3.1	1.9	0.0-3.3	2.2	0.2-3.0	2.5	1.9-3.2	2.4	1.8-2.9	1.3	0.0-3.6
Number of darter taxa	0.2	0.0-1.0	0.2	0.0-1.2	0.2	0.0-1.6	**0.0**	**0.0-0.3**	**2.3**	**1.8-2.8**	**0.8**	**0.0-1.7**	**0.0**	**0.0-0.2**
Number of intolerant fish taxa	0.0	0.0-1.1	0.0	0.0-0.9	0.0	0.0-3.2	**0.0**	**0.0-0.0**	**4.9**	**4.2-5.8**	**0.4**	**0.0-3.4**	**0.0**	**0.0-0.0**
Percent of individual fish that are tolerant taxa	76.4	55.6-88.5	74.9	48.5-86.9	92.9	32.4-99.4	**87.6**	**76.2-93.1**	**17.3**	**10.9-28.7**	**68.1**	**45.3-76.9**	**93.5**	**74.3-99.6**
Percent of ind. fish that are the dominant two taxa	62.6	54.7-76.7	**62.2**	**53.8-67.5**	**85.1**	**40.7-99.5**	**71.3**	**62.3-89.2**	**43.9**	**39.3-47.1**	**58.6**	**51.9-63.5**	**89.4**	**84.0-99.6**
Number of invertivore taxa w/o tolerant taxa	1.8	1.0-4.3	1.7	1.1-4.3	2.7	0.0-7.1	**1.0**	**0.2-1.8**	**8.2**	**7.3-9.0**	**2.6**	**1.2-5.6**	**0.9**	**0.0-3.3**
Number of benthic invertivore fish taxa	0.5	0.0-1.8	0.4	0.0-1.9	1.1	0.0-5.0	**0.0**	**0.0-0.6**	**6.4**	**5.8-6.8**	**1.4**	**0.0-3.4**	**0.0**	**0.0-1.1**
Number of omnivore fish taxa	0.6	0.2-1.0	0.6	0.3-0.9	0.6	0.0-2.0	0.4	0.0-1.1	0.9	0.7-1.2	0.6	0.3-1.0	0.3	0.0-2.5
Percent of individual fish that are piscivores	0.1	0.0-1.7	0.0	0.0-1.3	0.2	0.0-7.2	**0.0**	**0.0-0.1**	**12.3**	**9.5-18.1**	0.4	0.0-2.9	0.0	0.0-3.1
Percent of ind. fish that are lithophilic spawners	19.6	5.0-33.7	21.9	12.6-45.7	2.8	0.0-36.8	**5.2**	**1.2-20.7**	**50.0**	**40.0-59.6**	**33.7**	**20.7-47.7**	**1.1**	**0.0-7.5**
Number of fish per meter w/o tolerant taxa	0.4	0.3-0.6	0.5	0.4-0.7	0.1	0.0-0.8	**0.4**	**0.1-0.5**	**0.6**	**0.4-0.9**	0.5	0.4-0.7	0.1	0.0-0.5
Percent of individual fish with DELT anomalies	0.0	0.0-0.2	0.0	0.0-0.3	0.0	0.0-0.2	**0.0**	**0.0-0.1**	**0.3**	**0.2-0.5**	0.1	0.0-0.3	0.0	0.0-0.0
Other Fish Community Attributes														
Number of game fish taxa	0.0	0.0-1.6	0.0	0.0-0.7	1.4	0.0-4.2	**0.0**	**0.0-0.0**	**4.3**	**3.5-5.1**	0.3	0.0-2.2	0.0	0.0-2.7
Number of special concern fish taxa	0.0	0.0-0.0	0.0	0.0-0.0	0.0	0.0-0.0	0.0	0.0-0.0	0.0	0.0-0.0	0.0	0.0-0.0	0.0	0.0-0.0

The Macroinvertebrate Community

General Characteristics

Due to its designation as one of the nation's National and Scenic Riverways, the main stem of the St. Croix River has been the focus of the majority of invertebrate studies in the basin. Montz et al. (1990) and Boyle et al. (1992) conducted longitudinal surveys of the St. Croix River and found it to support a very healthy invertebrate community. In addition the St. Croix River watershed is the premier mussel watershed of the Upper Mississippi River watershed, and one of the premier mussel watersheds of the world (U.S. FWS 2003).

A total of 380 invertebrate taxa were collected from the 40 sites sampled for invertebrates. However, this value represents an underestimate of total species richness, as the majority of specimens (e.g., Ephemeroptera, Trichoptera, Plecoptera, Diptera) were only identified to genus and some groups (e.g., Pelecypoda) were only identified to higher taxonomic levels such as order or family. When considering the number of sites sampled within each of the four major watersheds of Minnesota's portion of the St. Croix River Basin, invertebrate taxa richness was similar: Snake – 279 (n = 15 sites), Kettle – 201 (n = 11), Upper St. Croix – 173 (n = 7), Lower St. Croix – 165 (n = 7).

The most frequently encountered taxa in the basin belonged to the family Chironomidae (Diptera). The genera *Cricotopus* and *Polypedilum* were collected at 98% and 95% of the study reaches, respectively. Three other chironomid genera, *Conchapelopia*, *Rheotanytarsus* and *Tanytarsus*, occurred at 78% of the study reaches. All of these genera are moderately tolerant of pollution, with assigned tolerance values of six or seven (Barbour et al. 1999), perhaps explaining their prevalence within the basin. However, it is worth noting that all of these genera are particularly species-rich (some are estimated to have 20+ species; Merritt and Cummins 1996), and their prevalence may be due to the increased probability of collecting at least one member of these diverse genera at any given site.

The most frequently encountered taxa varied slightly depending on ecoregion or watershed disturbance level. The most commonly encountered taxa in the NLF ecoregion and at sites with low watershed disturbance were the same as for the entire basin. In the NCHF ecoregion, the mayfly genus *Caenis*, the amphipod species *Hyalella azteca*, and mussels (Pelecypoda) replaced *Rheotanytarsus* and *Tanytarsus* on the basin-wide list of dominant taxa. In streams with highly disturbed watersheds, the two dominant taxa were once again *Cricotopus* and *Polypedilum*, occurring at 100% and 92% of the study reaches. However, the remainder of the dominant taxa listed for the entire basin was replaced at sites with highly disturbed watersheds by the following taxa: *Caenis*, *Belostoma flumineum*, *Dubiraphia*, and *Hyalella azteca*.

Stream order was only slightly related to the presence of the dominant taxa. The chironomid genera, *Cricotopus* and *Polypedilum*, were the top two dominant taxa in 1st and 2nd order streams as well as 3rd through 6th order streams. The other dominant taxa in low-order streams were the chironomid genera *Tanytarsus* and *Microspectra*, and the riffle beetle *Dubiraphia*. In higher-order streams, the chironomid *Rheotanytarsus* and the trichopteran *Ceratopsyche* were among the dominant taxa. The caddisfly *Ceratopsyche* was much more common in higher-order streams than in low-order streams.

In terms of the total number of individuals collected, pollution-tolerant taxa were the most abundant within the basin. The four most abundant taxa collected in the basin were the amphipod *Hyalella azteca*, the chironomid *Polypedilum*, the trichopteran *Ceratopysche*, and the limpet *Ferrissia*. With the exception of *Ceratopsyche*, all of these genera have tolerance values of seven or greater (Barbour et al. 1999). It is not surprising that the most abundant taxa in the basin were pollution-tolerant organisms, since they occur at natural densities in unimpaired streams and at increased densities in more-polluted streams. This, coupled with the fact that less-tolerant organisms occur at lower densities or are eliminated altogether from polluted sites, accounts for the dominance of pollution-tolerant organisms in this relatively unimpaired basin.

Species Richness and Composition

The median number of macroinvertebrate taxa for all stream reaches within the St. Croix River Basin was 49.8 (Table 2). Neither ecoregion nor stream size were related to the total number of macroinvertebrate taxa. Watershed disturbance, however, was related to total taxa richness, with a higher number of taxa in streams with low watershed disturbance (median = 55.6, Table 2, $p<0.05$) than in streams with high watershed disturbance (median = 39.3, Table 2, $p<0.05$). Total taxa richness is a commonly used metric in invertebrate IBIs that are used to assess the condition of both lotic (e.g., Barbour et al. 1996, Kerans and Karr 1994) and lentic (e.g., Burton et al. 1999, Helgen and Gernes 2001) habitats. The usefulness of this community attribute for determining impairment in aquatic ecosystems is demonstrated by the fact that as environmental disturbance increases, taxonomic diversity decreases (Lenat 1988). This relationship between disturbance and taxa richness also appears to exist in the St. Croix River Basin.

Another commonly employed metric in stream invertebrate IBI's is the combined richness of Ephemeroptera, Plecoptera, and Trichoptera (EPT). These insect orders are particularly sensitive to low dissolved oxygen conditions that often result from organic pollution. A diverse representation of these orders at a site indicates pristine or least-disturbed conditions. EPT values did not differ significantly between ecoregions. However, EPT did vary significantly depending on the amount of watershed disturbance and stream size, being higher in less-disturbed (median = 11.4) than in more-disturbed streams (median = 3.3) and higher in large (median = 17.0) than in small streams (median = 8.3, Table 2, $p<0.05$). The difference in EPT between the stream size categories can most likely be attributed to the naturally low dissolved oxygen concentrations of the low-gradient, wetland-associated headwater streams in the basin (Fig. 13). An examination of the CDFs for each order suggests that they are all sensitive to disturbance because the taxa richness for each group was significantly higher at less-disturbed streams. In addition, all three groups were more diverse at the larger streams, perhaps indicating their inability to exploit the wetland-like habitats of the headwater streams in the basin.

Tolerance and Dominance

Tolerance values ranging from 0 (least tolerant) to 10 (most tolerant), based on numerous studies on the sensitivities of aquatic invertebrate assemblages in lotic habitats, have been assigned to many invertebrates (Barbour et al. 1999). For the purposes of this study, organisms with tolerance values exceeding five were designated as "tolerant" and those with tolerance values below three were designated as "intolerant." The presence of many intolerant taxa in a stream reach is a good indication of a healthy ecosystem, whereas the abundance of tolerant organisms at a site indicates degraded conditions. Consequently, measures of tolerance are usually incorporated into invertebrate IBI's as two metrics: "Intolerant Taxa Richness" and "Percent Tolerant Taxa."

In the St. Croix River Basin, a total of 69 intolerant taxa were collected, with *Atherix variegata* (circular-seamed fly), *Hexatoma* spp. (crane fly), and *Acroneuria* spp. (perlid stonefly) the most frequently encountered. The number of intolerant taxa was significantly higher in large streams, the NLF ecoregion, and in streams with less-disturbed watersheds (Table 2, $p<0.05$).

Tolerant taxa were much more prevalent throughout the basin, with a total of 150 taxa collected. The most prevalent of these were the same chironomid genera that were listed above as the most frequently encountered taxa in the basin; *Cricotopus*, *Polypedilum*, *Conchapelopia*, *Rheotanytarsus*, and *Tanytarsus*. The percentage of tolerant taxa was higher in the NCHF ecoregion and in streams with more-disturbed watersheds (Table 2, $p<0.05$). There was little relationship with stream size and the percentage of tolerant taxa.

Streams impacted by human disturbance often support only a few species that tend to dominate the invertebrate community at the expense of other species. In the St. Croix River Basin the dominant two taxa comprised a median of 25% of the total number of individuals collected at a site. The percentage of the two dominant invertebrate taxa was significantly lower in the NLF ecoregion (median = 21.5) than in the NCHF ecoregion (median = 35.6, Table 2, $p<0.05$). Stream size and watershed disturbance level had little influence on the percentage of the dominant two invertebrate taxa.

Trophic Composition

Depending on the strategy employed for obtaining food, invertebrates can differ substantially in their sensitivity to the various types of disturbance. Filter-feeding organisms in lotic systems rely on stream flow to provide a source of suspended fine particulate organic matter (FPOM), for which they have adapted various morphological and behavioral characteristics in order to collect this food resource (Wallace and Merritt 1980). Typically, filterer taxa are less abundant in headwater streams due to a lack of suspended material in the water column. A watershed with a healthy riparian zone will have a continuous supply of organic matter being added to the stream which will be processed by shredders and natural breakdown processes resulting in a healthy supply of FPOM as it increases in drainage area. Steady flows, adequate FPOM, and suitable, clean substrates for filterer taxa to attach themselves will result in an abundant and diverse assemblage of filterers. When a stream becomes hydrologically altered, has increased sediment load or an altered riparian zone, filterer taxa may experience declines given their intimate connection to the water column. In the St. Croix River Basin, the number of filter-feeding taxa was higher in streams with a smaller amount of disturbance in the upstream watershed (Table 2, $p<0.05$). Stream size and ecoregional differences were not significantly different although stream size was nearly significant, with large streams having generally more filter-feeding taxa (Table 2).

Special Concern Species

Currently, there are two federally listed, endangered species of mussels found in the St. Croix River, the winged maple leaf (*Quadrula fragosa*) and the Higgins eye (*Lampsilis higginsi*). Two additional mussels found in the St. Croix are candidates for federal listing, and several other mussel species are on the state list of endangered, threatened, or special concern species (Hornbach 1996, Hornbach et. al. 1996). Mussels collected during this study were not identified to species, so therefore it can not be determined whether any state or federally listed species were encountered. In addition, two species of dragonflies with breeding populations in the St. Croix River Basin are on Minnesota's state list of special concern species. The St. Croix snaketail (*Ophiogomphus susbehcha*) and the extra-striped snaketail (*Ophiogomphus anomalus*) have both recently been collected from stream sites within the St. Croix River Basin (Steffens and Smith 1999). Dragonfly larvae of the genus *Ophiogomphus* were collected at numerous sites throughout the basin; however, most specimens were not identified to species. Therefore, it can not be accurately determined if any special concern dragonfly species were collected during this study.

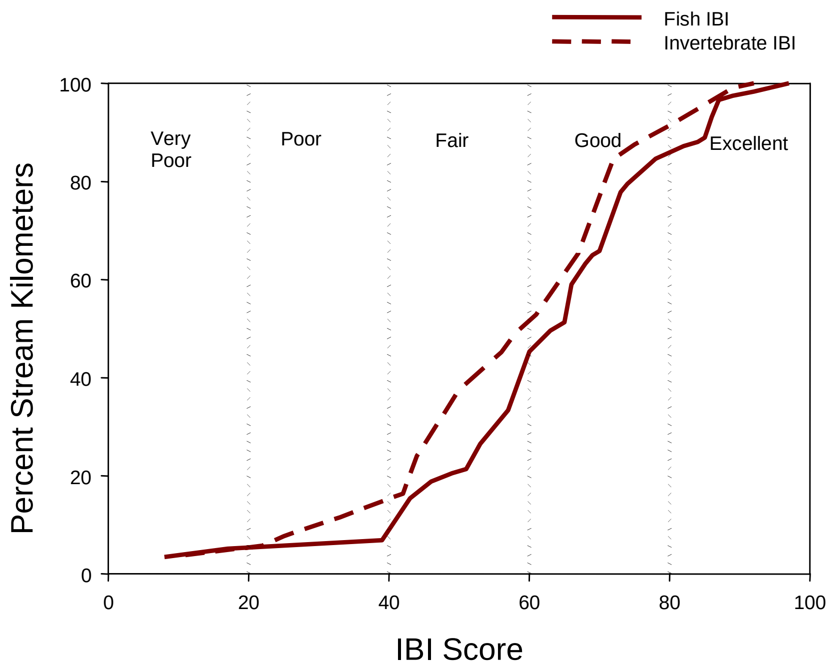
Table 2. Median values for the macroinvertebrate IBI and its metrics. Values in bold indicate that the CDF's (for the two categories of ecoregion or stream order or disturbance level) are statistically significantly different ($p<0.05$).

IBI Score and Macroinvertebrate Community Attributes	All Streams		Ecoregion: Northern Lakes and Forests		Ecoregion: North Central Hardwood Forests		Stream Order: 1st and 2nd		Stream Order: 3rd through 6th		Watershed Disturbance Level: Low (0-39%)		Watershed Disturbance Level: High (40-100%)	
	median	95% CI	median	95 % CI	median	95% CI	median	95% CI	median	95% CI	median	95% CI	median	95% CI
IBI Score	55.3	44.2 - 66.3	**64.3**	**47.4 - 70.3**	**36.8**	**22.5 - 52.8**	54.5	42.5 - 69.5	56.5	45.6 - 62.6	**67.5**	**59.1 - 71.4**	**42.8**	**17.7 - 53.6**
Invertebrate IBI Metrics														
Number of Chironomidae taxa	15.7	14.7 - 16.7	15.8	14.0 - 18.2	15.6	11.1 - 17.5	15.9	13.8 - 17.5	15.4	13.7 - 17.3	**16.4**	**15.4 - 19.2**	**13.5**	**9.5 - 16.8**
Number of clinger taxa	12.8	8.3 - 16.0	13.5	7.6 - 18.3	8.9	8.2 - 16.3	**8.8**	**6.2 - 13.9**	**20.0**	**16.9 - 23.2**	**15.6**	**12.8 - 18.8**	**8.4**	**5.0 - 16.2**
Number of intolerant taxa	5.0	2.6 - 8.6	**8.3**	**3.2 - 10.8**	**1.6**	**1.0 - 5.6**	**3.0**	**1.7 - 8.0**	**11.3**	**8.4 - 14.2**	**8.6**	**5.0 - 11.2**	**1.0**	**1.0 - 5.2**
Number of Ephemeroptera taxa	2.5	1.8 - 3.3	2.6	1.8 - 3.8	2.3	1.0 - 3.3	**1.8**	**1.2 - 2.5**	**5.2**	**3.5 - 6.4**	**3.2**	**1.9 - 5.2**	**1.0**	**1.0 - 2.7**
Number of Plecoptera taxa	0.0	0.0 - 0.6	0.0	0.0 - 1.4	0.0	0.0 - 0.8	**0.0**	**0.0 - 0.0**	**1.8**	**0.6 - 2.6**	**0.0**	**0.0 - 1.9**	**0.0**	**0.0 - 0.7**
Number of Tricoptera taxa	5.7	4.0 - 7.6	**7.2**	**3.0 - 9.5**	**5.1**	**2.2 - 6.6**	**4.3**	**1.8 - 7.4**	**8.7**	**7.2 - 10.3**	**7.6**	**5.6 - 9.6**	**2.3**	**1.0 - 5.7**
Number of collector-filterer invertebrate taxa	6.7	5.8 - 8.3	7.4	5.9 - 9.2	6.1	3.1 - 8.1	6.3	3.2 - 7.9	8.9	8.1 - 9.7	**8.3**	**6.8 - 9.5**	**5.2**	**1.0 - 6.8**
Number of collector-gatherer invertebrate taxa	17.0	14.1 - 17.8	17.3	14.0 - 19.0	14.7	12.6 - 17.9	16.8	13.3 - 17.9	17.7	15.2 - 19.4	**17.8**	**17.0 - 19.2**	**13.4**	**8.0 - 19.1**
Number of Tanytarsini taxa	3.7	2.7 - 4.3	4.1	2.7 - 4.5	3.1	2.1 - 4.4	**4.1**	**2.4 - 4.6**	**3.3**	**2.8 - 3.8**	4.2	3.2 - 4.6	2.9	2.1 - 4.4
Percent of individuals that are Amphipoda	0.9	0.2 - 2.6	**0.1**	**0.0 - 0.9**	**5.5**	**1.3 - 30.6**	0.9	0.0 - 5.3	1.0	0.6 - 1.7	0.3	0.0 - 1.0	5.4	0.2 - 32.2
Percent of individuals that are dominant two taxa	25.2	21.3 - 29.0	**21.5**	**18.2 - 27.8**	**35.6**	**22.9 - 47.2**	22.8	18.3 - 31.1	27.2	23.5 - 30.4	21.2	17.8 - 26.6	28.9	22.6 - 48.0
Percent of ind. invertebrates that are tolerant	39.2	30.8 - 50.4	**32.2**	**30.1 - 48.8**	**50.5**	**39.0 - 85.7**	48.8	30.6 - 53.2	35.5	29.0 - 39.2	**30.6**	**27.7 - 38.8**	**49.5**	**36.6 - 86.7**
Other Invertebrate Community Attributes														
HBI	5.5	4.9 - 6.2	5.0	4.8 - 6.0	5.8	5.5 - 7.5	5.7	4.9 - 6.5	5.2	4.6 - 5.5	4.9	4.8 - 5.3	6.5	5.6 - 7.5
EPT	9.9	7.8 - 11.5	10.5	8.0 - 11.9	8.3	3.2 - 11.8	**8.3**	**4.3 - 10.7**	**17.0**	**13.7 - 20.4**	**11.4**	**9.9 - 17.2**	**3.3**	**2.0 - 10.5**
Number of scraper taxa	7.2	6.1 - 8.1	7.5	6.0 - 9.4	6.5	4.7 - 8.1	**6.5**	**4.9 - 7.8**	**9.2**	**7.8 - 9.9**	**7.9**	**6.5 - 9.7**	**4.6**	**3.2 - 8.1**
Number of macroinvertebrate taxa -- all Chironomidae taxa included	49.8	44.6 - 55.8	53.0	44.7 - 56.4	45.0	39.2 - 56.5	48.0	40.5 - 55.2	56.7	51.2 - 59.8	**55.6**	**49.0 - 56.8**	**39.3**	**28.0 - 56.5**

Biological Condition of Streams

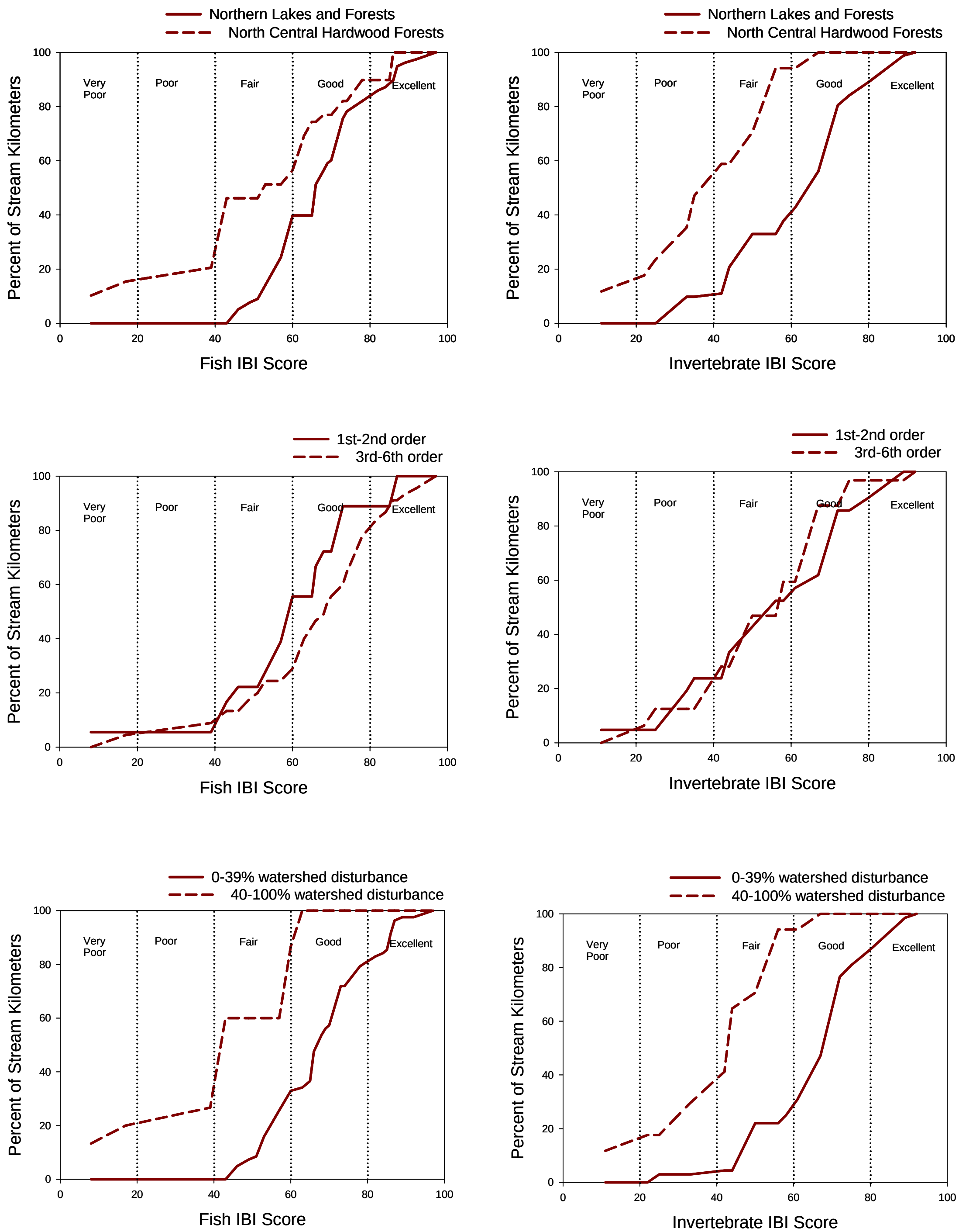
Fish IBI scores were based on data from 43 sites representing 1877 stream km or 69% of the target streams in the basin (Fig. 7). The basin-wide median fish IBI score was 63.5 (Table 1) and ranged from eight to 97 (Fig. 16). Invertebrate IBI scores were calculated at a total of 32 sites representing 1668 stream km or 62% of the target streams in the basin. The basin-wide median invertebrate IBI score was 59 (Table 2) and ranged from 11 to 92 (Fig. 16). The fish and invertebrate CDF's appear to be similar, although they are not directly comparable since they represent slightly different sets of streams.

Figure 16. CDF's of fish and invertebrate IBI scores for the St. Croix River Basin.



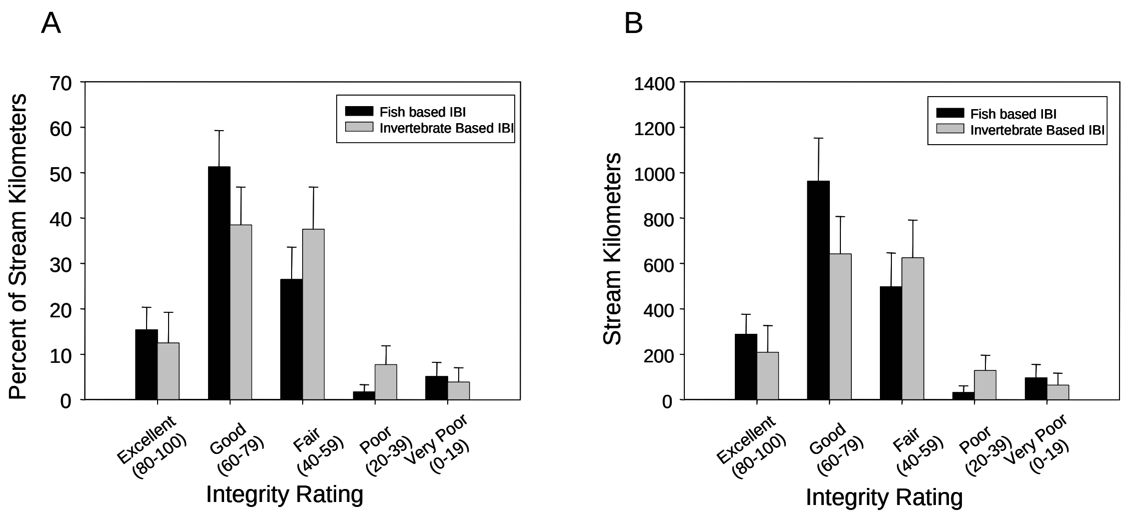
The median fish and invertebrate IBI scores were higher in the NLF ecoregion and at streams with little watershed disturbance. However, for ecoregions the difference in CDF's was only significant for invertebrates (Mean-Eigenvalue-Corrected Test, $p<0.05$, Fig. 17). The median fish and invertebrate IBI scores for large and small streams were not significantly different, nor were the CDF's for either assemblage significantly different (Fig. 17).

Figure 17. CDF's of fish and invertebrate IBI scores for each major ecoregion, two stream size classes, and two watershed disturbance levels.



An alternative way of viewing the IBI data is to categorize the IBI scores using narrative ratings (Figs. 18 and 19). IBI scores for the vast majority of streams (93% for fish and 88% for invertebrates) were over 40, placing them in the fair, good, or excellent integrity classes. Fifteen percent (288 km) of streams had fish IBI scores considered excellent (IBI ≥ 80), while only 7% (128 km) of streams had fish IBI scores that were considered poor or very poor (IBI <40). For invertebrates, 12% (208 km) of streams had IBI scores in the excellent range and 11% (192 km) in the poor or very poor range.

Figure 18. Narrative ratings for fish and invertebrate IBI scores expressed as a percentage of stream kilometers (A) and number of kilometers (B). Error bars represent the standard error.

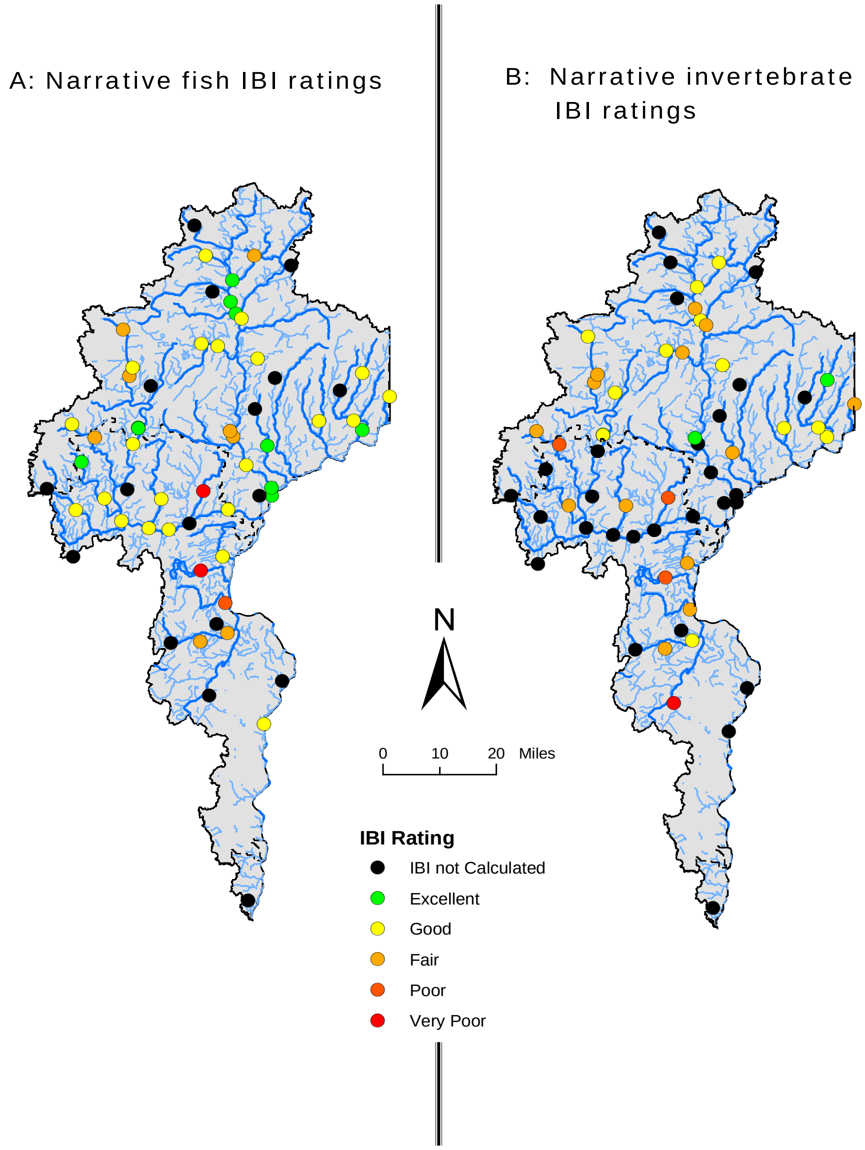


A disproportionate percentage of streams with excellent IBI ratings were in watersheds in the NLF ecoregion. Sixty seven percent (1251 km) of streams for which fish IBI scores were calculated were in the NLF ecoregion, but 78% (224 km) of all streams with fish IBI ratings in the excellent range were in the NLF ecoregion. Streams with an excellent invertebrate IBI rating were located exclusively in the NLF ecoregion.

The narrative IBI ratings were influenced by the level of watershed disturbance. All streams (273 km) with an excellent fish IBI rating and all streams (209 km) with an excellent invertebrate IBI rating occurred in watersheds with low disturbance. Streams with poor or very poor ratings were found almost exclusively in watersheds with greater than 40% disturbance. For example, only 17% (32 km) of streams with poor or very poor invertebrate IBI ratings and no streams with poor or very poor fish IBI ratings occurred in watersheds with less than 40% watershed disturbance.

Fish and invertebrate IBI ratings were somewhat contradictory in regards to stream size. For fish, only 44% (128 km) of streams with an excellent IBI rating were 1st and 2nd order streams although these smaller streams comprise 62% (1155 km) of all streams in the basin for which fish IBI scores were calculated. However, for invertebrates 92% (192km) of streams with an excellent IBI rating were 1st and 2nd order streams although these smaller streams comprise 69% (1155 km) of all streams in the basin for which invertebrate IBI scores were calculated. Streams with poor or very poor IBI ratings were found in low percentages in both stream size classes for both assemblages.

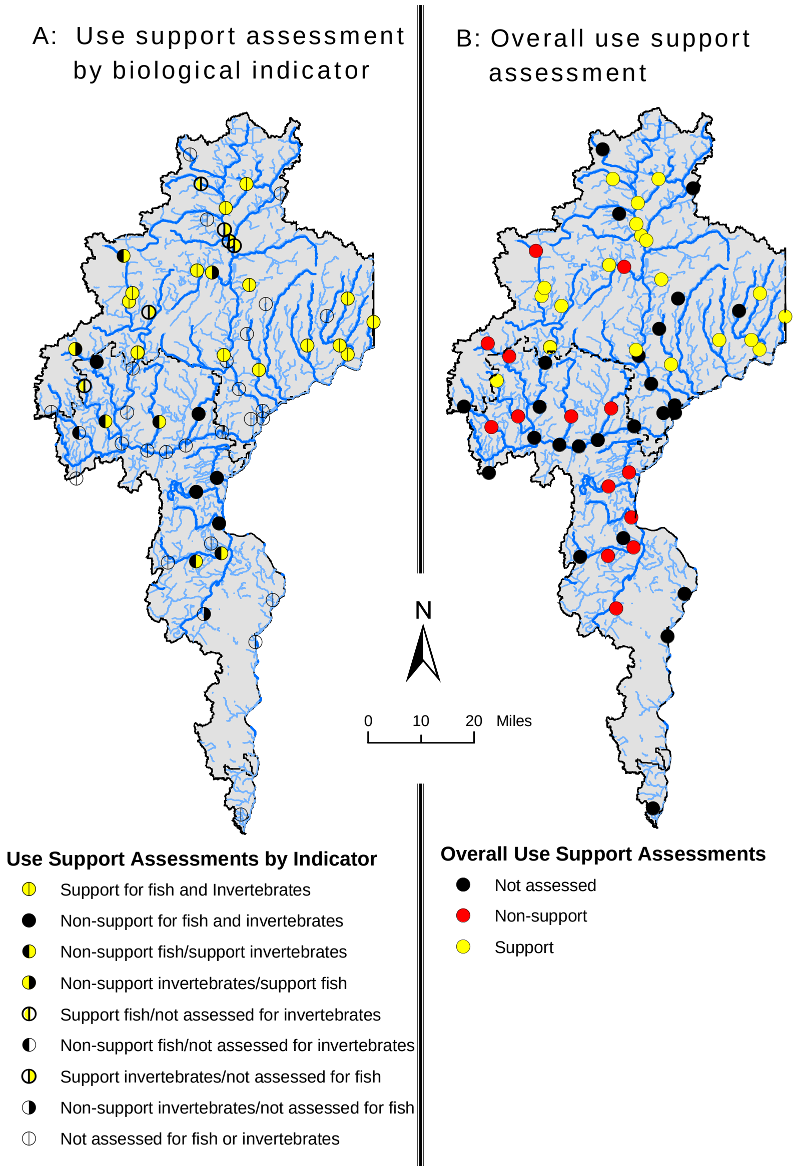
Figure 19. Narrative ratings for (A) fish and (B) invertebrate IBI scores. Dashed lines represent ecoregion boundaries.



The EMAP results can be used to estimate the number of streams in the St. Croix River Basin that support their designated uses (Figs. 20 and 21). The MPCA assesses whether or not streams are supportive or non-supportive of their aquatic life uses by analyzing monitoring information gathered over the proceeding 10-year period. The assessments are required per section 305(b) of the federal Clean Water Act (CWA). Waters that are identified as non-supportive are listed as impaired waters in accordance with section 303(d) of the federal CWA. The assessments are used, in part, to prioritize water management activities that are aimed at improving the condition of impaired waters.

The use support assessments based on the fish and invertebrate IBI's represented 61% (1652 km) and 62% (1668 km) respectively of the target streams in the basin (Fig. 21). Streams with watersheds greater than 270 mi^2 were not assessed using fish IBI's because there was not enough variability in conditions within

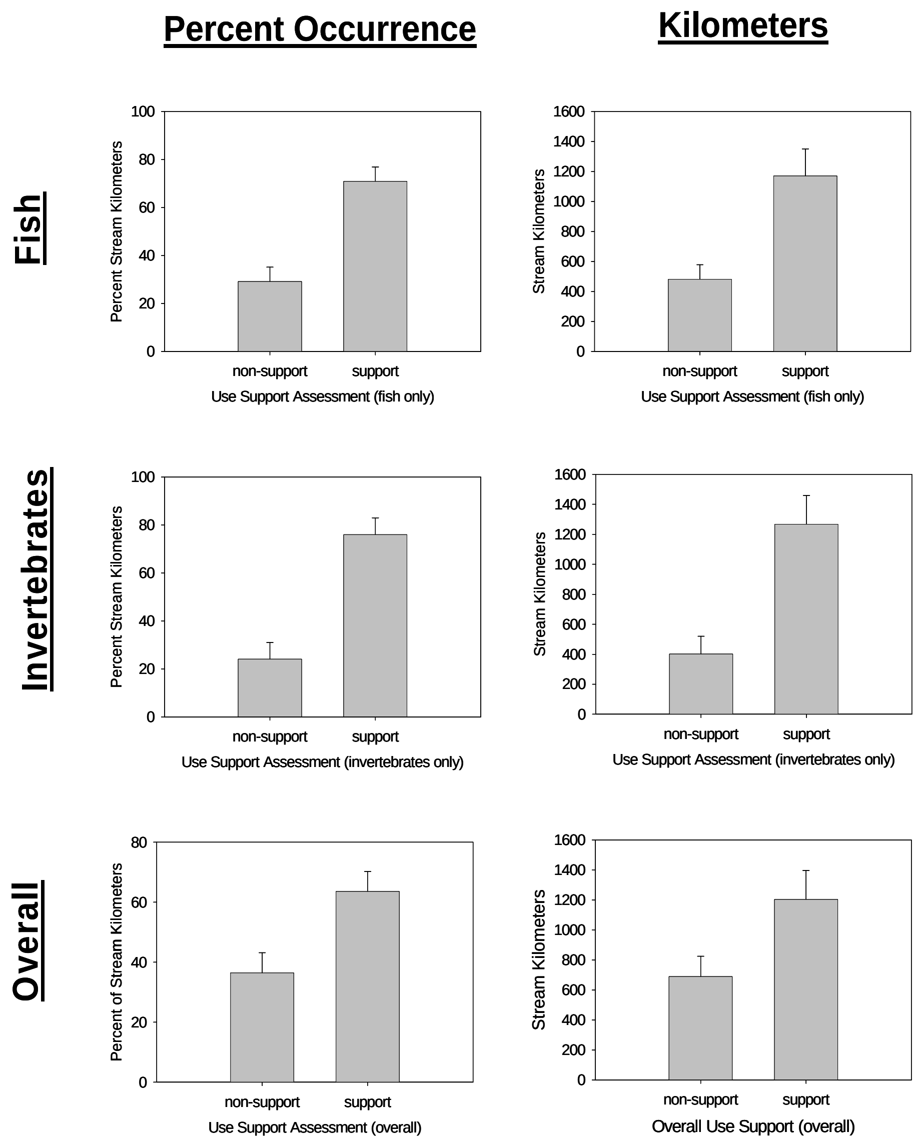
Figure 20. Use support assessments for (A) each biological indicator (i.e. fish and invertebrates) and (B) overall use support.



the basin to test the IBI metrics against an adequate gradient of disturbance. Streams with watersheds greater than 500 mi^2 drainage area were not assessed using the invertebrate IBI because they were too deep to wade and therefore could not be sampled effectively.

Twenty nine percent (481 km) of the streams that were assessed with the fish IBI were estimated to be biologically impaired (fig. 21). The majority of the impaired streams were in the NCHF ecoregion (87%, 449 km, Fig. 20). In the NLF ecoregion, only 3% (32 km) of the streams were impaired. Only 17% (192 km) of 1^{st} and 2^{nd} order streams were impaired. Third through 6^{th} order streams were impaired 58% of the time but, because there were fewer large streams, the total length of impaired large streams was only moderately higher (289 km). Forty eight percent (353 km) of streams with greater than 40% watershed disturbance were impaired, while only 15% (128 km) of streams with less than 40% watershed disturbance were impaired

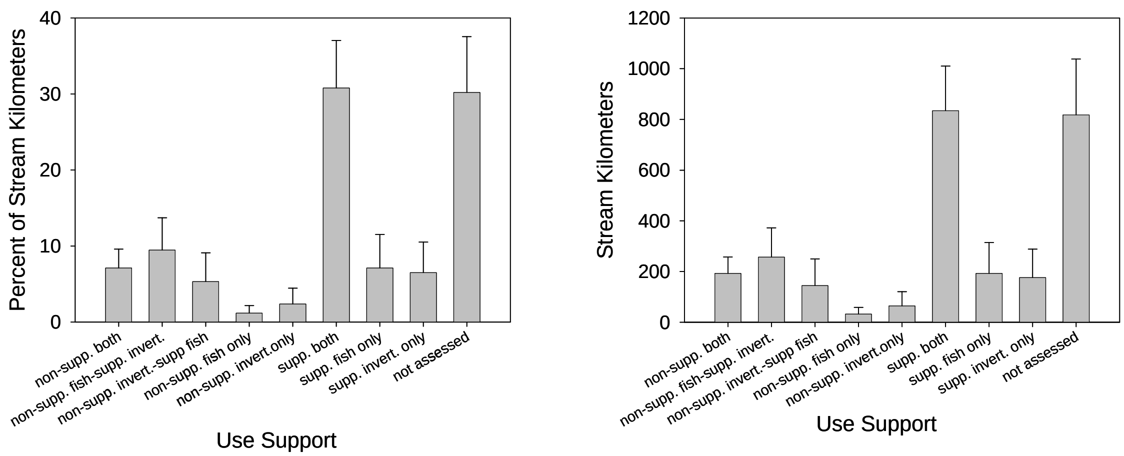
Figure 21. Use support assessments based on the fish and invertebrate IBI scores and an overall assessment based on the combined results of both assemblages. Error bars represent the standard error of the estimate.



The results of the invertebrate assessments were similar to those of the fish community. Twenty four percent (400 km) of the streams that were assessed with the invertebrate IBI were estimated to be biologically impaired (Fig. 21). Streams in the NCHF ecoregion (Fig.20), large streams, and streams with greater than 40% watershed disturbance were impaired at a higher rate.

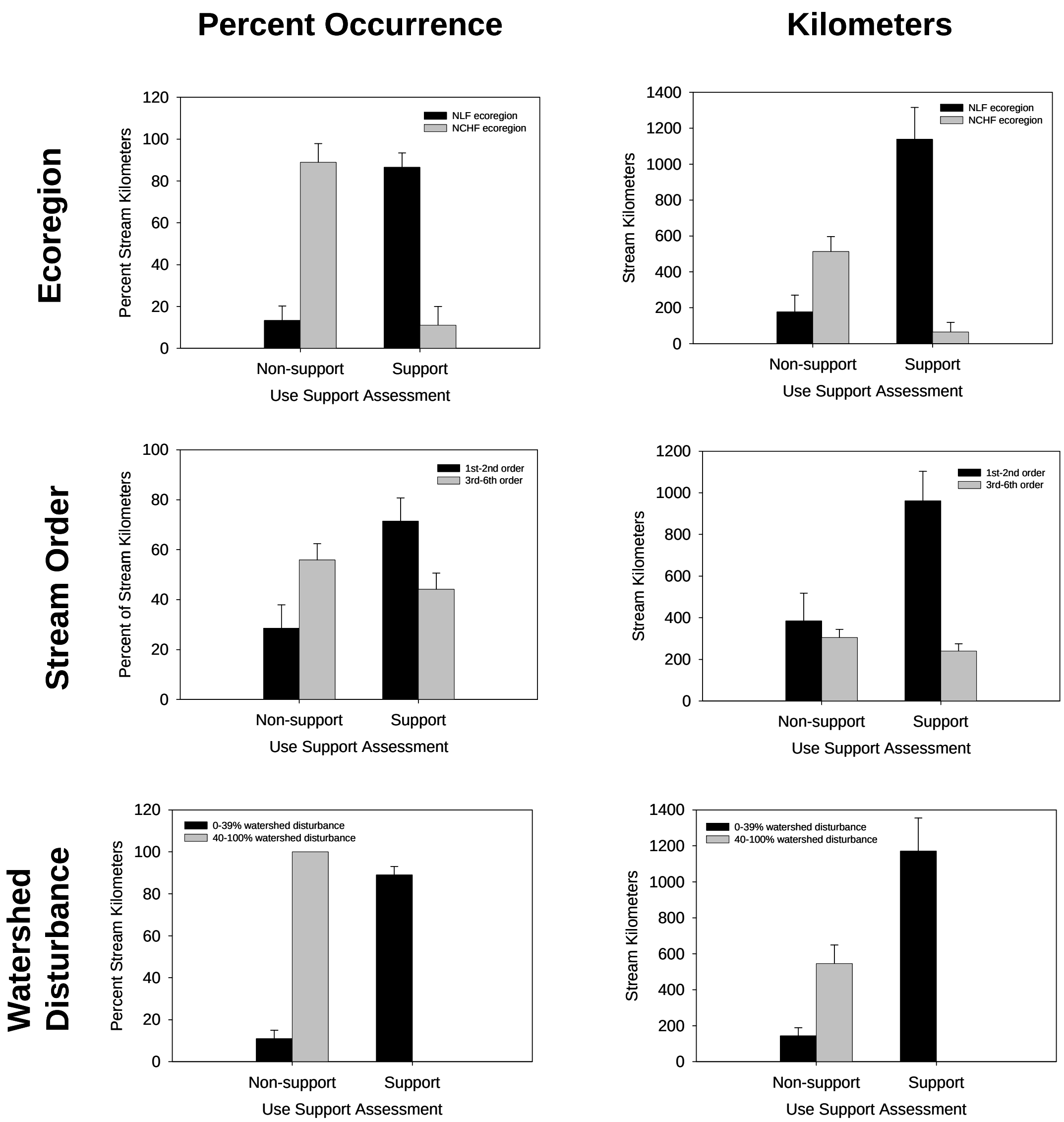
The combined results of the fish and invertebrate assessments were used to make an overall use support assessment representing 1893 km or 70% of the target streams in the basin (Figs. 20 and 21). Streams were considered fully supporting (not impaired) if the fish and invertebrate assemblages both indicated support or, if only one assemblage was used to assess the stream, the one assemblage indicated support. Streams were considered to be non-supporting if either of the assemblages was non-supporting (impaired). Thirty six percent (690 km) of streams in the basin that were assessed for fish and/or invertebrates were biologically impaired and were considered to be non-supporting of their aquatic life uses (Fig. 21). Both assemblages were used to make assessments at 75% (1427 km) of the assessed streams in the basin (Fig. 22). The assessment results agreed (both assemblages indicated either support or non-support) at 72% (1026 km) of the streams (Fig. 22). When the assessment results disagreed, the fish community indicated that the stream was non-supporting at 64% (256 km) of the streams and the invertebrate community indicated non-support at 36% (144 km) of the streams.

Figure 22. Use support assessments for each assessment scenario. Estimates are provided for each indicator (i.e fish and invertebrates) when the assessments agree, disagree, and when only one indicator was used to make the assessment. Error bars represent the standard error of the estimate.



Ecoregion, stream size, and watershed disturbance level influenced stream impairment (Fig. 23). Only 13% (176 km) of streams in the NLF ecoregion were impaired compared to 89% (513 km) in the NCHF ecoregion. Fifty six percent (305 km) of large streams were impaired compared to 29% (385 km) of small streams. All streams (545 km) with greater than 40% watershed disturbance were impaired compared to only 11% (144 km) of streams with less than 40% watershed disturbance.

Figure 23. Overall use support assessments for each major ecoregion, two stream size classes, and two watershed disturbance levels. Error bars represent the standard error.



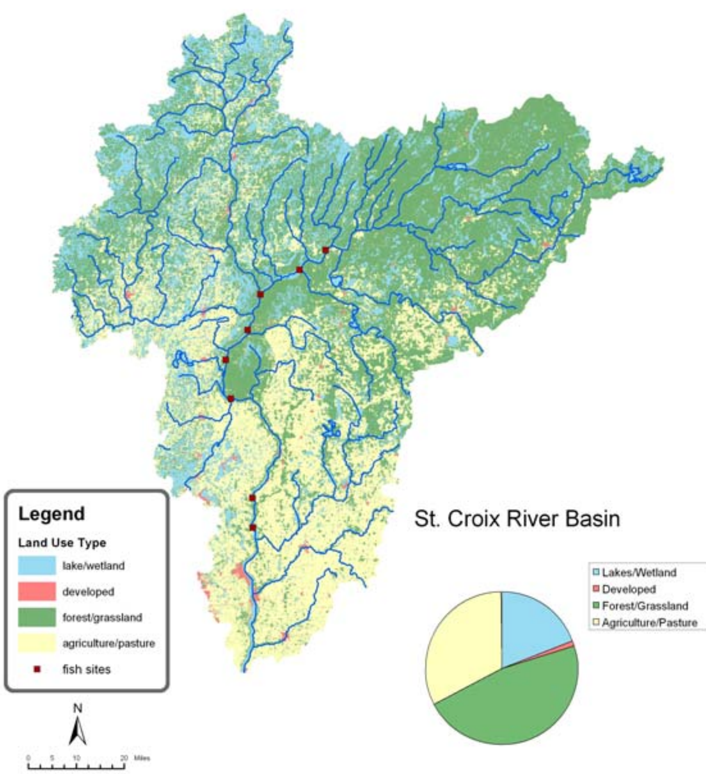
The 2002 list of impaired waters (i.e. 303(d) list) identified 406 biologically impaired stream kilometers in the St. Croix River Basin. The data used to produce the list included the random sites used in this study as well as all other credible biological monitoring information that the MPCA had collected. A comparison of the estimated impairments versus identified impairments suggests that water quality monitoring activities have uncovered over half (approximately 58%) of the impaired reaches in the basin for the 70% of target streams that were able to be biologically assessed. These results are probably not unreasonable because in 1998, the monitoring associated with biological criteria development specifically targeted suspected problem streams throughout the basin. Also, the basin is relatively small, there are a limited number of impaired reaches, and the impaired reaches are primarily limited geographically to the southern portion of the basin.

Longitudinal Stream Surveys

Six to 10 sites were selected along the St. Croix, Snake, and Kettle Rivers and Rush Creek to obtain longitudinal profiles of their condition (Figs. 24 and 25). The sampling sites were located from the mouth to the headwaters, with the exception of the St. Croix, where sampling locations were restricted to Minnesota-Wisconsin border waters. All sampling methods were identical to those used at the randomly selected sites.

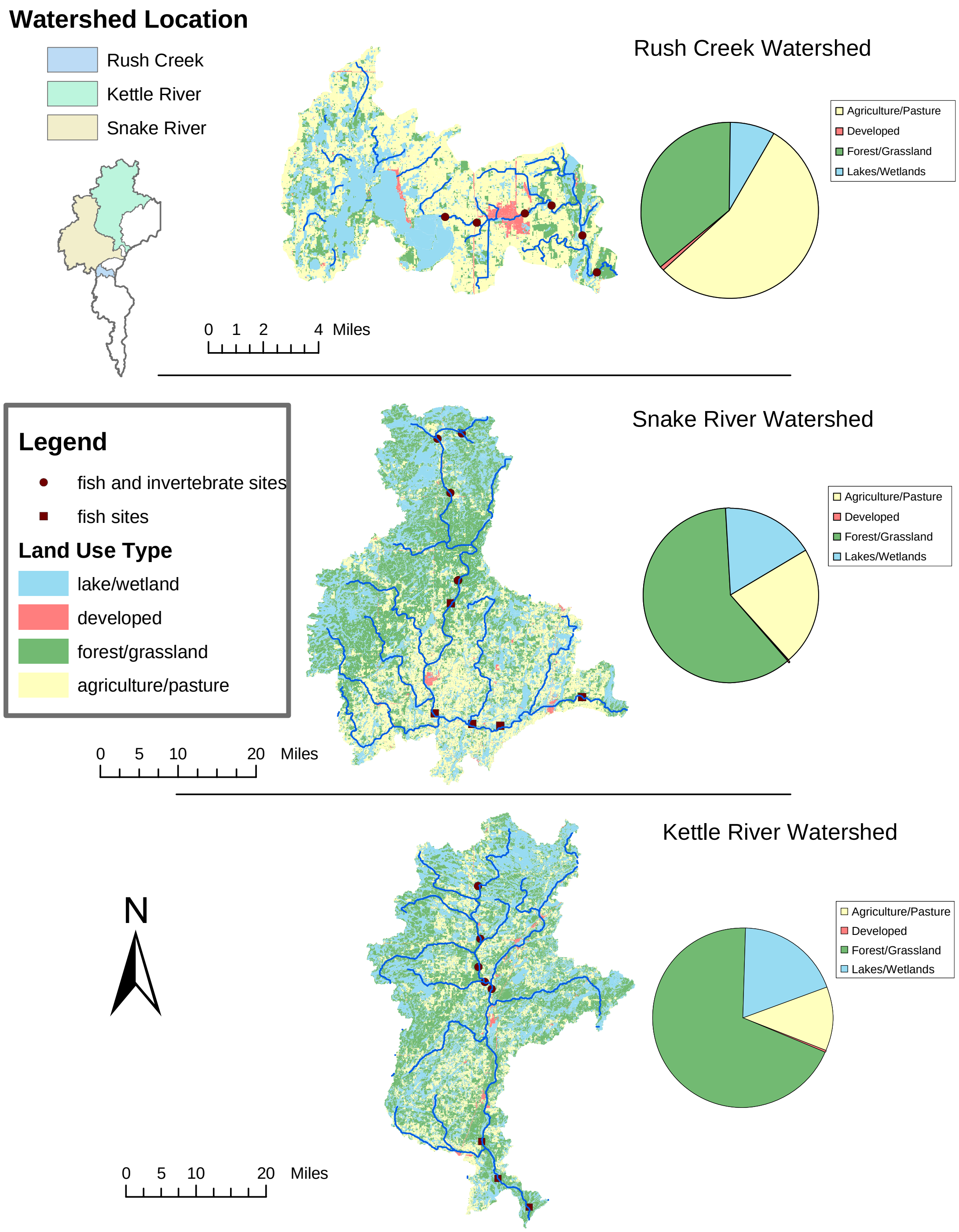
The Snake, Kettle, and St. Croix Rivers are either wholly confined within the NLF ecoregion or have headwater reaches that originate within the NLF ecoregion. Each of these streams has headwaters that are in watersheds dominated by vast wetland complexes with relatively little watershed disturbance. Rush Creek differs appreciably from the other three in a number of ways. Rush Creek has a significantly smaller watershed than the other streams; it is the only stream whose watershed is entirely confined within the NCHF ecoregion; and the watershed of upper Rush Creek has fewer wetland complexes and significant agricultural and urban development.

Figure 24. Fish sampling locations on the St. Croix River, and land use percentages.



Fish community sampling occurred at eight sites on the St. Croix River from river mile 120, at St. Croix State Park, to river mile 35 near Marine on the St. Croix (Fig. 24). Invertebrate samples were not taken because the river was not wadeable. The fish IBI indicated that the St. Croix River was in good to excellent biological condition (Fig. 26). The impaired tributary streams that are prevalent throughout the southern portion of the St. Croix River Basin have thus far appeared to have had very little effect on the biological integrity of the lower St. Croix River sites that were sampled. However, the results of this survey suggest that the St. Croix River, in particular the lower reaches, should be monitored closely to

Figure 25. Fish and invertebrate sampling locations on Rush Creek, the Snake River, and the Kettle River, and land use percentages for each watershed.



detect biological changes that may result from the degradation of tributary streams in the lower St. Croix River Basin.

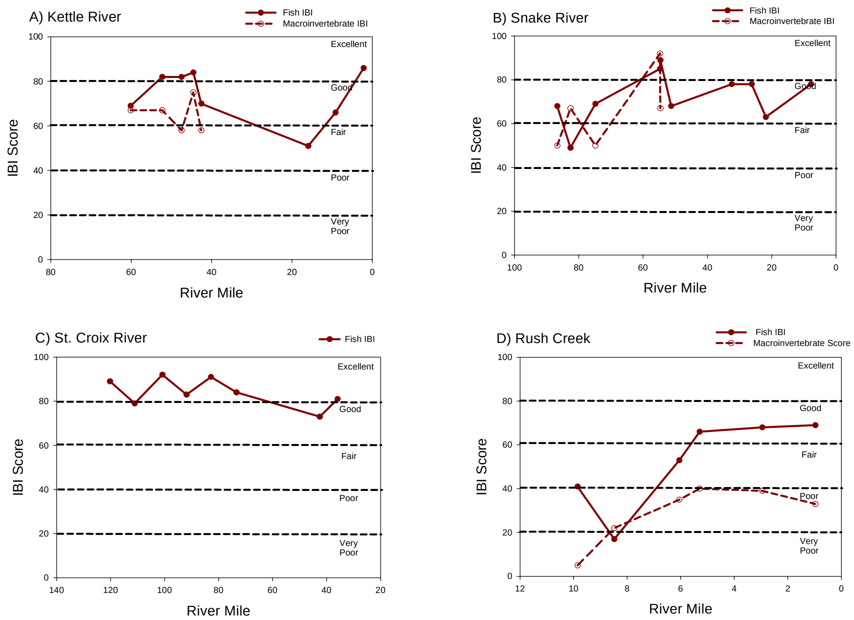
The fish IBI indicated that the Snake and the Kettle Rivers were in fair to excellent biological condition (Fig. 26). The invertebrate IBI scores were usually lower than the fish IBI scores but, like the fish, the invertebrate IBI scores were also in the fair to excellent range (Fig. 26). Watershed disturbance within these watersheds was generally low, particularly near the headwaters. Much of the Snake and Kettle Rivers were unchannelized and retained a connection to riparian wetlands. One exception occurred on the Snake River at river mile 82, one of the few channelized reaches of the river (Fig. 26). Here, the fish IBI score dropped to 49, corresponding to a rating of fair. The appearance of the stream channel combined with the lack of any agricultural or urban development within the area suggested that the channelization had occurred many years ago and was not currently being maintained. In spite of the seemingly long recovery period, the negative effects of this disturbance were still manifested in the fish community. The same pattern was not observed in the invertebrate IBI, where IBI scores increased in the channelized reach. The fish IBI score also dipped into the fair category in the lower reaches of the Kettle (Fig. 26). The habitat, particularly the substrate, in this particular river reach was much less diverse than in other reaches of the Kettle. The lower gradient of this reach and the removal of the dam at Sandstone in 1995 may have contributed to the poor substrate quality at this site. The Sandstone dam held back tons of sand and silt that were released into the downstream reaches once the dam was removed. This plume of sediment may have filled in deeper pools and infiltrated the interstitial spaces of coarse substrates. The biological community may recover as high-flow events transport the remaining fine sediments downstream.

The Rush Creek longitudinal survey was part of a four-year study to address concerns regarding the expansion of the Rush City waste water treatment plant. Thus, the initial longitudinal survey results from Rush Creek have been corroborated by three additional years of data. The fish and invertebrate IBI's indicated that the upper reaches of Rush Creek were in poor condition (Fig. 26). Both indices improved in downstream sampling reaches. However, the fish community improved to a good condition at the most downstream site while the invertebrate community remained poor. The fish community in the upper reaches of Rush Creek had a low number of species and no intolerant species, as well as other characteristics indicative of a degraded condition. The invertebrate community was dominated by tolerant taxa and few intolerant forms. Also, habitat and water chemistry indicators were generally worse in the upper reaches of Rush Creek.

The impaired conditions in the headwater reaches of Rush Creek have been attributed to the non-point source pollution problems that have accompanied the relatively high level of watershed development (Niemela and Feist 2003). Of particular concern were the effects related to excessive nutrient concentrations in Rush Lake, the source of Rush Creek.

The results of the longitudinal surveys corroborate the statistically based survey results by showing that streams in the St. Croix River Basin are in fair to excellent condition. Potential problem areas tend to be in the NCHF ecoregion where watershed development is more intensive.

Figure 26. Fish IBI scores (solid lines) and invertebrate IBI scores (dashed lines) for targeted sites on the (A) Kettle River, (B) Snake River, (C) St. Croix River, and (D) Rush Creek.



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Appendix 1. -- St. Croix River Basin Measured Variables

Short Description	Full Description	Database Field Name
Site ID	Site ID Provided by EPA	SiteID
Field #	Site Field Number Assigned by MPCA	FieldNum
Water Body	Water Body Name	WBName
Latitude	Latitude in Decimal Degrees (NAD-83)	LAT8xDD
Longitude	Longitude in Decimal Degrees (NAD-83)	LON8xDD
Ecoregion	Ecoregion (NLF = Northern Lakes and Forests, NCHF = North Central Hardwood Forests)	EcoRegion
Strahler Order	Strahler Order (1-6)	strahler
Strahler Group	Strahler Order Group (1-2,3-6)	strahlerclass
Stream Class	Stream Class (Coolwater, Coolwater-Intermittent, Wetland)	Class
Site Status	Site Status (TS = Target Site, NT = Non-Target Site, LD = Landowner Denial)	Status
Recon Result	Reconnaissance Result (Sampleable or Unsampleable for Fish or Macroinvertebrates)	ReconResult
Recon Reason	Reconnaissance Result Reason (i.e. Reason for Sampleable or Unsampleable Status)	ResultReason
Visit Date – Fish	Date That Fish, Habitat, and Water Chemistry Sampling Was Conducted (mm/dd/yyyy)	VisitDate
Visit Result – Fish	Reportable (Fish IBI Calculated), Non-reportable (Fish IBI Could Not Be Calculated)	VisitResult
Visit Date – Inverts	Date That Macroinvertebrate Sampling Was Conducted (mm/dd/yyyy)	Date
Visit Result – Inverts	Reportable (Macroinvertebrate IBI Calculated), Non-reportable (Macroinvertebrate IBI Could Not Be Calculated)	VisitResult2
% Disturbed	Percent Disturbed Land Use in Watershed	DisturbedPercent
% Disturbed Group	Percent Disturbed Land Use in Watershed Group	DistPerClass
% Ag/Range	Percent Agriculture/Rangeland in Watershed	AgRangePercent
% Agriculture	Percent Agriculture in Watershed	AgPercent
% Rangeland	Percent Rangeland in Watershed	RangePercent
% Urban	Percent Urban in Watershed	UrbanPercent
% Mining	Percent Mining in Watershed	MiningPercent
% Forest	Percent Forest in Watershed	ForestPercent
% Wetland	Percent Wetland in Watershed	WetlandPercent
% Pre-Settle Wetland	Percent Pre-Settlement Wetland in Watershed	PreSettleWetlandPct
% Remaining Wetlands	Percent of Original Wetlands in Watershed Remaining	PctOfOrigWetlands
% Agriculture < 100M	Percent Agriculture within 100 Meters of Streams in the Watershed	Ag100mPercent
% Forest < 100M	Percent Forest Within 100 Meters of Streams in the Watershed	Forest100mPercent
% Wetland < 100M	Percent Wetland Within 100 Meters of Streams in the Watershed	Wetland100mPercent

FHR	Fish Habitat Rating (0-12)	FHR
FHR Group	Fish Habitat Rating Group (0-8, 9-12, Not Measured)	FHRClass
Revised FHR	Revised Fish Habitat Rating (Based on LOWESS Residuals)	RevisedFHR
Revised FHR Group	Revised Fish Habitat Rating Group (0-7, 8-12, Not Measured)	RevisedFHRClass
Depth	Mean Stream Depth (cm)	MDepth
Thalweg	Mean Stream Thalweg Depth (cm)	MThalDepth
Width	Mean Stream Width (m)	MWidth
Log Width	Log (ln) of Mean Stream Width	lnMWidth
Gradient	Gradient (m/km)	Gradient
Sinuosity	Sinuosity (Total Length/Straight-Line Length)	Sinuosity
Res Sinuosity	Residuals of Sinuosity	resSinuositylnMWidth
# Features/100M	Number of Stream Features per 100 Meters	numstreamftsper100
Res # FeatuRes/100M	Residuals of Number of Stream Features per 100 Meters	resnumstreamftsper100lnMWidth
% Riffle	Percent Riffle	PctRiffle
% Pool	Percent Pool	PctPool
% Run	Percent Run	PctRun
# Riffles	Total Number of Riffles	TotalRiff
# Pools	Total Number of Pools	TotalPool
# Runs	Total Number of Runs	TotalRun
# Bends	Total Number of Bends	TotalBends
Riffle Length	Sum of Riffle Lengths (m)	SumRiff
Pool Length	Sum of Pool Lengths (m)	SumPool
Run Length	Sum of Run Lengths (m)	SumRun
Distance Riffles	Mean Distance Between Riffles (m)	MDistRiff
Distance Bends	Mean Distance Between Bends (m)	MDistBend
Width/Depth	Width to Depth Ratio	WDRatio
Riffle/Riffle	Riffle to Riffle Ratio	RRRatio
Bend/Bend	Bend to Bend Ratio	BBRatio
# Substrate Types	Number of Substrate Types	NumSubTypes
Res # Substrate Types	Residuals of Number of Substrate Types	resNumSubTypeslnMWidth
% Fines	Percent Fine Substrates (i.e. Smaller Than Gravel)	PctFines
Depth Fines	Mean Depth of Fines (cm)	MDepthFine
% Embeddedness	Percent Substrate Embeddedness	PctEmbed
% Coarse	Percent Coarse Substrates (i.e. Gravel or Larger)	PctRock
Res % Coarse	Residuals of Percent Coarse Substrates	resPctRocklnMWidth
% Boulder	Percent Boulder	PctBoulder
CV Depth	Coefficient of Variation of Depth	CVDepth
Res CV Depth	Residuals of Coefficient of Variation of Depth	resCVDepthlnMWidth

% Stream Cover	Percent Stream Cover	PctCover
% Overhanging Veg	Percent Overhanging Vegetation	PctOverVeg
% Emerg Macrophytes	Percent Emergent Macrophytes	PctEmerMac
% Submerg Macrophytes	Percent Submergent Macrophytes	PctSubMac
% Woody Debris	Percent Woody Debris	PctWoody
# Log Jams	Number of Log Jams	NLogJam
% Undercut Bank	Percent Undercut Bank	PctUnderCut
Bank Erosion	Mean Bank Erosion (m)	MBankEros
Channel	Channel Condition (NA = Natural, OC = Old Channelization)	ChanCon
% Disturbed < 100M	Percent Disturbed Land Use Within 100 Meters of Stream Bank (Reach Level)	PctDistLU
% Disturbed < 30M	Percent Disturbed Land Use Within 30 Meters of Stream Bank (Reach Level)	PctDistLU30
Std Exc	Exceedance of Water Chemistry Standards	StdVio
Expect Exc	Exceedance of Ecoregion Expectations	ExpectVio
Std/Expect Exc	Exceedance of Standards or Ecoregion Expectations	ChemVio
Flow	Flow (CMS)	Flow
Temp	Water Temperature (°C)	TempH2O
pH	pH	pH
DO	Dissolved Oxygen (mg/l)	DO
Pre Phosphorus	Prefix Total Phosphorus	PrePhos
Phosphorus	Total Phosphorus (mg/l)	Phos
Pre NO2/NO3	Prefix Nitrite/Nitrate	PreNitrogen
NO2/NO3	Nitrite/Nitrate (mg/l)	Nitrogen
Pre NH3/NH4	Prefix Ammonia	PreNH4
NH3/NH4	Total Ammonia (mg/l)	NH4
Un-ion %	Un-ionized Ammonia Percent	UnionPer
NH3	Un-ionized Ammonia (mg/l)	UnionAmmonia
Conduct	Conductivity (µmhos/cm)	Conduct
Pre TSS	Prefix Total Suspended Solids	PreTSS
TSS	Total Suspended Solids (mg/l)	TSS
Turbidity	Turbidity (NTU)	Turbid

Fish IBI	Fish IBI (0-100)	FishIBI
Fish IBI Rating	Fish IBI Rating (Excellent, Good, Fair, Poor, Very Poor)	FishIBIRating
305b Fish	305b Assessment for Fish (Support, Non-Support, Other)	305bassessment
305b (2) Fish	305b Assessment Summary for Fish (Support, Non-Support)	305bassessment2
Fish Reference Site	Reference Site for Fish (True or False)	RefFish
# Fish Taxa	Number of Fish Taxa	CountofTaxa
# Intolerant	Number of Intolerant Fish Taxa	Sensitive
# Special Concern	Number of Special Concern Fish Taxa	Special Concern Sp
# Headwater	Number of Headwater Fish Taxa	Headwater
# Headwater w/o Tolerant	Number of Headwater Fish Taxa w/o Tolerant Taxa	HeadwaterTolerant
# Minnow	Number of Minnow Taxa	Minnow
# Minnow w/o Tolerant	Number of Minnow Taxa w/o Tolerant Taxa	MinnowsTolerant
# Darter	Number of Darter Taxa	Darter
# Invertivore	Number of Invertivore Fish Taxa	Insect
# Invertivore w/o Tolerant	Number of Invertivore Fish Taxa w/o Tolerant Taxa	InsectTolerant
# Benthic Invertivore	Number of Benthic Invertivore Fish Taxa	BenInsect
# Omnivore	Number of Omnivore Fish Taxa	Omnivore
# Game Fish	Number of Game Fish Taxa	Gamefish Species
# Fish/M w/o Tolerant	Number of Fish per Meter w/o Tolerant Fish Taxa	NumPerMeterTolerant
% Dom 2	Percent of Individual Fish that are the Dominant Two Taxa	DomTwoPct
% Tolerant	Percent of Individual Fish that are Tolerant Taxa	TolerantPct
% DELT	Percent of Individual Fish with DELT Anomalies	FishDELTPct
% Piscivore	Percent of Individual Fish that are Piscivores	PiscivorePct
% Lith Spawn	Percent of Individual Fish that are Simple Lithophilic Spawners	SLithopPct
White Sucker	White Sucker Presence	White Sucker Presence
Common Shiner	Common Shiner Presence	Common Shiner Presence
Creek Chub	Creek Chub Presence	Creek Chub Presence
Johnny Darter	Johnny Darter Presence	Johnny Darter Presence
Central Mudminnow	Central Mudminnow Presence	Central Mudminnow Presence
Brook Stickleback	Brook Stickleback Presence	Brook Stickleback Presence
Burbot	Burbot Presence	Burbot Presence
Rock Bass	Rock Bass Presence	Rock Bass Presence
Blacknose Dace	Blacknose Dace Presence	Blacknose Dace Presence
Smallmouth	Smallmouth Presence	Smallmouth Presence
Gamefish Taxa	Gamefish Taxa Presence	Gamefish Species
Northern	Northern Pike Presence	Northern Presence
Common Carp	Common Carp Presence	common carp presence
Brassy Minnow	Brassy Minnow Presence	brassy minnow presence

Longnose Dace	Longnose Dace Presence	longnose dace presence
Hornyhead Chub	Hornyhead Chub Presence	hornyhead chub presence
Emerald Shiner	Emerald Shiner Presence	emerald shiner presence
Mimic Shiner	Mimic Shiner Presence	mimic shiner presence
Bluntnose Minnow	Bluntnose Minnow Presence	bluntnose minnow presence
Fathead Minnow	Fathead Minnow Presence	fathead minnow presence
Northern Redbelly Dace	Northern Redbelly Dace Presence	northern redbelly dace presence
Finescale Dace	Finescale Dace Presence	finescale dace presence
Pearl Dace	Pearl Dace Presence	pearl dace presence
Shorthead Redhorse	Shorthead Redhorse Presence	shorthead redhorse presence
Golden Redhorse	Golden Redhorse Presence	golden redhorse presence
Silver Redhorse	Silver Redhorse Presence	silver redhorse presence
Northern Hogsucker	Northern Hogsucker Presence	northern hogsucker presence
Channel Catfish	Channel Catfish Presence	channel catfish presence
Tadpole Madtom	Tadpole Madtom Presence	tadpole madtom presence
Stonecat	Stonecat Presence	stonecat presence
Black Bullhead	Black Bullhead Presence	black bullhead presence
Mottled Sculpin	Mottled Sculpin Presence	mottled sculpin presence
Bluegill	Bluegill Presence	bluegill presence
Pumpkinseed	Pumpkinseed Presence	pumpkinseed presence
Largemouth Bass	Largemouth Bass Presence	largemouth bass presence
Black Crappie	Black Crappie Presence	black crappie presence
Yellow Perch	Yellow Perch Presence	yellow perch presence
Logperch	Logperch Presence	logperch presence
Gilt Darter	Gilt Darter Presence	gilt darter presence
Blackside Darter	Blackside Darter Presence	blackside darter presence
Slenderhead Darter	Slenderhead Darter Presence	slenderhead darter presence
Walleye	Walleye Presence	walleye presence
Spotfin Shiner	Spotfin Shiner Presence	spotfin shiner presence
Golden Shiner	Golden Shiner Presence	golden shiner presence
Chestnut Lamprey	Chestnut Lamprey Presence	chestnut lamprey presence

Invert IBI	Macroinvertebrate IBI (0-100)	MIBI
Invert IBI Rating	Macroinvertebrate IBI Rating (Excellent, Good, Fair, Poor, Very Poor)	InvertRating
305b Inverts	305b Assessment for Macroinvertebrates (Support, Non-Support, Other)	InvertAssessment
305b (2) Inverts	305b Assessment Summary for Macroinvertebrates (Support, Non-Support)	InvertAssessment2
Hilsenhoff	Hilsenhoff Biological Index Score	HBI
# Invert Taxa	Number of Macroinvertebrate Taxa	TaxaCount
# Tolerant	Number of Tolerant Macroinvertebrate Taxa	Tolerant
# Very Tolerant	Number of Very Tolerant Macroinvertebrate Taxa	VeryTolerant
# EPT	Number of Ephemeroptera/Plecoptera/Tricoptera Taxa	EPT
# Ephemeroptera	Number of Ephemeroptera Taxa	Ephemeroptera
# Plecoptera	Number of Plecoptera Taxa	Plecoptera
# Tricoptera	Number of Tricoptera Taxa	Tricoptera
# Chironomidae	Number of Chironomidae Taxa	ChironomidaeCh
# Invert Taxa (w/ Ch)	Number of Macroinvertebrate Taxa--All Chironomidae Taxa Included	TaxaCountAllChir
# Intolerant (w/ Ch)	Number of Intolerant Macroinvertebrate Taxa--All Chironomidae Taxa Included	IntolerantCh
# Predator (w/ Ch)	Number of Predator Macroinvertebrate Taxa--All Chironomidae Taxa Included	PredatorCh
# Clinger (w/ Ch)	Number of Clinger Macroinvertebrate Taxa--All Chironomidae Taxa Included	ClingerCh
# Scraper (w/ Ch)	Number of Scraper Macroinvertebrate Taxa--All Chironomidae Taxa Included	ScraperCh
# Collect-Filt (w/ Ch)	Number of Collector-Filterer Macroinvertebrate Taxa--All Chironomidae Taxa Included	Collector-filtererCh
# Collect-Gath (w/ Ch)	Number of Collector-Gatherer Macroinvertebrate Taxa--All Chironomidae Taxa Included	Collector-gathererCh
# Tanytarsini (w/ Ch)	Number of Tanytarsini Macroinvertebrate Taxa--All Chironomidae Taxa Included	TanytarsiniCh
# Long-Lived (w/ Ch)	Number of Long-Lived Macroinvertebrate Taxa--All Chironomidae Taxa Included	LongLivedCh
% Dom 2 (w/ Ch)	Percent of Individual Macroinvertebrates That Are the Dominant Two Taxa--All Chironomidae Taxa Included	DomTwoChPct
% Tolerant	Percent of Individual Macroinvertebrates That Are Tolerant Taxa	InvertTolerantPct
% Very Tolerant	Percent of Individual Macroinvertebrates That Are Very Tolerant Taxa	VeryTolerantPct
% EPT	Percent of Individual Macroinvertebrates That Are Ephemeroptera/Plecoptera/Tricoptera	EPTPct
% Ephemeroptera	Percent of Individual Macroinvertebrates That Are Ephemeroptera	EphemeropteraPct
% Plecoptera	Percent of Individual Macroinvertebrates That Are Plecoptera	PlecopteraPct
% Tricoptera	Percent of Individual Macroinvertebrates That Are Tricoptera	TricopteraPct
% Chironomids	Percent of Individual Macroinvertebrates That Are Chironomidae	ChironomidaeChPct
% Amphipods	Percent of Individual Macroinvertebrates That Are Amphipoda	AmphipodaPct
% Predators	Percent of Individual Macroinvertebrates That Are Predators	PredatorPct
% Scrapers	Percent of Individual Macroinvertebrates That Are Scrapers	ScraperPct
% Collector-Filterers	Percent of Individual Macroinvertebrates That Are Collector-Filterers	Collector-filtererPct
% Collector-Gatherers	Percent of Individual Macroinvertebrates That Are Collector-Gatherers	Collector-gathererPct

305b Overall	305b Overall Assessment (Not Assessed, Non-Support or Support for Fish and/or Macroinvertebrates)	OverallAssessment
305b (2) Overall	305b Overall Assessment Summary (Support, Non-Support)	OverallAssessment2
TMDL	TMDL Status (No = Not Listed, Yes = Listed)	TMDLStatus
stratum	stratum	stratum
panel	panel	panel
oversamp	oversamp	oversamp
division	division	division
md_caty	md_caty	md_caty
partiton	partiton	partiton
nest_id	nest_id	nest_id
nest1	nest1	nest1
nest1_n	nest1_n	nest1_n
nest1_wt	nest1_wt	nest1_wt

Appendix 1. (continued) -- St. Croix River Basin Measured Variables

site #	Site ID	Field #	Water Body	Latitude	Longitude	Ecoregion	Strahler Order	Strahler Group	Stream Class	Site Status	Recon Result
1	R5STCR96-001	96SC001	W. Fork Groundhouse River	45.89735	-93.55550	NLF	1	1-2	wetland	NT	UnSamp
2	R5STCR96-002	96SC002	Snake River	46.06186	-93.21950	NLF	4	3-6	coolwater	TS	SampFishInvert
3	R5STCR96-003	96SC003	Snake River	46.06032	-93.22000	NLF	4	3-6	coolwater	TS	SampFishInvert
4	R5STCR96-004	96SC004	Little Ann River	45.96872	-93.42880	NCHF	2	1-2	coolwater	TS	SampFish
5	R5STCR96-005	96SC005	trib to Spring Lake	45.89664	-93.25930	NCHF	1	1-2	coolwater-intermittent	TS	SampFish
6	R5STCR96-006	96SC006	Knife River	46.03534	-93.38000	NCHF	3	3-6	coolwater	TS	SampFishInvert
7	R5STCR96-007	96SC007	Snake River	46.01763	-93.23880	NCHF	4	3-6	coolwater	TS	SampFish
8	R5STCR96-008	96SC008	Knife River	46.07000	-93.46440	NLF	1	1-2	coolwater	TS	SampFishInvert
9	R5STCR96-009	96SC009	trib to Snake River	45.80657	-93.03180	NCHF	1	1-2	wetland	NT	UnSamp
10	R5STCR96-010	96SC010	Snake River	45.78951	-93.10690	NCHF	5	3-6	coolwater	TS	SampFishInvert
11	R5STCR96-011	96SC011	Mud Creek	45.87187	-93.13500	NCHF	3	3-6	coolwater	TS	SampFishInvert
12	R5STCR96-012	96SC012	Snake River	45.84351	-92.88970	NCHF	5	3-6	coolwater	TS	SampFishInvert
13	R5STCR96-013	96SC013	Mission Creek	45.89314	-92.98040	NCHF	2	1-2	coolwater	TS	SampFishInvert
14	R5STCR96-014	96SC014	trib to N. Br. Sunrise River	45.48743	-93.10020	NCHF	2	1-2	coolwater	LD	UnSamp
15	R5STCR96-015	96SC015	Rush Creek	45.68060	-92.99010	NCHF	3	3-6	coolwater	TS	SampFishInvert
16	R5STCR96-016	96SC016	trib ditch to Hay Creek	45.53847	-92.93280	NCHF	1	1-2	coolwater-intermittent	TS	SampFish
17	R5STCR96-017	96SC017	Groundhouse River	45.84102	-93.44770	NCHF	3	3-6	coolwater	TS	SampFish
18	R5STCR96-018	96SC018	Snake River	45.81297	-93.28070	NCHF	4	3-6	coolwater	TS	SampFishInvert
19	R5STCR96-019	96SC019	Snake River	45.79365	-93.18110	NCHF	5	3-6	coolwater	TS	SampFishInvert
20	R5STCR96-020	96SC020	Krone Bog	45.71648	-93.45650	NCHF	1	1-2	coolwater	NT	UnSamp
21	R5STCR96-021	96SC021	Ann River	45.87211	-93.34390	NCHF	3	3-6	coolwater	TS	SampFishInvert
22	R5STCR96-022	96SC022	Rock Creek	45.71850	-92.91020	NCHF	3	3-6	coolwater	TS	SampFishInvert
23	R5STCR96-023	96SC023	Goose Creek	45.59438	-92.90090	NCHF	3	3-6	coolwater	TS	SampFishInvert
24	R5STCR96-024	96SC024	trib to S. Br. Sunrise River	45.34657	-92.95970	NCHF	2	1-2	wetland	TS	SampFishInvert
25	R5STCR96-025	96SC025	N. Branch Sunrise River	45.51293	-92.89320	NCHF	3	3-6	coolwater	TS	SampFishInvert
26	R5STCR96-026	96SC026	Lawrence Creek	45.38493	-92.69430	NCHF	2	1-2	coolwater	TS	SampInvert
27	R5STCR96-027	96SC027	county ditch #7	45.49064	-92.99110	NCHF	1	1-2	coolwater	TS	SampFishInvert
28	R5STCR96-028	96SC028	St. Croix River	45.26966	-92.76060	NCHF	6	3-6	coolwater	TS	SampFish
29	R5STCR96-029	96SC029	Lower Tamarack River	46.05375	-92.39670	NLF	3	3-6	coolwater	TS	SampFishInvert
30	R5STCR96-030	96SC030	St. Croix River	45.88046	-92.72960	NLF	5	3-6	coolwater	TS	SampFishInvert
31	R5STCR96-031	96SC031	trib to Redhorse Creek	45.87974	-92.77510	NLF	1	1-2	coolwater	NT	UnSamp
32	R5STCR96-032	96SC032	Kettle River	45.96081	-92.82280	NLF	5	3-6	coolwater	TS	SampFish
33	R5STCR96-033	96SC033	Kettle River	45.90111	-92.73090	NLF	5	3-6	coolwater	TS	SampFishInvert
34	R5STCR96-034	96SC034	Bear Creek	46.01327	-92.74480	NLF	2	1-2	coolwater	TS	SampFishInvert
35	R5STCR96-035	96SC035	trib to Split Rock River	46.42462	-92.94720	NLF	1	1-2	coolwater	NT	UnSamp
36	R5STCR96-036	96SC036	trib to Dead Moose River	46.52150	-92.97220	NLF	1	1-2	coolwater	TS	SampFish
37	R5STCR96-037	96SC037	Upper Tamarack River	46.14191	-92.29440	NLF	3	3-6	coolwater	TS	SampFishInvert
38	R5STCR96-038	96SC038	McDermott Creek	46.20651	-92.39440	NLF	2	1-2	coolwater	TS	SampFishInvert
39	R5STCR96-039	96SC039	W. Branch Kettle River	46.60133	-93.01390	NLF	1	1-2	wetland	TS	SampFish
40	R5STCR96-040	96SC040	Kettle River	46.45581	-92.87360	NLF	3	3-6	coolwater	TS	SampFishInvert
41	R5STCR96-041	96SC041	Little Hanging Horn Lake trib	46.49463	-92.65560	NLF	1	1-2	wetland	NT	UnSamp
42	R5STCR96-042	96SC042	Gillespie Brook	46.52123	-92.79180	NLF	2	1-2	coolwater	TS	SampFishInvert
43	R5STCR96-043	96SC043	Pine River	46.28033	-92.92780	NLF	4	3-6	coolwater	TS	SampFishInvert
44	R5STCR96-044	96SC044	trib to Burnam Creek	46.28567	-92.98710	NLF	1	1-2	coolwater	TS	SampFishInvert
45	R5STCR96-045	96SC045	Cane Creek	46.24627	-92.78090	NLF	2	1-2	coolwater	TS	SampFishInvert
46	R5STCR96-046	96SC046	Kettle River	46.36701	-92.86100	NLF	4	3-6	coolwater	TS	SampFishInvert
47	R5STCR96-047	96SC047	Kettle River	46.39814	-92.87970	NLF	4	3-6	coolwater	TS	SampFishInvert
48	R5STCR96-048	96SC048	Kettle River	46.35320	-92.84020	NLF	4	3-6	coolwater	TS	SampFishInvert
49	R5STCR96-049	96SC049	trib to Snake River	46.20014	-93.25390	NLF	2	1-2	coolwater	TS	SampFishInvert
50	R5STCR96-050	96SC050	Snake River	46.32371	-93.27620	NLF	3	3-6	coolwater	TS	SampFishInvert
51	R5STCR96-051	96SC051	trib to Chelsey Brook	46.17338	-93.17530	NLF	1	1-2	coolwater-intermittent	TS	SampFishInvert
52	R5STCR96-052	96SC052	Snake River	46.22269	-93.24180	NLF	3	3-6	coolwater	TS	SampFishInvert
53	R5STCR96-053	96SC053	Kettle River	46.03728	-92.87150	NLF	5	3-6	coolwater	TS	SampFish
54	R5STCR96-054	96SC054	Deer Creek	46.05324	-92.88170	NLF	1	1-2	coolwater	TS	SampFishInvert
55	R5STCR96-055	96SC055	Bear Creek	46.11163	-92.79070	NLF	2	1-2	wetland	TS	SampFish
56	R5STCR96-056	96SC056	Lower Tamarack River	46.07923	-92.42780	NLF	3	3-6	coolwater	TS	SampFishInvert
57	R5STCR96-057	96SC057	Partridge Creek	46.19384	-92.71650	NLF	1	1-2	coolwater	NT	UnSamp
58	R5STCR96-058	96SC058	East Fork Crooked Creek	46.07920	-92.55500	NLF	2	1-2	coolwater	TS	SampFishInvert
59	R5STCR96-059	96SC059	Keene Creek	46.15933	-92.47710	NLF	1	1-2	coolwater	TS	SampInvert
60	R5STCR96-060	96SC060	trib to St. Croix River	44.79936	-92.81980	WCBP	1	1-2	coolwater	NT	UnSamp

Appendix 1. (continued) -- St. Croix River Basin Measured Variables

site #	Recon Reason	Visit Date--Fish	Visit Result--Fish	Visit Date--Inverts	Visit Result--Inverts
1	Wetland (no definable channel)				
2	Regular (flowing water/defined channel)	7/24/1996	reportable	8/27/1996	reportable
3	Regular (flowing water/defined channel)	7/24/1996	reportable	8/27/1996	reportable
4	Regular (flowing water/defined channel)	7/3/1996	reportable		
5	Regular (flowing water/defined channel)	7/9/1996	non-reportable		
6	Regular (flowing water/defined channel)	6/25/1996	reportable	9/4/1996	reportable
7	Regular (flowing water/defined channel)	9/25/1996	reportable		
8	Regular (flowing water/defined channel)	7/2/1996	reportable	9/4/1996	reportable
9	Wetland (no definable channel)				
10	Regular (flowing water/defined channel)	7/17/1996	reportable	9/3/1996	reportable
11	Regular (flowing water/defined channel)	7/19/1996	reportable	8/22/1996	reportable
12	Regular (flowing water/defined channel)	8/1/1996	reportable	9/3/1996	reportable
13	Regular (flowing water/defined channel)	8/6/1996	reportable	8/27/1996	reportable
14	Access permission denied				
15	Regular (flowing water/defined channel)	6/28/1996	reportable	9/11/1996	reportable
16	Regular (flowing water/defined channel)	7/23/1996	non-reportable		
17	Regular (flowing water/defined channel)	6/27/1996	reportable		
18	Regular (flowing water/defined channel)	6/26/1996	reportable	9/9/1996	reportable
19	Regular (flowing water/defined channel)	7/9/1996	reportable	9/9/1996	reportable
20	Dry (no water anywhere along reach)				
21	Regular (flowing water/defined channel)	9/3/1996	reportable	9/4/1996	reportable
22	Regular (flowing water/defined channel)	7/31/1996	reportable	8/26/1996	reportable
23	Regular (flowing water/defined channel)	7/30/1996	reportable	9/16/1996	reportable
24	Regular (flowing water/defined channel)	7/29/1996	non-reportable	9/17/1996	reportable
25	Regular (flowing water/defined channel)	8/19/1996	reportable	9/16/1996	reportable
26	Dry (no water anywhere along reach)			8/27/1996	reportable
27	Regular (flowing water/defined channel)	7/8/1996	reportable	8/21/1996	reportable
28	Regular (flowing water/defined channel)	8/2/1996	reportable		
29	Regular (flowing water/defined channel)	8/14/1996	reportable	9/10/1996	reportable
30	Regular (flowing water/defined channel)	9/19/1996	reportable	9/19/1996	reportable
31	Impounded (beaver dam)				
32	Regular (flowing water/defined channel)	7/24/1996	reportable		
33	Regular (flowing water/defined channel)	8/15/1996	reportable	8/29/1996	reportable
34	Regular (flowing water/defined channel)	7/18/1996	reportable	8/29/1996	reportable
35	Impounded (beaver dam)				
36	Regular (flowing water/defined channel)	7/16/1996	reportable		
37	Regular (flowing water/defined channel)	8/13/1996	reportable	9/9/1996	reportable
38	Regular (flowing water/defined channel)	9/12/1996	reportable	9/2/1996	reportable
39	Regular (flowing water/defined channel)	9/11/1996	non-reportable		
40	Regular (flowing water/defined channel)	8/21/1996	reportable	8/28/1996	reportable
41	Wetland (no definable channel)				
42	Regular (flowing water/defined channel)	7/16/1996	reportable	8/28/1996	reportable
43	Regular (flowing water/defined channel)	9/4/1996	reportable	9/23/1996	reportable
44	Regular (flowing water/defined channel)	7/17/1996	reportable	9/5/1996	reportable
45	Regular (flowing water/defined channel)	7/11/1996	reportable	8/29/1996	reportable
46	Regular (flowing water/defined channel)	8/20/1996	reportable	8/28/1996	reportable
47	Regular (flowing water/defined channel)	8/21/1996	reportable	8/25/1996	reportable
48	Regular (flowing water/defined channel)	8/22/1996	reportable	8/25/1996	reportable
49	Regular (flowing water/defined channel)	8/20/1996	reportable	9/5/1996	reportable
50	Regular (flowing water/defined channel)	7/26/1996	reportable	9/10/1996	reportable
51	Regular (flowing water/defined channel)	8/20/1996	non-reportable	9/10/1996	reportable
52	Regular (flowing water/defined channel)	7/25/1996	reportable	9/5/1996	reportable
53	Regular (flowing water/defined channel)	7/25/1996	reportable		
54	Regular (flowing water/defined channel)	7/18/1996	reportable	9/18/1996	reportable
55	Regular (flowing water/defined channel)	9/24/1996	non-reportable		
56	Regular (flowing water/defined channel)	8/14/1996	reportable	9/10/1996	reportable
57	No channel or water body present				
58	Regular (flowing water/defined channel)	9/11/1996	reportable	9/12/1996	reportable
59	Inaccessible (unable to reach site)			9/12/1996	reportable
60	Dry (no water anywhere along reach)				

Appendix 1. (continued) -- St. Croix River Basin Measured Variables

site #	% Disturbed	% Disturbed Group	% Ag/Range	% Agriculture	% Rangeland	% Urban	% Mining	% Forest	% Wetland	% Pre-Settle Wetland	% Remaining Wetlands	% Agriculture < 100M	% Forest < 100M	% Wetland < 100M	FHR	FHR Group	Revised FHR	Revised FHR Group	Depth	Thalweg	Width	Log Width	Gradient	Sinuosity	Res Sinuosity	# Features/100M	Res # FeatuRes/100M	% Riffle	% Pool	% Run	# Riffles
1		NM														NM		NM													
2	10	0-39	10	1	10	0	0	61	26	49	54	13	52	29	7	0-8	8	8-12	68	134	29	3.35	1.35	1.07	-0.14	0.8	-1.33	40	36	25	2
3	10	0-39	10	1	10	0	0	61	26			13	52	29	8	0-8	8	8-12	59	121	26	3.24	1.34	1.05	-0.19	1.2	-1.31	54	6	40	3
4	4	0-39	3	1	2	0	0	71	24	29	83	10	66	22	12	9-12	12	8-12	29	72	7	1.96	2.05	1.63	0.30	7.5	0.06	35	53	12	7
5	65	40-100	62	35	28	0	0	28	6	8	76				5	0-8	1	0-7	7	15	1	-0.15	4.94	1.07	-0.19	7.1	-16.95	13	0	87	5
6	21	0-39	20	3	18	0	0	63	15	30	48	24	52	19	10	9-12	8	8-12	42	70	21	3.05	2.02	1.16	-0.11	3.3	0.18	11	66	23	5
7	13	0-39	13	2	11	0	0	62	23	46	51	16	53	25		NM		NM													
8	52	40-100	51	5	46	0	1	32	15	44	35	75	6	14	5	0-8	3	0-7	47	63	8	2.13	0.95	1.20	-0.16	1.8	-4.90	0	100	0	0
9		NM														NM		NM													
10	32	0-39	31	13	18	0	0	52	15	31	47	28	49	16		NM		NM													
11	49	40-100	48	14	33	0	0	41	9	44	21	43	35	15	9	9-12	8	8-12	69	152	14	2.64	0.60	1.39	0.03	2.8	-1.89	0	22	78	0
12	36	0-39	34	12	22	1	0	47	15	32	45	29	44	17		NM	9	8-12	77	162	45	3.82	1.07	1.12	0.01	1.3	0.83	19	24	56	1
13	60	40-100	59	7	52	1	0	17	21	40	53	27	16	39	11	9-12	5	0-7	49	85	7	2.01	0.33	1.50	0.16	3.9	-3.33	0	15	85	0
14		NM														NM		NM													
15	60	40-100	57	27	31	1	0	25	2	17	11	39	20	2	10	9-12	6	0-7	63	88	7	2.01	0.79	1.57	0.23	3.0	-4.20	0	14	86	0
16	73	40-100	68	54	15	3	0	27	0	37	0	100	0	0	2	0-8	0	0-7	14	26	1	0.15	0.00	0.00	-1.27	0.7	-20.71	0	0	100	0
17	13	0-39	13	5	8	0	0	60	27	32	85	19	50	29	10	9-12	9	8-12	24	57	8	2.10	1.89	1.56	0.20	6.7	-0.18	15	19	66	4
18	23	0-39	21	7	14	0	0	58	17	33	51	22	52	18		NM		NM													
19	31	0-39	30	13	17	0	0	52	15	31	48	27	49	16		NM		NM													
20		NM														NM		NM													
21	20	0-39	19	7	13	0	0	65	13	19	66	23	54	14	10	9-12	10	8-12	29	77	13	2.53	1.66	2.11	0.74	6.3	1.26	30	36	34	10
22	80	40-100	79	34	45	1	0	13	7	33	21	73	14	9	11	9-12	8	8-12	33	63	12	2.47	1.13	2.16	0.78	4.8	-0.51	9	12	79	6
23	57	40-100	54	33	21	1	0	35	4	23	17	42	39	11	9	9-12	7	0-7	27	60	9	2.16	1.04	1.42	0.06	4.2	-2.43	1	19	80	1
24	60	40-100	53	32	21	4	0	23	5	9	54	34	31	16		NM	6	0-7	61	110	11	2.38	0.76	1.41	0.02	6.7	0.99	0	27	77	0
25	64	40-100	59	42	17	2	0	32	3	21	12	42	50	3	8	0-8	3	0-7	32	59	10	2.33	1.03	1.99	0.61	1.5	-4.42	0	1	90	0
26		NM														NM		NM													
27	62	40-100	59	32	27	0	0	36	2	23	10	82	18	0	6	0-8	0	0-7	22	42	1	0.32	0.76	1.05	-0.22	5.5	-14.12	0	5	95	0
28		NM														NM		NM													
29	3	0-39	3	0	3	0	0	69	27	59	46	5	57	29	9	9-12	8	8-12	49	110	23	3.16	1.96	1.10	-0.15	2.3	-0.48	9	16	75	4
30		NM														NM	8	8-12	59	105	101	4.62	1.06	1.03	0.03	0.4	0.40	105	0	100	1
31		NM														NM		NM													
32	28	0-39	26	2	24	1	0	49	20	35	58	23	40	24		NM		NM													
33	28	0-39	26	2	24	1	0	49	20	35	58	22	41	24		NM	9	8-12	58	99	57	4.04	1.78	1.21	0.15	0.4	0.39	48	0	52	1
34	34	0-39	33	2	31	0	0	49	16	28	59	38	28	32	9	9-12	6	0-7	54	87	8	2.07	0.74	2.06	0.71	4.8	-2.15	4	9	87	2
35		NM														NM		NM													
36	25	0-39	24	0	24	0	0	47	27	38	70	61	3	30	8	0-8	4	0-7	42	62	2	0.73	3.86	1.30	0.04	4.0	-11.05	0	9	91	0
37		NM													7	0-8	6	0-7	37	68	20	3.01	2.15	1.07	-0.21	2.9	-0.26	23	15	62	6
38	0	0-39	0	0	0	0	0	40	60	66	91	0	51	43	10	9-12	8	8-12	68	130	9	2.15	1.98	1.20	-0.16	4.1	-2.52	5	30	65	2
39	15	0-39	15	0	15	0	0	36	46	82	56	21	6	46		NM		NM													
40	23	0-39	21	1	21	1	0	43	32	47	68	26	28	35	9	9-12	8	8-12	43	89	19	2.95	4.15	1.09	-0.20	2.1	-1.32	40	35	25	3
41		NM														NM		NM													
42	10	0-39	10	0	10	0	0	58	31	56	56	7	32	61	10	9-12	4	0-7	87	124	4	1.42	1.33	1.10	-0.19	6.0	-3.64	0	7	93	0
43	25	0-39	24	2	22	0	0	56	15	26	57	22	46	16	11	9-12	9	8-12	60	110	17	2.83	0.59	1.84	0.52	3.7	-0.10	2	40	68	1
44	8	0-39	8	0	8	0	0	86	6			13	81	6	9	9-12	10	8-12	15	33	1	0.20	6.29	1.51	0.25	35.9	14.98	33	49	18	19
45	30	0-39	30	0	30	0	0	43	26	43	60	34	13	53	6	0-8	4	0-7	53	75	1	0.38	1.80	1.29	0.02	0.6	-18.21	0	0	100	0
46	24	0-39	23	1	22	1	0	48	27	48	56	26	34	32		NM	12	8-12	42	134	18	2.90	2.13	1.48	0.17	8.3	4.73	33	41	83	11
47	23	0-39	22	1	21	1	0	47	29	48	60	24	33	34		NM	10	8-12	47	91	34	3.53	1.15	1.05	-0.12	1.5	0.04	15	9	76	2
48	24	0-39	23	1	22	1	0	48	26	42	62	22	34	33		NM	7	0-7	71	143	31	3.45	0.47	1.16	-0.03	0.8	-0.98	2	19	81	1
49	16	0-39	16	0	16	0	0	69	12	24	50	8	55	26	9	9-12	9	8-12	23	49	3	1.00	7.66	1.16	-0.11	7.3	-5.08	27	53	0	4
50	7	0-39	7	0	7	0	0	55	37	71	52	12	22	63	3	0-8	2	0-7	44	71	9	2.21	0.56	1.02	-0.35	0.3	-6.07	0	0	100	0
51	4	0-39	4	0	3	0	0	83	8	22	35	4	64	20	11	9-12	11	8-12	5	11	2	0.41	17.23	1.48	0.21	22.9	4.30	57	35	8	15
52	10	0-39	10	0	10	0	0	51	37	64	58	16	28	51	9	9-12	7	0-7	57	91	28	3.34	1.51	1.24	0.02	2.5	0.42	9	23	68	4
53	26	0-39	25	1	24	1	0	50	21	36	59	22	40	25		NM		NM													
54	23	0-39	23	3	20	0	0	61	16	28	56	13	68	19	12	9-12	11	8-12	14	34	5	1.66	10.47	1.36	0.05	16.8	8.27	22	44	33	7
55	52	40-100	51	2	49	1	0	39	8	18	45	59	16	23		NM		NM													
56	3	0-39	3	0	3	0	0	66	30	58	52	5	54	33	11	9-12	9	8-12	53	109	18	2.89	0.99	1.49	0.19	2.9	-0.70	11	29	60	2
57		NM														NM		NM													
58	5	0-39	5	0	5	0	0	73	21	42	51	5	55	34	11	9-12	7	0-7	85	128	13	2.54	1.00	1.81	0.44	3.9	-1.11	0	47	52	0
59		NM														NM		NM													
60		NM														NM		NM													

Appendix 1. (continued) -- St. Croix River Basin Measured Variables

site #	# Pools	# Runs	# Bends	Riffle Length	Pool Length	Run Length	Distance Riffles	Distance Bends	Width/Depth	Riffle/Riffle	Bend/Bend	# Substrate Types	Res # Substrate Types	% Fines	Depth Fines	% Embeddedness	% Coarse	Res % Coarse	% Boulder	CV Depth	Res CV Depth	% Stream Cover	% Overhanging Veg	% Emerg Macrophytes	% Submerg Macrophytes	% Woody Debris	# Log Jams	% Undercut Bank	Bank Erosion	Channel	% Disturbed < 100M	% Disturbed < 30M
1																																
2	1	1	0	210	190	130	130		26.2	4.6		4	0.10	0	4	25	98	13.96	22	39	0.10	32	7	1	0	1	0	1	0.00	NA	0	0
3	1	2	0	280	30	210	105		26.4	4.1		4	-0.04	5	3	20	95	12.42	26	40	0.91	37	7	2	0	1	0	1	0.00	NA	0	0
4	6	2	1	75	112	26	16		13.8	2.2		6	1.29	6	4	26	87	15.99	4	82	33.98	62	48	0	0	9	1	0	0.00	NA	0	0
5	0	6	0	20	0	136	20		8.7	23.3		4	-0.55	79	21		0	-40.00	0	53	-24.30	61	37	9	0	8	8	0	0.00	NA	52	15
6	4	6	0	51	302	104	97		35.8	4.6		5	0.71	15	7	38	85	5.68	8	22	-18.17	31	3	0	17	2	0	0	0.00	NA	0	0
7																														NA		
8	1	0	2	0	164	0		21	15.4		2.5	3	-1.75	88	24		0	-71.59	0	14	-33.18	103	2	25	75	0	0	0	0.00	NA	0	0
9																																
10																														NA		
11	5	6	2	0	102	371		278	13.1		19.9	6	1.30	94	39	58	6	-67.49	1	32	-11.03	68	2	57	0	9	3	0	0.00	NA	10	0
12	2	3	0	87	108	253			34.1			3	-0.28	12	4	13	88	-4.45	10	43	8.41	41	8	8	12	4	1	0	0.00	NA	6	12
13	3	3	2	0	32	174		43	10.9		5.7	5	0.28	87	38	29	13	-57.62	0	26	-21.65	95	13	25	43	13	3	1	0.00	NA	12	8
14																																
15	2	3	4	0	41	259		74	10.3		9.9	6	1.28	83	20	41	17	-53.83	1	16	-31.85	60	6	3	44	2	1	5	0.13	NA	0	0
16	0	1	0	0	0	141			6.6			2	-2.65	79	60		0	-43.54	0	37	-35.03	126	85	42	0	0	0	0	0.00	OC	100	100
17	3	6	2	33	44	149	35	83	19.6	4.3	10.1	7	2.26	17	6	39	83	11.14	3	47	-0.13	11	0	1	6	0	0	0	1.00	NA	100	100
18																														NA		
19																														NA		
20																																
21	4	12	2	132	158	151	28	182	21.2	2.3	14.5	5	0.24	12	4	0	88	16.49	4	94	50.94	39	2	0	26	7	3	0	0.00	NA	100	100
22	6	9	3	43	62	395	78	35	25.0	6.6	3.0	6	1.22	20	9	65	79	7.06	9	35	-8.61	36	18	0	0	10	6	0	0.00	NA	2	4
23	4	6	1	3	55	232			20.7			6	1.25	92	40	31	8	-63.90	2	36	-10.83	53	40	0	0	11	8	1	0.13	NA	0	0
24	8	8	5	0	86	243		48	12.6		4.4	3	-1.79	100	48		0	-71.13	0	23	-21.39	117	5	35	75	2	0	0	0.00	NA	0	0
25	1	3	1	0	5	308			23.3			4	-0.79	94	56	25	2	-69.27	0	26	-18.48	35	10	0	0	16	11	1	0.23	NA	10	8
26																																
27	3	4	2	0	8	157		3	5.4		2.2	4	-0.71	50	51		0	-44.97	0	52	-16.05	70	53	9	1	5	1	2	0.00	OC	50	50
28																														NA		
29	1	6	0	43	78	367	23		36.6	1.0		4	-0.15	13	9	22	83	2.55	2	58	18.22	29	13	0	1	10	1	3	0.17	NA	0	0
30	0	1	0	524	0	499			138.0			5	2.30	38	17	14	62	-37.39	8	18	-14.77	24	3	1	9	3	1	1	0.00	NA	0	0
31																																
32																														NA		
33	0	1	0	247	0	270			60.5			3	0.03	0	1	10	100	2.79	67	26	-6.68	88	5	0	16	0	0	0	0.00	NA	0	0
34	3	4	5	12	26	254	236	49	11.5	29.7	6.1	7	2.26	58	15	16	40	-31.09	1	20	-27.52	44	22	0	0	20	7	1	0.08	NA	0	0
35																																
36	1	2	3	0	14	136		45	4.0		21.8	6	1.12	73	7	35	23	-25.19	0	18	-42.12	74	52	8	1	13	0	1	0.00	NA	96	96
37	3	5	1	117	75	317	76		36.5	3.7		3	-1.33	0	2	24	100	21.58	16	32	-9.25	36	10	1	2	7	0	0	0.00	NA	0	0
38	3	4	1	11	74	160	44		10.5	5.1		6	1.25	13	6	22	71	-0.44	7	56	9.66	48	30	0	1	9	2	0	0.00	NA	0	0
39																														NA		
40	3	4	2	229	197	144	147	120	28.3	7.7	6.3	4	-0.40	4	3	15	96	18.93	48	43	1.54	65	11	0	0	5	2	1	0.00	NA	5	0
41																																
42	1	2	6	0	10	140		21	4.0		5.0	5	0.11	81	22	23	19	-39.78	0	16	-34.49	47	18	3	0	18	1	7	0.00	NA	0	0
43	7	8	3	8	201	343		75	21.1		4.4	5	0.47	48	16	42	52	-24.02	2	39	-2.62	60	5	1	38	12	1	1	0.00	NA	0	0
44	17	5	10	48	69	26	5	10	4.9	3.7	7.8	3	-1.67	31	9	40	52	7.98	0	78	7.31	140	92	6	0	33	19	8	0.00	NA	0	0
45	0	1	0	0	0	155			2.4			4	-0.74	85	48		0	-45.47	0	23	-43.99	103	65	28	0	4	0	6	0.00	OC	0	0
46	8	16	7	165	206	418	56	64	24.6	3.1	3.5	6	1.54	14	7	25	86	9.46	1	68	26.04	9	3	0	0	4	4	1	0.38	NA	0	0
47	2	4	0	79	45	401	38		47.4	1.1		4	0.32	2	6	10	98	10.96	19	29	-8.70	34	11	0	1	1	0	2	0.02	NA	0	0
48	1	2	0	10	100	425			33.3			3	-0.78	39	13	57	61	-25.11	0	41	3.34	31	18	0	0	11	4	1	0.07	NA	0	0
49	4	0	3	40	79	0	11	7	6.4	3.9	2.7	7	2.05	33	4	23	61	9.87	21	84	28.58	100	62	14	0	2	1	0	0.00	NA	0	0
50	0	1	0	0	0	350			16.7			2	-2.77	81	15	23	19	-52.29	0	26	-20.48	48	16	17	0	14	2	0	0.00	OC	0	0
51	14	3	3	87	54	12	4	38	16.8	2.9	25.1	5	0.25	23	3	23	62	15.87	28	56	-11.05	98	45	0	0	22	3	4	0.00	NA	0	0
52	3	5	2	51	124	377	75	158	37.8	2.7	5.6	4	0.09	15	4	25	85	0.66	29	25	-14.04	50	14	1	2	4	0	0	0.00	NA	10	4
53																														NA		
54	7	7	5	35	69	52	18	26	21.6	3.4	4.9	6	1.23	27	3	25	71	6.92	8	55	6.15	124	85	5	0	21	3	5	0.00	NA	0	0
55																														OC		
56	4	6	3	58	148	305	443	212	24.0	24.6	11.8	5	0.53	46	17	31	54	-22.81	4	45	2.97	25	13	0	0	6	0	1	0.00	NA	0	0
57																																
58	4	4	2	0	122	134		12	11.7		1.0	5	0.25	83	14	67	17	-54.85	0	17	-26.34	23	8	1	2	11	0	0	0.02	NA	4	0
59																																
60																																

site #	Std Exc	Expect Exc	Std/Expect Exc	Flow	Temp	pH	DO	Pre Phosphorus	Phosphorus	Pre NO2/NO3	NO2/NO3	Pre NH3/NH4	NH3/NH4	Un-ion %	NH3	Conduct	Pre TSS	TSS	Turbidity
1																			
2	no	yes	yes	3.65	20	7.3	7.1		0.07	<	0.02		0.02	0.009	0.00	111		2	4
3	no	yes	yes	3.65	20	7.3	7.1		0.07	<	0.02		0.02	0.009	0.00	111		2	4
4	no	yes	yes	0.05	21	8.1	6.5		0.12		0.06		0.03	0.054	0.00	105		21	3
5	yes	yes	yes	0.00	16	7.0	1.4		0.19	<	0.02		0.87	0.003	0.00	104		4	13
6	no	no	no	0.09	21	7.7	10.6									262		4	3
7	no	no	no	0.54	12	7.7	8.7		0.02	<	0.02	<	0.01	0.010	0.00	263		2	2
8	yes	yes	yes	0.02	22	7.3	0.6		0.17	<	0.02		0.03	0.008	0.00	198		10	5
9																			
10	no	yes	yes	10.65	22	7.1	5.3		0.09		0.21		0.04	0.006	0.00	147		9	4
11	yes	no	yes	0.09	24	8.2	3.7		0.15		0.08		0.05	0.081	0.00	225		10	5
12	no	no	no	6.90	25	8.9	8.6		0.05		0.10		0.06	0.311	0.02	198		6	5
13	yes	no	yes	0.03	23	8.4	3.7		0.10	<	0.02	<	0.01	0.112	0.00	215		14	7
14																			
15	no	no	no	0.87	27	7.0	6.0		0.06	<	0.02		0.03	0.006	0.00	293		10	
16	yes	yes	yes	0.01	25	7.4	0.4		0.31	<	0.02		0.22	0.013	0.00	340		770	9
17	no	no	no	0.08	27	7.4	8.4		0.08		0.05		0.03	0.015	0.00	183		2	3
18	no	yes	yes	3.85	22	7.1	9.6		0.05		0.18	<	0.01	0.005	0.00	229		4	2
19	no	yes	yes	7.31	20	7.1	5.6		0.09		0.30		0.03	0.005	0.00	187		10	4
20																			
21	no	no	no	0.11	23	8.5	9.7		0.05	<	0.02	<	0.01	0.128	0.00	293		3	1
22	no	yes	yes	0.15	20	8.4	11.2		0.08		0.77	<	0.01	0.083	0.00	537		4	3
23	no	yes	yes	0.33		8.2	8.9		0.09		0.68		0.04	0.013	0.00	356		24	7
24	no	yes	yes	0.14	20	7.9	6.6		0.04		0.18		0.05	0.030	0.00	353		2	1
25	no	yes	yes	0.77	18	8.9			0.11		1.90	<	0.01	0.217	0.00	363		2	3
26																			
27	no	yes	yes	0.02	22	7.4	8.7		0.11		0.24		0.10	0.011	0.00	409		4	11
28	no	yes	yes	132.52	22	7.7	7.2	<	0.01		0.15		0.03	0.022	0.00	140		22	
29	no	no	no	1.42	20	7.7	7.9		0.04	<	0.02		0.02	0.020	0.00	136		2	2
30	no	yes	yes	48.54	15	7.6	9.8		0.03		0.05	<	0.01	0.010	0.00	142		3	2
31																			
32	no	yes	yes	23.25	21	7.6	6.7		0.05		0.07	<	0.01	0.017	0.00	112		5	20
33	no	no	no	10.59	20	8.1	7.9		0.05	<	0.02		0.02	0.043	0.00	147		2	2
34	no	yes	yes	0.50	25	7.8	6.4		0.07		0.07		0.03	0.031	0.00	120		6	4
35																			
36	yes	yes	yes	0.10	25	7.0	4.0		0.11	<	0.02		0.12	0.005	0.00	120		6	3
37	no	no	no	0.48	25	7.8	7.5		0.05	<	0.02		0.03	0.036	0.00	76		3	2
38	no	yes	yes	0.09	15	8.0	7.5		0.09	<	0.02	<	0.01	0.026	0.00	66		36	7
39	yes	yes	yes		18	6.6	2.7		0.05	<	0.02		0.11	0.001	0.00	66		48	3
40	no	yes	yes	0.97	19	7.3	7.6		0.06		0.06	<	0.01	0.007	0.00	117		2	4
41																			
42	no	yes	yes	0.40	19	6.8	5.7		0.09	<	0.02		0.05	0.002	0.00	72		24	4
43	no	yes	yes	0.77	20	7.5			0.13	<	0.02		0.02	0.013	0.00	168		76	3
44	no	yes	yes	0.00	19	7.5	6.3		0.05		0.06		0.05	0.011	0.00	200	<	1	2
45	no	yes	yes	0.12	16	6.7	5.3		0.11	<	0.02	<	0.01	0.001	0.00	60		20	8
46	no	yes	yes	1.62	21	7.4	7.6		0.06	<	0.02		0.02	0.010	0.00	139		6	3
47	no	yes	yes	1.50	20	7.4	7.1		0.06	<	0.02		0.04	0.010	0.00	130	<	1	3
48	no	yes	yes	3.51	21	7.4	6.5		0.13	<	0.02		0.02	0.011	0.00	136		18	
49	no	yes	yes	0.00	16	7.2	5.0		0.10		0.07		0.10	0.004	0.00	153		4	4
50	yes	yes	yes	0.74	19	5.2	6.3		0.07	<	0.02		0.04	0.000	0.00	85		8	
51	no	yes	yes	0.00	18	7.5	8.1		0.10		0.17	<	0.01	0.012	0.00	234		12	3
52	no	yes	yes	1.55	19	7.0	6.5		0.07	<	0.02		0.03	0.004	0.00	93		5	7
53	no	no	no	22.91	20		7.6		0.05	<	0.02	<	0.01	0.000	0.00	113		5	2
54	no	yes	yes	0.02	25	7.6	5.9		0.13		0.10		0.07	0.020	0.00	120		6	8
55	no	yes	yes	0.00	14	7.4	7.9		0.09	<	0.02		0.03	0.007	0.00	194		3	
56	no	no	no	0.85	22	8.1	8.2		0.05	<	0.02		0.04	0.051	0.00	115		1	3
57																			
58	no	no	no	0.14	18	8.2	7.9		0.03	<	0.02	<	0.01	0.053	0.00	167		5	3
59																			
60																			

site #	Fish IBI	Fish IBI Rating	305b Fish	305b (2) Fish	Fish Reference Site	# Fish Taxa	# Sensitive	# Special Concern	# Headwater	# Headwater w/o Tolerant	# Minnow	# Minnow Tolerant	# Darter	# Invertivore	# Invertivore w/o Tolerant	# Benthic Invertivore	# Omnivore	# Fish/M w/o Tolerant	% Dom 2	% Tolerant	% DELT	% Piscivore	% Lith Spawn	White Sucker	Common Shiner	Creek Chub	Johnny Darter	Central Mudminnow	Brook Stickleback
1			not sampled		FALSE																								
2	85	Excellent	support	support	TRUE	17	8	1	0	0	3	2	3	9	8	6	1	0.2	36	4	1	48	66	Yes	No	Yes	No	Yes	No
3	89	Excellent	support	support	TRUE	23	11	2	0	0	6	5	4	12	11	7	1	0.4	28	10	2	29	63	Yes	Yes	Yes	Yes	Yes	No
4	86	Excellent	support	support	TRUE	17	2	0	5	3	9	6	3	9	7	3	2	1.3	35	57	0	0	51	Yes	Yes	Yes	Yes	Yes	Yes
5			not scored		FALSE	2	0	0	1	0	0	0	0	2	0	0	0	0.0	100	100	0	0	0	No	No	No	No	Yes	Yes
6	53	Fair	non-support	non-support	FALSE	16	3	0	1	0	7	3	2	6	5	2	3	1.0	46	27	0	28	37	Yes	Yes	Yes	Yes	Yes	No
7	68	Good	not assessed		TRUE	23	7	3	0	0	3	3	4	11	10	7	3	0.3	33	13	1	18	24	Yes	Yes	No	Yes	Yes	No
8	60	Good	support	support	FALSE	10	0	0	4	3	6	4	0	4	2	0	3	1.3	90	88	0	0	1	Yes	Yes	Yes	No	Yes	Yes
9			not sampled		FALSE																								
10	63	Good	not assessed		FALSE	24	5	0	0	0	5	3	2	12	11	7	2	0.4	37	17	2	16	63	Yes	Yes	No	Yes	Yes	No
11	63	Good	non-support	non-support	FALSE	17	2	0	0	0	4	2	1	6	5	2	3	0.4	39	33	16	27	25	Yes	Yes	Yes	Yes	Yes	No
12	78	Good	not assessed		TRUE	33	11	1	1	0	9	6	4	21	19	12	2	1.5	44	7	1	18	29	Yes	Yes	No	Yes	Yes	Yes
13	8	Very Poor	non-support	non-support	FALSE	6	0	0	0	0	1	0	0	2	1	0	1	0.0	94	94	1	4	1	Yes	No	Yes	Yes	Yes	Yes
14			not sampled		FALSE																								
15	17	Very Poor	non-support	non-support	FALSE	5	0	0	0	0	0	0	1	4	3	2	0	0.0	100	99	0	0	0	No	No	No	No	Yes	No
16			not scored		FALSE	2	0	0	1	0	0	0	0	2	0	0	0	0.0	100	100	0	0	0	No	No	No	No	Yes	Yes
17	60	Good	non-support	non-support	FALSE	22	5	0	4	2	11	7	2	11	9	7	2	1.8	45	35	0	6	44	Yes	Yes	Yes	Yes	Yes	Yes
18	78	Good	not assessed		TRUE	24	7	1	0	0	5	4	4	13	12	9	1	0.9	55	18	2	13	81	Yes	Yes	No	Yes	Yes	No
19	78	Good	not assessed		TRUE	27	5	0	0	0	5	3	3	14	13	9	1	0.7	33	8	1	22	61	Yes	Yes	No	Yes	Yes	No
20			not sampled		FALSE																								
21	65	Good	non-support	non-support	FALSE	25	6	0	2	1	8	5	2	11	10	7	3	0.9	36	32	0	7	58	Yes	Yes	Yes	Yes	Yes	No
22	63	Good	non-support	non-support	FALSE	26	5	0	4	2	11	7	2	11	9	6	3	2.2	35	29	0	7	45	Yes	Yes	Yes	Yes	Yes	Yes
23	39	Poor	non-support	non-support	FALSE	17	2	0	0	0	3	2	2	5	4	2	3	0.4	71	65	0	14	12	Yes	Yes	No	Yes	Yes	No
24			not scored		FALSE	16	1	0	1	1	4	1	1	6	5	2	6	0.4	89	90	0	2	0	Yes	No	No	No	Yes	No
25	43	Fair	non-support	non-support	FALSE	18	4	0	3	1	7	4	2	10	8	6	2	0.4	42	32	4	3	26	Yes	Yes	Yes	Yes	Yes	Yes
26			not sampled		FALSE																								
27	43	Fair	non-support	non-support	FALSE	7	0	0	4	2	5	3	0	3	1	0	0	0.1	86	95	0	0	5	No	No	Yes	No	Yes	Yes
28	73	Good	not assessed		FALSE	31	8	2	0	0	6	4	4	18	18	10	2	0.9	37	15	2	12	37	No	No	No	No	No	No
29	97	Excellent	support	support	TRUE	22	8	1	0	0	4	3	5	12	11	9	1	1.1	48	9	0	31	75	Yes	Yes	Yes	Yes	Yes	No
30	92	Excellent	not assessed		FALSE	25	9	2	0	0	4	4	5	15	14	11	1	1.0	24	4	0	22	39	Yes	Yes	No	Yes	Yes	No
31			not sampled		FALSE																								
32	66	Good	not assessed		TRUE	19	6	0	0	0	2	2	2	10	10	7	1	0.2	31	2	13	38	53	Yes	No	No	No	No	No
33	86	Excellent	not assessed		TRUE	15	7	1	0	0	2	2	5	8	8	8	0	0.4	39	0	0	27	75	No	Yes	No	Yes	No	No
34	87	Excellent	support	support	TRUE	17	4	0	4	2	7	5	2	8	6	4	1	0.8	54	47	0	1	46	Yes	Yes	Yes	Yes	Yes	Yes
35			not sampled		FALSE																								
36	73	Good	support	support	FALSE	11	1	0	5	3	6	4	1	5	3	2	1	0.7	62	73	0	0	22	Yes	Yes	Yes	Yes	Yes	Yes
37	74	Good	support	support	FALSE	19	6	0	2	1	6	4	3	10	9	7	1	0.9	44	18	0	9	77	Yes	Yes	Yes	Yes	Yes	Yes
38	68	Good	support	support	TRUE	13	1	0	3	1	5	3	2	7	5	4	1	0.7	66	65	0	0	48	Yes	Yes	Yes	Yes	Yes	Yes
39			not scored		FALSE	3	0	0	0	0	1	0	0	1	0	0	0	0.0	99	99	0	1	0	No	No	No	No	Yes	No
40	82	Excellent	support	support	TRUE	17	5	0	2	1	4	2	3	8	7	7	1	0.6	50	5	0	25	71	Yes	Yes	Yes	Yes	Yes	No
41			not sampled		FALSE																								
42	53	Fair	support	support	TRUE	7	0	0	1	0	3	1	1	3	1	1	2	0.2	58	81	0	0	55	Yes	Yes	Yes	Yes	Yes	Yes
43	78	Good	support	support	TRUE	24	7	1	3	1	7	4	4	12	10	8	2	1.6	53	10	0	4	62	Yes	Yes	Yes	Yes	Yes	Yes
44	66	Good	support	support	TRUE	8	0	0	5	3	6	3	0	4	2	0	1	0.5	63	78	0	0	5	No	No	Yes	No	Yes	Yes
45	60	Good	support	support	FALSE	7	0	0	3	2	4	3	0	3	1	0	1	0.6	58	39	0	0	8	Yes	Yes	Yes	No	Yes	Yes
46	84	Excellent	not assessed		TRUE	26	6	1	3	1	5	3	4	13	11	9	1	2.6	53	13	0	12	69	Yes	Yes	Yes	Yes	Yes	Yes
47	82	Excellent	not assessed		TRUE	17	5	0	0	0	3	2	3	8	7	7	1	0.6	41	8	0	26	71	Yes	Yes	Yes	Yes	Yes	No
48	70	Good	not assessed		TRUE	17	4	0	1	1	3	2	3	8	7	5	1	0.6	45	9	0	13	33	Yes	Yes	Yes	Yes	Yes	No
49	46	Fair	support	support	TRUE	5	0	0	0	0	2	1	0	1	0	0	1	0.1	65	87	0	3	50	Yes	Yes	Yes	No	Yes	No
50	49	Fair	non-support	non-support	FALSE	15	4	0	1	0	3	2	3	7	5	5	1	0.5	70	71	2	2	42	Yes	Yes	Yes	Yes	Yes	Yes
51			not scored		FALSE	5	0	0	2	0	3	1	1	2	1	1	0	0.2	84	93	0	0	34	No	Yes	Yes	Yes	No	Yes
52	69	Good	support	support	TRUE	19	6	0	1	0	3	2	3	10	8	8	1	0.4	52	52	0	13	50	Yes	Yes	Yes	Yes	Yes	Yes
53	51	Fair	not assessed		FALSE	18	4	0	0	0	5	4	0	9	8	3	1	0.4	43	4	5	12	51	Yes	Yes	Yes	No	Yes	No
54	57	Fair	support	support	TRUE	9	0	0	4	2	6	3	0	4	2	0	2	0.4	69	89	0	0	19	Yes	No	Yes	No	Yes	Yes
55			not scored		FALSE	11	0	0	4	3	8	5	0	4	2	0	2	0.5	42	76	0	0	8	Yes	Yes	Yes	No	Yes	Yes
56	78	Good	support	support	TRUE	19	7	0	0	0	4	3	4	10	9	7	1	0.7	48	12	1	11	62	Yes	Yes	Yes	Yes	Yes	No
57			not sampled		FALSE																								
58	73	Good	support	support	TRUE	17	4	1	2	0	6	4	2	7	5	2	2	0.5	52	45	0	3	22	Yes	Yes	Yes	Yes	Yes	Yes
59			not sampled		FALSE																								
60			not sampled		FALSE																								

site #	Burbot	Rock Bass	Blacknose Dace	Smallmouth	Gamefish Taxa	Northern	Common Carp	Brassy Minnow	Longnose Dace	Hornyhead Chub	Emerald Shiner	Mimic Shiner	Bluntnose Minnow	Fathead Minnow	Northern Redbelly Dace	Finescale Dace	Pearl Dace	Shorthead Redhorse	Golden Redhorse	Silver Redhorse	Northern Hogsucker	Channel Catfish	Tadpole Madtom	Stonecat	Black Bullhead	Mottled Sculpin	Bluegill	Pumpkinseed	Largemouth Bass
1																													
2	Yes	Yes	No	Yes	5	Yes	No	No	Yes	No	No	Yes	No	No	No	No	No	No	No	No	Yes	No	No	Yes	No	No	No	No	No
3	Yes	Yes	No	Yes	5	Yes	No	No	Yes	Yes	No	Yes	No	No	No	No	No	No	No	No	Yes	No	No	Yes	No	No	No	No	No
4	No	No	Yes	No	2	No	No	Yes	No	Yes	No	No	No	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No	No
5	No	No	No	No	0	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
6	No	Yes	Yes	Yes	4	No	No	No	No	Yes	No	No	No	Yes	No	No	No	No	No	No	No	No	No	No	Yes	No	Yes	No	No
7	Yes	Yes	No	Yes	6	Yes	No	No	No	No	No	Yes	No	No	No	No	No	No	Yes	No	Yes	Yes	No	No	Yes	No	No	No	No
8	No	No	No	No	0	No	No	No	No	No	No	No	No	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	Yes	No	No	No	No
9																													
10	Yes	Yes	No	Yes	7	Yes	Yes	No	No	No	No	Yes	Yes	No	No	No	No	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No
11	Yes	Yes	No	No	5	Yes	No	No	No	Yes	No	No	No	No	No	No	No	No	No	No	No	No	Yes	No	Yes	No	No	No	Yes
12	Yes	Yes	No	Yes	9	Yes	No	No	Yes	Yes	No	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	No	No	Yes	No	No	Yes	Yes	Yes
13	No	No	No	No	3	Yes	No	No	No	No	No	No	No	Yes	No	No	No	No	No	No	No	No	Yes	No	Yes	No	Yes	No	Yes
14																													
15	No	No	No	No	2	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	Yes	No	No	No	No	No	Yes
16	No	No	No	No	0	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
17	Yes	Yes	Yes	Yes	2	No	No	No	Yes	Yes	No	No	Yes	Yes	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	No	No	No	No	No
18	Yes	Yes	No	Yes	6	Yes	No	Yes	No	Yes	No	No	Yes	No	No	No	No	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	Yes
19	Yes	Yes	No	Yes	8	Yes	No	No	No	No	No	No	Yes	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	Yes
20																													
21	Yes	Yes	Yes	Yes	7	Yes	No	No	Yes	Yes	No	No	No	Yes	No	No	Yes	Yes	No	No	Yes	No	Yes	Yes	Yes	No	No	No	Yes
22	Yes	No	Yes	Yes	4	Yes	No	No	Yes	Yes	No	No	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	No	No	No	Yes	No	No	No	Yes
23	Yes	No	No	Yes	5	Yes	No	No	No	Yes	No	No	No	No	No	No	No	No	No	No	No	No	No	No	Yes	No	No	No	Yes
24	No	No	No	No	5	No	Yes	No	No	No	No	No	No	Yes	Yes	No	No	No	No	No	No	No	Yes	No	Yes	No	Yes	Yes	Yes
25	Yes	No	Yes	No	1	No	No	Yes	Yes	No	No	Yes	No	Yes	No	No	No	Yes	No	No	Yes	No	No	No	No	Yes	No	No	No
26																													
27	No	No	Yes	No	0	No	No	Yes	No	No	No	No	No	No	Yes	No	Yes	No	No	No	No	No	No	No	No	No	No	No	No
28	Yes	Yes	No	Yes	9	Yes	Yes	No	No	No	Yes	Yes	Yes	No	No	No	No	Yes	Yes	Yes	Yes	Yes	No	No	No	No	Yes	No	Yes
29	Yes	Yes	No	Yes	6	Yes	No	No	Yes	Yes	No	No	No	No	No	No	No	No	Yes	No	Yes	No	No	Yes	No	No	Yes	No	Yes
30	Yes	Yes	No	Yes	7	Yes	No	No	Yes	Yes	No	No	No	No	No	No	No	Yes	Yes	No	Yes	No	No	Yes	No	No	No	No	Yes
31																													
32	Yes	Yes	No	Yes	6	Yes	No	No	No	No	No	Yes	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No
33	Yes	Yes	No	Yes	4	No	No	No	Yes	No	No	No	No	No	No	No	No	No	No	No	Yes	No	No	Yes	No	No	No	No	Yes
34	Yes	Yes	Yes	No	1	No	No	Yes	No	Yes	No	No	No	No	Yes	No	Yes	No	Yes	No	Yes	No	No	No	No	No	No	No	No
35																													
36	No	No	Yes	No	0	No	No	Yes	No	No	No	No	No	No	Yes	Yes	No	No	No	No	No	No	No	No	No	Yes	No	No	No
37	Yes	Yes	Yes	Yes	4	Yes	No	No	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	No	No	Yes	Yes	No
38	Yes	No	Yes	No	0	No	No	Yes	No	No	No	No	No	No	No	Yes	No	No	Yes	No	Yes	No	No	No	No	No	No	No	No
39	No	No	No	No	1	Yes	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
40	Yes	No	Yes	Yes	3	Yes	No	No	Yes	No	No	No	No	No	No	No	No	Yes	No	No	No	No	No	Yes	No	Yes	No	No	No
41																													
42	No	No	No	No	0	No	No	No	No	No	No	No	No	Yes	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
43	Yes	Yes	Yes	No	5	Yes	No	Yes	Yes	Yes	No	No	No	Yes	No	No	No	Yes	Yes	No	No	No	No	No	No	Yes	Yes	No	Yes
44	No	No	Yes	No	0	No	No	No	No	No	No	No	No	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No	No
45	No	No	No	No	0	No	No	No	No	No	No	No	No	No	Yes	No	Yes	No	No	No	No	No	No	No	No	No	No	No	No
46	Yes	Yes	Yes	Yes	7	Yes	No	Yes	Yes	No	No	No	No	No	No	No	No	Yes	Yes	Yes	No	No	No	No	No	Yes	Yes	No	Yes
47	Yes	Yes	No	Yes	4	Yes	No	No	Yes	No	No	No	No	No	No	No	No	Yes	Yes	No	No	No	No	Yes	No	No	No	No	No
48	Yes	Yes	No	No	6	Yes	No	No	Yes	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	Yes	Yes	No	Yes
49	No	No	No	No	1	Yes	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
50	Yes	Yes	Yes	Yes	3	Yes	No	No	Yes	No	No	No	No	Yes	Yes	Yes	No	Yes	Yes	No	No	No	No	No	No	No	No	No	No
51	No	No	Yes	No	0	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
52	Yes	Yes	No	Yes	4	Yes	No	No	Yes	No	No	No	No	No	No	No	No	Yes	Yes	No	Yes	No	No	Yes	No	No	No	No	No
53	Yes	Yes	No	Yes	6	Yes	No	No	No	No	No	Yes	No	No	No	No	No	Yes	Yes	Yes	No	No	No	No	No	No	Yes	No	No
54	No	No	Yes	No	0	No	No	Yes	No	No	No	No	No	Yes	No	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No	No
55	No	No	No	No	0	No	No	Yes	No	No	No	No	No	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No	No
56	Yes	Yes	No	Yes	5	Yes	No	No	Yes	Yes	No	No	No	No	No	No	No	No	Yes	No	Yes	No	No	No	No	No	No	No	Yes
57																													
58	Yes	Yes	Yes	No	3	No	No	Yes	No	Yes	No	No	No	No	No	No	No	No	No	No	No	No	No	No	Yes	No	No	No	Yes
59																													
60																													

site #	Black Crappie	Yellow Perch	Logperch	Gilt Darter	Blackside Darter	Slenderhead Darter	Walleye	Spotfin Shiner	Golden Shiner	Chestnut Lamprey
1										
2	No	Yes	Yes	Yes	No	Yes	Yes	No	No	Yes
3	No	Yes	Yes	Yes	No	Yes	Yes	No	No	Yes
4	Yes	Yes	Yes	No	No	No	No	No	No	No
5	No	No	No	No	No	No	No	No	No	No
6	No	Yes	Yes	No	No	No	No	No	Yes	No
7	No	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes
8	No	No	No	No	No	No	No	No	No	No
9										
10	Yes	Yes	Yes	No	No	No	Yes	Yes	No	Yes
11	Yes	Yes	No	No	No	No	No	No	Yes	No
12	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No
13	No	Yes	No	No	No	No	No	No	Yes	No
14										
15	No	Yes	No	No	Yes	No	No	No	No	No
16	No	No	No	No	No	No	No	No	No	No
17	No	No	Yes	No	No	No	No	No	No	No
18	No	Yes	Yes	Yes	No	Yes	Yes	No	No	Yes
19	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes
20										
21	Yes	Yes	Yes	No	No	No	Yes	No	No	No
22	No	No	No	No	Yes	No	Yes	No	No	Yes
23	No	Yes	No	No	Yes	No	Yes	No	Yes	Yes
24	Yes	Yes	No	No	No	No	No	No	Yes	No
25	Yes	No	No	No	Yes	No	No	Yes	No	Yes
26										
27	No	No	No	No	No	No	No	No	No	No
28	Yes	Yes	Yes	No	Yes	No	Yes	Yes	No	No
29	No	No	Yes	Yes	Yes	Yes	Yes	No	No	Yes
30	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
31										
32	Yes	No	Yes	No	No	Yes	Yes	Yes	No	Yes
33	No	No	Yes	Yes	Yes	Yes	Yes	No	No	Yes
34	No	No	No	No	Yes	No	No	No	No	No
35										
36	No	No	No	No	No	No	No	No	No	No
37	No	No	Yes	No	Yes	Yes	Yes	No	Yes	No
38	No	No	No	No	Yes	No	No	No	No	No
39	No	No	No	No	No	No	No	No	Yes	No
40	No	No	Yes	No	No	Yes	Yes	No	No	Yes
41										
42	No	No	No	No	No	No	No	No	No	No
43	No	No	Yes	No	No	Yes	Yes	No	No	No
44	No	No	No	No	No	No	No	No	No	No
45	No	No	No	No	No	No	No	No	No	No
46	No	Yes	Yes	Yes	No	Yes	Yes	No	No	Yes
47	No	No	Yes	No	No	Yes	Yes	No	No	Yes
48	No	Yes	Yes	No	No	Yes	Yes	No	No	Yes
49	No	No	No	No	No	No	No	No	No	No
50	No	No	Yes	No	No	Yes	No	No	No	Yes
51	No	No	No	No	No	No	No	No	No	No
52	No	No	Yes	No	No	Yes	Yes	No	No	Yes
53	No	Yes	No	No	No	No	Yes	Yes	No	Yes
54	No	No	No	No	No	No	No	No	No	No
55	No	No	No	No	No	No	No	No	Yes	No
56	No	Yes	Yes	No	Yes	Yes	No	No	No	No
57										
58	No	Yes	No	No	Yes	No	No	No	No	No
59										
60										

site #	Invert IBI	Invert IBI Rating	305b Inverts	305b (2) Inverts	Hilsenhoff	# Invert Taxa	# Tolerant	# Very Tolerant	# EPT	# Ephemeroptera	# Plecoptera	# Tricoptera	# Chironomidae	# Invert Taxa (w/ Ch)	# Intolerant (w/ Ch)	# Predator (w/ Ch)	# Clinger (w/ Ch)	# Scraper (w/ Ch)	# Collect-Filt (w/ Ch)	# Collect-Gath (w/ Ch)	# Tanytarsini (w/ Ch)	# Long-Lived (w/ Ch)	% Dom 2 (w/ Ch)	% Tolerant	% Very Tolerant	% EPT	% Ephemeroptera	% Plecoptera	% Tricoptera	% Chironomids	% Amphipods	% Predators	% Scrapers	% Collector-Filterers	% Collector-Gatherers
1			not sampled																																
2	92	Excellent	support	support	3.9	56	21	10	25	6	3	16	13	68	21	31	36	14	16	17	3	21	28	22	7	56	10	3	44	8	1	9	48	26	10
3	67	Good	support	support	3.4	41	8	2	23	6	4	13	10	51	15	14	25	9	12	15	3	10	35	10	3	72	15	1	56	7	0	5	54	25	9
4			not sampled																																
5			not sampled																																
6	25	Poor	non-support	non-support	6.8	29	15	7	12	3	0	9	16	44	5	13	17	8	7	13	4	5	38	81	23	18	13	0	6	32	5	11	34	10	33
7			not sampled																																
8	44	Fair	non-support	non-support	6.6	18	11	6	3	1	0	2	13	28	1	11	5	4	1	8	3	1	29	49	9	17	15	0	2	75	0	6	1	6	38
9			not sampled																																
10			not scored		7.8	42	20	9	14	4	2	8	9	49	7	16	15	9	7	9	3	11	77	90	81	5	2	0	3	5	63	9	19	3	66
11	50	Fair	support	support	5.6	43	27	9	10	3	0	7	20	60	2	27	9	6	2	20	4	10	49	47	9	7	4	0	3	38	33	14	4	4	59
12			not scored		5.5	33	11	5	16	6	4	6	11	45	10	13	21	8	10	15	1	9	23	31	2	17	8	1	8	73	0	2	10	26	7
13	33	Poor	non-support	non-support	7.5	39	30	14	8	2	1	5	17	53	1	21	12	9	6	17	5	7	42	89	59	6	2	2	2	17	27	10	41	8	36
14			not sampled																																
15	22	Poor	non-support	non-support	7.5	31	17	9	8	3	0	5	10	39	1	19	9	8	2	11	3	5	75	87	77	13	7	0	6	6	71	9	8	2	80
16			not sampled																																
17			not sampled																																
18			not scored		7.3	52	28	14	17	8	0	9	15	66	5	26	17	8	10	24	4	10	59	79	61	8	4	0	3	21	53	8	6	3	66
19			not scored		6.7	50	20	10	19	7	1	11	21	67	6	21	16	11	10	22	5	12	27	78	33	25	15	0	10	43	14	8	14	25	42
20			not sampled																																
21	50	Fair	support	support	5.4	44	13	7	18	7	4	7	19	61	14	24	17	11	9	18	3	14	27	39	10	47	20	6	20	25	1	8	33	22	31
22	42	Fair	non-support	non-support	5.6	41	20	6	15	6	1	8	18	58	6	19	17	10	9	20	4	10	24	37	11	42	19	2	22	28	1	10	18	25	40
23	42	Fair	non-support	non-support	4.8	46	18	9	12	4	2	6	14	57	10	26	20	7	9	20	3	13	17	36	15	37	13	3	21	18	8	12	12	32	40
24	11	Very Poor	non-support	non-support	7.8	29	16	8	4	1	0	3	8	35	1	19	7	3	4	9	2	4	71	87	80	7	2	0	5	6	63	20	2	5	68
25	67	Good	support	support	4.4	26	9	3	11	3	2	6	13	38	9	11	20	6	6	15	1	7	35	22	1	60	23	7	29	20	2	9	8	38	37
26			not scored		6.5	34	16	4	9	3	0	6	18	50	2	17	7	7	3	18	3	5	37	80	11	9	7	0	3	48	1	8	34	6	36
27	56	Fair	support	support	5.8	27	15	7	2	1	0	1	16	41	2	14	9	5	7	14	5	3	23	50	6	11	3	0	8	58	6	9	2	35	19
28			not sampled																																
29	67	Good	support	support	3.4	47	11	5	22	7	3	12	16	62	20	20	26	12	11	20	4	14	31	18	5	61	41	2	18	16	1	6	29	13	48
30			not scored		5.2	44	12	5	22	8	3	11	13	56	17	17	24	14	13	16	4	11	33	44	27	50	31	3	17	11	25	5	22	24	44
31			not sampled																																
32			not sampled																																
33			not scored		4.9	35	12	2	21	4	4	13	16	49	12	17	28	10	10	15	5	9	27	24	1	58	29	4	25	25	0	8	15	23	37
34	50	Fair	support	support	6.1	40	16	8	9	6	0	3	19	55	8	24	14	7	7	20	6	12	26	53	3	8	4	0	3	73	0	9	11	11	18
35			not sampled																																
36			not sampled																																
37	58	Fair	support	support	4.6	37	18	6	17	5	1	11	16	53	12	17	24	12	9	17	4	14	21	32	4	51	20	3	28	14	0	9	44	18	21
38	80	Excellent	support	support	4.2	43	14	5	18	4	3	11	20	61	20	23	23	10	7	19	5	15	18	32	3	39	19	2	17	47	0	7	26	10	30
39			not sampled																																
40	67	Good	support	support	3.8	40	9	2	22	8	3	11	20	57	20	18	22	10	10	19	5	15	27	20	2	57	21	7	29	23	0	6	38	20	24
41			not sampled																																
42	61	Good	support	support	4.9	30	13	3	11	4	1	6	15	44	4	15	13	7	8	17	5	5	27	37	1	26	18	0	8	36	0	10	30	19	36
43	42	Fair	non-support	non-support	5.3	51	21	9	22	8	3	11	14	63	13	21	25	13	8	17	3	16	24	39	21	46	25	3	18	10	14	9	29	9	42
44	72	Good	support	support	4.8	42	15	3	10	2	0	8	17	56	9	20	8	6	6	18	3	4	16	17	3	13	2	0	10	70	0	19	5	5	22
45	67	Good	support	support	5.3	22	11	2	6	3	0	3	14	34	4	12	8	3	7	13	5	4	16	27	1	7	5	0	2	85	0	9	2	13	17
46	75	Good	support	support	4.5	47	16	4	26	11	3	12	20	67	21	19	29	12	10	24	6	13	18	35	2	48	29	4	15	36	0	5	24	25	35
47	58	Fair	support	support	4.4	43	17	5	19	9	2	8	17	58	16	19	23	13	10	18	5	15	18	30	5	52	36	1	14	26	1	9	33	15	36
48	58	Fair	support	support	5.1	48	17	4	24	7	4	13	23	67	18	23	26	9	12	27	6	16	22	42	4	43	29	3	11	36	1	11	17	26	38
49	50	Fair	support	support	7.6	36	25	11	7	3	0	4	17	50	2	25	12	6	11	14	3	3	32	52	40	16	5	0	11	36	10	16	3	26	53
50	67	Good	support	support	5.6	29	14	8	9	4	0	5	16	43	5	18	7	4	5	15	4	7	18	29	7	11	9	0	2	84	0	10	1	4	22
51	72	Good	support	support	4.9	44	17	6	12	2	0	10	16	57	11	25	16	12	9	18	5	9	21	31	12	38	12	0	26	26	1	13	29	28	18
52	50	Fair	support	support	5.5	50	21	9	21	9	3	10	27	74	16	22	25	10	12	32	6	16	21	52	11	29	15	2	12	28	0	17	31	16	27
53			not sampled																																
54	89	Excellent	support	support	5.1	28	11	3	12	2	2	8	24	49	9	15	19	8	10	20	5	8	12	30	12	26	5	10	10	62	0	12	10	13	22
55			not sampled																																
56	75	Good	support	support	4.5	44	10	2	23	4	4	15	14	57	18	17	28	10	11	20	3	13	27	24	3	47	9	10	28	21	1	6	24	26	29
57			not sampled																																
58	72	Good	support	support	6.3	42	23	10	11	6	0	5	22	61	4	22	14	10	8	23	5	11	22	60	21	17	10	0	6	38	4	10	20	9	37
59			not scored		6.7	34	19	8	5	3	0	2	14	45	4	18	5	8	3	14	2	6	32	83	30	5	3	0	2	34	20	8	37	5	34
60			not sampled																																

Appendix 1. (continued) -- St. Croix River Basin Measured Variables

site #	305b Overall	305b (2) Overall	TMDL	stratum	panel	oversamp	division	md_caty	partiton	nest_id	nest1	nest1_n	nest1_wt
1	not assessed			2	1	0	1	5	0	1	1	17	129.552
2	suppBoth	support	no	2	1	0	1	8	0	1	1	15	16.194
3	suppBoth	support	no	2	1	0	1	8	0	1	1	15	16.194
4	suppF	support	no	2	1	0	1	6	0	1	1	14	64.776
5	not assessed			2	1	0	1	5	0	1	1	17	129.552
6	non-suppBoth	non-support	yes	2	1	0	1	7	0	1	1	14	32.388
7	not assessed			2	1	0	1	8	0	1	1	15	16.194
8	non-suppMsuppF	non-support	no	2	1	0	1	5	0	1	1	17	129.552
9	not assessed			2	1	0	1	5	0	1	1	17	129.552
10	not assessed			2	1	0	1	8	0	1	1	15	16.194
11	non-suppFsuppM	non-support	yes	2	1	0	1	7	0	1	1	14	32.388
12	not assessed			2	1	0	1	8	0	1	1	15	16.194
13	non-suppBoth	non-support	yes	2	1	0	1	6	0	1	1	14	64.776
14	not assessed			2	1	0	1	6	0	1	1	14	64.776
15	non-suppBoth	non-support	yes	2	1	0	1	7	0	1	1	14	32.388
16	not assessed			2	1	0	1	5	0	1	1	17	129.552
17	non-suppF	non-support	yes	2	1	0	1	7	0	1	1	14	32.388
18	not assessed			2	1	0	1	8	0	1	1	15	16.194
19	not assessed			2	1	0	1	8	0	1	1	15	16.194
20	not assessed			2	1	0	1	5	0	1	1	17	129.552
21	non-suppFsuppM	non-support	yes	2	1	0	1	7	0	1	1	14	32.388
22	non-suppBoth	non-support	yes	2	1	0	1	7	0	1	1	14	32.388
23	non-suppBoth	non-support	yes	2	1	0	1	7	0	1	1	14	32.388
24	non-suppM	non-support		2	1	0	1	6	0	1	1	14	64.776
25	non-suppFsuppM	non-support	yes	2	1	0	1	7	0	1	1	14	32.388
26	not assessed			2	1	0	1	6	0	1	1	14	64.776
27	non-suppFsuppM	non-support	yes	2	1	0	1	5	0	1	1	17	129.552
28	not assessed			2	1	0	1	7	0	1	1	14	32.388
29	suppBoth	support	no	2	1	0	1	7	0	1	1	14	32.388
30	not assessed			2	1	0	1	8	0	1	1	15	16.194
31	not assessed			2	1	0	1	5	0	1	1	17	129.552
32	not assessed			2	1	0	1	8	0	1	1	15	16.194
33	not assessed			2	1	0	1	8	0	1	1	15	16.194
34	suppBoth	support	no	2	1	0	1	6	0	1	1	14	64.776
35	not assessed			2	1	0	1	5	0	1	1	17	129.552
36	suppF	support	no	2	1	0	1	5	0	1	1	17	129.552
37	suppBoth	support	no	2	1	0	1	7	0	1	1	14	32.388
38	suppBoth	support	no	2	1	0	1	6	0	1	1	14	64.776
39	not assessed			2	1	0	1	5	0	1	1	17	129.552
40	suppBoth	support	no	2	1	0	1	7	0	1	1	14	32.388
41	not assessed			2	1	0	1	5	0	1	1	17	129.552
42	suppBoth	support	no	2	1	0	1	6	0	1	1	14	64.776
43	non-suppMsuppF	non-support	no	2	1	0	1	8	0	1	1	15	16.194
44	suppBoth	support	no	2	1	0	1	5	0	1	1	17	129.552
45	suppBoth	support	no	2	1	0	1	6	0	1	1	14	64.776
46	suppM	support		2	1	0	1	8	0	1	1	15	16.194
47	suppM	support		2	1	0	1	8	0	1	1	15	16.194
48	suppM	support		2	1	0	1	8	0	1	1	15	16.194
49	suppBoth	support	no	2	1	0	1	6	0	1	1	14	64.776
50	non-suppFsuppM	non-support	yes	2	1	0	1	7	0	1	1	14	32.388
51	suppM	support		2	1	0	1	5	0	1	1	17	129.552
52	suppBoth	support	no	2	1	0	1	7	0	1	1	14	32.388
53	not assessed			2	1	0	1	8	0	1	1	15	16.194
54	suppBoth	support	no	2	1	0	1	5	0	1	1	17	129.552
55	not assessed			2	1	0	1	6	0	1	1	14	64.776
56	suppBoth	support	no	2	1	0	1	7	0	1	1	14	32.388
57	not assessed			2	1	0	1	5	0	1	1	17	129.552
58	suppBoth	support	no	2	1	0	1	6	0	1	1	14	64.776
59	not assessed			2	1	0	1	5	0	1	1	17	129.552
60	not assessed			2	1	0	1	5	0	1	1	17	129.552

Appendix 2. -- St. Croix River Basin Statistical Correlations --
IBIs vs. Water Chemistry, Habitat, and Land Use

	Fish IBI rho	Fish IBI p-value	Macroinvertebrate IBI rho	Macroinvertebrate IBI p-value
Water Chemistry				
Dissolved Oxygen	0.23	0.14	0.08	0.66
Total Phosphorus	***-0.40***	***0.01***	-0.18	0.33
Nitrite/Nitrate	-0.18	0.24	-0.18	0.34
Total Ammonia	-0.17	0.28	-0.15	0.43
Conductivity	***-0.35***	***0.02***	***-0.53***	***0.00***
Total Suspended Solids	***-0.33***	***0.03***	-0.21	0.26
Turbidity	***-0.33***	***0.04***	0.06	0.75
Habitat				
Number of Stream Features per 100 Meters	-0.26	0.13	-0.06	0.75
Number of Substrate Types	-0.15	0.39	-0.10	0.59
Percent Coarse Substrates	***0.63***	***0.00***	0.31	0.08
Coefficient of Variation of Depth	0.17	0.32	***0.44***	***0.01***
Sinuosity	-0.18	0.29	-0.22	0.23
Percent Land-Use Disturbance within 30 Meters	-0.29	0.09	-0.26	0.14
Fish Habitat Rating	0.04	0.84	-0.05	0.81
residuals Number of Stream Features per 100 Meters	***0.46***	***0.00***	0.14	0.44
residuals Number of Substrate Types	0.08	0.65	-0.10	0.60
residuals Percent Coarse Substrates	***0.47***	***0.00***	***0.38***	***0.03***
residuals Coefficient of Variation of Depth	***0.37***	***0.02***	***0.38***	***0.03***
residuals Sinuosity	0.00	1.00	-0.15	0.43
Percent Disturbed Land Use within 30 Meters	-0.29	0.09	-0.26	0.14
revised Fish Habitat Rating	***0.43***	***0.01***	0.34	0.06
(residuals are from LOESS regressions against log mean width, calculated for basin reference sites)				
Percent Riffle	***0.62***	***0.00***	***0.43***	***0.01***
Percent Pool	0.00	0.98	0.08	0.65
Percent Run	-0.21	0.23	-0.19	0.30
Percent Fines	***-0.62***	***0.00***	***-0.39***	***0.03***
Mean Depth of Fines	***-0.48***	***0.00***	***-0.38***	***0.03***
Percent Embededness	***-0.39***	***0.03***	-0.22	0.27
Percent Boulder	***0.45***	***0.01***	0.16	0.37
Percent Cover	***-0.37***	***0.03***	-0.23	0.21
Percent Overhanging Vegetation	-0.21	0.23	0.31	0.09
Percent Emergent Macrophytes	***-0.41***	***0.01***	-0.20	0.28
Percent Submergent Macrophytes	-0.02	0.93	***-0.52***	***0.00***
Percent Woody Debris	-0.19	0.27	0.23	0.20
Number of Log Jams	-0.25	0.14	0.03	0.86
Percent Under-cut Bank	-0.08	0.64	0.31	0.09
Mean Bank Erosion	0.00	0.98	0.02	0.92
Mean Thalweg Depth	***0.52***	***0.00***	0.13	0.49
Mean Depth	0.31	0.07	-0.05	0.77
Mean Width	***0.59***	***0.00***	0.04	0.84
Width to Depth Ratio	***0.53***	***0.00***	0.08	0.68
RRRatio	-0.13	0.59	-0.01	0.96
BBRatio	0.16	0.50	0.09	0.70
Gradient	0.20	0.24	***0.46***	***0.01***
Percent Disturbed Land Use	-0.26	0.12	-0.19	0.29
Land Use				
Disturbed Percent	***-0.39***	***0.01***	***-0.62***	***0.00***
Agriculture/Rangeland Percent	***-0.40***	***0.01***	***-0.62***	***0.00***
Agriculture Percent	***-0.37***	***0.02***	***-0.61***	***0.00***
Rangeland Percent	-0.28	0.08	***-0.63***	***0.00***
Urban Percent	-0.04	0.80	***-0.49***	***0.01***
Forest Percent	***0.35***	***0.03***	***0.50***	***0.00***
Wetland Percent	***0.42***	***0.01***	***0.48***	***0.01***
Mining Percent	-0.06	0.74	-0.34	0.06
Agriculture within 100 Meters Percent	-0.28	0.08	***-0.60***	***0.00***
Forest within 100 Meters Percent	0.26	0.10	***0.49***	***0.00***
Wetland within 100 Meters Percent	0.25	0.11	0.35	0.05
Pre-Settlement Wetland Percent	0.32	0.05	***0.50***	***0.01***
Percent of Original Wetlands Remaining	***0.39***	***0.01***	0.29	0.13

Appendix 2. (continued) -- St. Croix River Basin Statistical Correlations -- Water Chemistry vs. Habitat and Land Use

	DO		Phosphorus		Nitrogen		Ammonia		Conductivity		TSS		Turbidity	
	rho	p-value	rho	p-value	rho	p-value	rho	p-value	rho	p-value	rho	p-value	rho	p-value
Habitat														
Number of Stream Features per 100 Meters	0.02	0.91	0.11	0.51	***0.37***	***0.02***	0.23	0.17	0.18	0.27	0.08	0.61	-0.05	0.75
Percent Riffle	***0.41***	***0.01***	***-0.37***	***0.02***	0.06	0.71	-0.22	0.18	-0.22	0.18	***-0.47***	***0.00***	-0.32	0.05
Percent Pool	0.11	0.50	-0.04	0.80	0.11	0.49	-0.07	0.69	0.11	0.48	0.01	0.97	-0.15	0.39
Percent Run	-0.18	0.27	0.16	0.33	-0.09	0.60	0.12	0.48	-0.02	0.93	0.28	0.08	0.22	0.19
Number of Substrate Types	0.11	0.50	0.14	0.40	0.25	0.13	-0.08	0.61	0.06	0.71	0.22	0.18	0.05	0.76
Percent Fines	***-0.45***	***0.00***	***0.38***	***0.02***	0.17	0.29	0.20	0.22	***0.33***	***0.04***	***0.43***	***0.01***	0.28	0.09
Mean Depth of Fines	-0.28	0.08	0.31	0.06	0.09	0.57	0.17	0.29	***0.36***	***0.02***	***0.33***	***0.04***	0.26	0.11
Percent Embededness	-0.16	0.39	***0.39***	***0.02***	0.07	0.70	0.09	0.61	0.33	0.05	0.27	0.12	0.07	0.72
Percent Coarse Substrates	***0.48***	***0.00***	***-0.48***	***0.00***	-0.15	0.37	-0.29	0.07	-0.30	0.06	***-0.44***	***0.00***	***-0.39***	***0.02***
Percent Boulder	***0.47***	***0.00***	***-0.35***	***0.03***	0.07	0.68	-0.26	0.11	-0.19	0.24	***-0.35***	***0.03***	-0.19	0.27
Percent Stream Cover	***-0.59***	***0.00***	***0.48***	***0.00***	0.21	0.20	***0.37***	***0.02***	0.14	0.40	0.31	0.05	***0.40***	***0.02***
Percent Emergent Macrophytes	***-0.63***	***0.00***	***0.34***	***0.04***	-0.06	0.70	***0.47***	***0.00***	0.01	0.97	0.26	0.10	***0.45***	***0.01***
Percent Submergent Macrophytes	0.23	0.16	-0.30	0.06	-0.26	0.11	-0.14	0.40	0.24	0.14	-0.06	0.70	***-0.34***	***0.04***
Mean Bank Erosion	0.18	0.28	-0.16	0.33	0.04	0.79	-0.17	0.30	0.19	0.24	-0.06	0.70	-0.20	0.23
Mean Thalweg Depth	0.15	0.37	***-0.38***	***0.02***	***-0.33***	***0.04***	-0.28	0.08	-0.28	0.08	-0.01	0.93	-0.12	0.47
Sinuosity	0.12	0.46	-0.01	0.95	0.27	0.10	-0.31	0.05	***0.35***	***0.03***	0.11	0.48	-0.28	0.09
Gradient	0.09	0.57	-0.10	0.55	0.07	0.69	0.00	0.98	***-0.32***	***0.05***	-0.29	0.07	-0.16	0.34
Percent Disturbed Land Use	-0.04	0.80	0.22	0.18	0.10	0.55	0.12	0.45	***0.32***	***0.05***	0.01	0.96	0.21	0.21
Percent Disturbed Land Use within 30 Meters	0.02	0.92	0.23	0.17	0.08	0.61	0.18	0.26	***0.33***	***0.04***	0.02	0.92	0.18	0.28
Fish Habitat Rating	***0.39***	***0.03***	-0.19	0.30	0.20	0.27	-0.34	0.06	0.14	0.44	0.11	0.55	-0.34	0.06
Land Use														
Disturbed Percent	-0.22	0.16	***0.38***	***0.01***	***0.33***	***0.03***	0.17	0.25	***0.49***	***0.00***	0.17	0.27	***0.33***	***0.03***
Agriculture/Rangeland Percent	-0.21	0.17	***0.39***	***0.01***	***0.32***	***0.03***	0.18	0.25	***0.49***	***0.00***	0.17	0.25	***0.34***	***0.03***
Agriculture Percent	0.03	0.86	0.29	0.06	***0.47***	***0.00***	0.09	0.54	***0.64***	***0.00***	0.13	0.40	0.18	0.25
Rangeland Percent	-0.22	0.15	***0.33***	***0.03***	0.10	0.53	0.06	0.69	0.25	0.09	0.15	0.31	***0.34***	***0.03***
Urban Percent	-0.04	0.82	0.00	0.99	0.12	0.44	-0.12	0.43	***0.34***	***0.02***	0.02	0.89	0.02	0.92
Forest Percent	0.28	0.06	***-0.34***	***0.02***	-0.08	0.60	-0.14	0.34	-0.22	0.15	-0.29	0.05	***-0.41***	***0.01***
Wetland Percent	-0.03	0.86	-0.28	0.07	***-0.53***	***0.00***	-0.18	0.23	***-0.77***	***0.00***	-0.02	0.88	-0.05	0.75
Mining Percent	0.09	0.56	-0.08	0.59	0.06	0.70	-0.17	0.26	0.05	0.72	-0.03	0.85	-0.01	0.97
Agriculture within 100 Meters Percent	-0.13	0.40	***0.32***	***0.03***	0.29	0.06	0.18	0.25	***0.52***	***0.00***	0.12	0.44	0.24	0.13
Forest within 100 Meters Percent	***0.37***	***0.01***	-0.28	0.06	0.19	0.21	-0.21	0.17	0.00	0.98	***-0.35***	***0.02***	***-0.36***	***0.02***
Wetland within 100 Meters Percent	-0.17	0.27	-0.19	0.21	***-0.54***	***0.00***	-0.15	0.34	***-0.80***	***0.00***	0.02	0.87	0.09	0.57
Pre-Settlement Wetland Percent	-0.15	0.34	-0.24	0.12	***-0.50***	***0.00***	-0.10	0.53	***-0.56***	***0.00***	0.05	0.74	0.05	0.76
Percent of Original Wetlands Remaining	-0.09	0.56	-0.08	0.63	***-0.39***	***0.01***	-0.15	0.33	***-0.69***	***0.00***	-0.05	0.75	-0.04	0.82

APPENDIX 3. - ST. CROIX RIVER BASIN FISH ASSEMBLAGE* AND IBI CLASSIFICATION

Common name	*Scientific name*	IBI Classification[a]		
		Taxa	Trophic status	Reproductive guild
Lampreys	**Petromyzontidae**			
American brook lamprey	*Lampetra appendix*	He In		
Chestnut lamprey	*Ichthyomyzon castaneus*	In	Pi	
Northern brook lamprey***	*Ichthyomyzon fossor*	In		
Southern brook lamprey***	*Ichthyomyzon gagei*	In		
Silver lamprey	*Ichthyomyzon unicuspis*	In	Pi	
Sturgeons	**Acipenseridae**			
Lake sturgeon***	*Acipenser fulvescens*		Bi In	Sl
Shovelnose sturgeon**	*Scaphirhynchus platorynchus*		Bi In	Sl
Paddlefishes	Polyodontidae			
Paddlefish****	*Polydon spathula*	In		Sl
Gars	**Lepisosteidae**			
Longnose gar	*Lepisosteus osseus*		Pi	
Shortnose gar	*Lepisosteus platostomus*		Pi	
Bowfins	**Amiidae**			
Bowfin	*Amia calva*		Pi	
Freshwater eels	**Anguillidae**			
American eel	*Anguilla rostrata*		Pi	
Herrings	**Clupeidae**			
Skipjack herring** ***	*Alosa chrysochloris*		Pi	
Gizzard shad	*Dorosoma cepedianum*			
Mooneyes	**Hiodontidae**			
Goldeye**	*Hiodon alosoides*	In	In	
Mooneye	*Hiodon tergisus*	In	In	
Trouts	**Salmonidae**			
Cisco (lake herring)	*Coregonus artedii*			
Rainbow trout	*Oncorhynchus mykiss*		Pi	
Brown trout	*Salmo trutta*		Pi	
Lake trout	*Salvelinus namaycush*		Pi	
Brook trout	*Salvelinus fontinalis*	In	Pi	
Pikes	**Esocidae**			
Northern pike	*Esox lucius*		Pi	
Muskellunge	*Esox masquinongy*	In	Pi	
Mudminnows	**Umbridae**			
Central mudminnow	*Umbra limi*	To	In	

APPENDIX 3. (continued)

Common name	*Scientific name*	IBI Classification[a] Taxa	Trophic status	Reproductive guild
Minnows	***Cyprinidae***			
Common carp	*Cyprinus carpio*	To	Om	
Brassy minnow	*Hybognathus hankinsoni*	Mi		
Golden shiner	*Notemigonus crysoleucas*	To		
Creek chub	*Semotilus atromaculatus*	To		
Blacknose dace	*Rhinichthys atratulus*	To		Sl
Longnose dace	*Rhinichthys cataractae*	Mi In	Bi In	Sl
Hornyhead chub	*Nocomis biguttatus*	Mi In	In	
Spottail shiner	*Notropis hudsonius*	Mi In	In	
Pallid shiner** ***	*Notropis amnis*	Mi In	In	
Emerald shiner	*Notropis atherinoides*	Mi	In	Sl
Sand shiner	*Notropis stramineus*	Mi	In	
Weed shiner**	*Notropis texanus*	Mi In	In	
Mimic shiner	*Notropis volucellus*	Mi In	In	
Pugnose shiner***	*Notropis anogenus*	Mi In	In	
River shiner**	*Notropis blennius*	Mi	In	Sl
Bigmouth shiner	*Notropis dorsalis*	Mi	In	
Blackchin shiner	*Notropis heterodon*	Mi In	In	
Blacknose shiner	*Notropis heterolepis*	Mi In	In	
Central stoneroller	*Campostoma anomalum*	Mi		
Largescale stoneroller	*Campostoma oligolepis*	Mi		
Bluntnose minnow	*Pimephales notatus*	To		
Fathead minnow	*Pimephales promelas*	To	Om	
Northern redbelly dace	*Phoxinus eos*	He Mi	In	
Finescale dace	*Phoxinus neogaeus*	He Mi	In	
Spotfin shiner	*Cyprinella spiloptera*	Mi	In	
Common shiner	*Luxilus cornutus*	Mi		Sl
Speckled chub	*Macrhybopisis aestivalis*	Mi In	Bi In	
Silver chub	*Macrhybopsis storeriana*	Mi	Bi In	
Pearl dace	*Margariscus margarita*	He Mi	In	
Pugnose minnow	*Opsopoeodus emiliae*	Mi In	In	
Suckers	**Catostomidae**			
White sucker	*Catostomus commersoni*	To	Om	
Quillback	*Carpiodes cyprinus*		Om	
Highfin carpsucker	*Carpiodes velifer*	In	Om	
Shorthead redhorse	*Moxostoma macrolepidotum*		Bi In	Sl
Silver redhorse	*Moxostoma anisurum*		Bi In	Sl
River redhorse	*Moxostoma carinatum*	In	Bi In	Sl
Golden redhorse	*Moxostoma erythrurum*		Bi In	Sl
Greater redhorse	*Moxostoma valenciennesi*	In	Bi In	Sl
Northern hogsucker	*Hypentelium nigricans*	In	Bi In	Sl
Smallmouth buffalo	*Ictiobus bubalus*		Om	
Bigmouth buffalo	*Ictiobus cyprinellus*	To	Om	
Spotted sucker	*Minytrema melanops*		Bi In	Sl

APPENDIX 3. (continued)

Common name	*Scientific name*	IBI classification[a]		
		Taxa	Trophic status	Reproductive guild
Catfishes	**Ictaluridae**			
Blue catfish	*Ictalurus furcatus*		Pi	
Channel catfish	*Ictalurus punctatus*		Pi	
Tadpole madtom	*Noturus gyrinus*		Bi In	
Stonecat	*Noturus flavus*	In	Bi In	
Flathead catfish	*Pylodictis olivaris*		Pi	
Black bullhead	*Ameiurus melas*	To	Om	
Yellow bullhead	*Ameiurus natalis*		Om	
Brown bullhead	*Ameiurus nebulosus*		Om	
Trout-perches	**Percopsidae**			
Trout-perch	*Percopsis omiscomaycus*		Bi In	
Codfishes	**Gadidae**			
Burbot	*Lota lota*		Pi	Sl
Killifishes	**Cyprinodontidae**			
Banded killifish	*Fundulus diaphanus*		In	
Silversides	**Atherinidae**			
Brook silverside	*Labidesthes sicculus*		In	
Sticklebacks	**Gasterostidae**			
Brook stickleback	*Culaea inconstans*	To	In	
Sculpins	**Cottidae**			
Slimy sculpin	*Cottus cognatus*	He In	Bi In	
Mottled sculpin	*Cottus bairdi*	He In	Bi In	
Temperate basses	**Percichthyidae**			
White bass	*Morone chrysops*		Pi	
Sunfishes	**Centrarchidae**			
Rock bass	*Ambloplites rupestris*	In	Pi	
Green sunfish	*Lepomis cyanellus*	To		
Warmouth	*Lepomis gulosus*		Pi	
Bluegill	*Lepomis macrochirus*		In	
Pumpkinseed	*Lepomis gibbosus*		In	
Longear sunfish	*Lepomis megalotis*	In	In	
Smallmouth bass	*Micropterus dolomieui*	In	Pi	
Largemouth bass	*Micropterus salmoides*		Pi	
White crappie	*Pomoxis annularis*		Pi	
Black crappie	*Pomoxis nigromaculatus*		Pi	
Perches	**Percidae**			
Johnny darter	*Etheostoma nigrum*	Da	Bi In	
Mud darter**	*Etheostoma asprigene*	Da	Bi In	
Rainbow darter	*Etheostoma caeruleum*	Da In	Bi In	Sl

APPENDIX 3. (continued)

Common name	Scientific name	IBI classification[a]		
		Taxa	Trophic status	Reproductive guild
Perches (continued)	**Percidae**			
Iowa darter	*Etheostoma exile*	Da In	Bi In	
Fantail darter	*Etheostoma flabellare*	Da He	Bi In	
Least darter***	*Etheostoma microperca*	Da In	Bi In	
Yellow perch	*Perca flavescens*		In	
Logperch	*Percina caprodes*	Da	Bi In	Sl
Gilt darter***	*Percina evides*	Da In	Bi In	Sl
Blackside darter	*Percina maculata*	Da	Bi In	Sl
Slenderhead darter	*Percina phoxocephala*	Da In	Bi In	Sl
River darter	*Percina shumardi*	Da	Bi In	Sl
Walleye	*Sander vitreus*		Pi	Sl
Sauger	*Sander canadense*		Pi	Sl
Crystal darter***	*Ammocrypta asprella*	Da In	Bi In	Sl
Western sand darter	*Ammocrypta clara*	Da In	Bi In	Sl
Freshwater drum	**Sciaenidae**			
Freshwater drum	*Aplodinotus grunniens*		In	

[a] Taxa- Da=darters, He=headwater, Mi=minnows, In=intolerant, To=tolerant

Trophic status- Bi=benthic invertivore, In=invertivore, Om=omnivore, Pi=piscivore
Reproductive guild- Sl=simple lithophil
* Fish species list is from Fago and Hatch (1993). Underlined common names identify species collected during this survey
** Fish species not collected in St. Croix River Basin since 1974
*** Minnesota listed special concern species
**** Minnesota listed threatened species