Manual of Instructions for Lake Survey

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A Note to Fisheries Staff

May 3, 2017

To: DNR Section of Fisheries Employees

Re: Revised Lake Survey Manual

The Minnesota DNR manages a diverse suite of lakes that provide an impressive array of sport fisheries for many species. We have over 4400 lakes with fishery management plans, and over a thousand more that offer angling opportunities. As you are aware, it requires a well- organized, sophisticated effort to gather the large amount of information to keep our management plans updated. Our lake survey system is the backbone of a program that allows fisheries management in Minnesota to remain relevant and keep pace with a world undergoing many changes.

This revision to the lake survey manual is significant and advances several components of the lake survey system. All the latest survey techniques are included here, such as electrofishing standardization and additional options for habitat assessments, among others. Revised recommendations for sampling effort and the core components of a survey will maintain the integrity of long-term data sets while increasing program efficiency. This revision also incorporates the goals and objectives of the MN Pollution Control Agency's Clean Water Program to help guide lake survey prioritization and frequency. And as you may expect, all of the changes in this revision mesh with the lake survey database module. Our survey system is now more streamlined, we will be more efficient, and our data will be more accessible.

As you are aware, the founders of Minnesota fisheries management showed great foresight in starting the lake survey and assessment program almost 70 years ago. Since that beginning, many of our staff have expended considerable energy and commitment in helping to upgrade and update this program. I want to extend a warm thanks to all of our staff starting with the lake survey committee who worked tirelessly and professionally to move this revision forward. This effort clearly shows that we can be adaptive as needed to face the new challenges of an uncertain future. I am confident that our fisheries management program will remain relevant, effective and efficient.

Sincerely,

Donald L. Pereira
Chief, Section of Fisheries

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Using this manual

This manual was written for use in an electronic format. To help navigate the document if using a Word version, select the VIEW tab and check “navigation pane” in the “Show” panel. If using an Adobe PDF version, open the bookmark pane. In both, you can return to your previous view, from internal or external links, by hitting the Alt + Left Arrow key combination one or more times.

Manual of Instructions for Lake Survey

Introduction

Surveys are the foundation of Minnesota's lake management program. They are needed to collect physical, chemical, and biological information concerning habitat, water quality, and fish population characteristics. Surveys allow us to develop lake-specific management plans, evaluate management techniques such as stocking and harvest regulations, and help monitor long-term changes or trends in aquatic environments. Surveys also allow us to feed the growing public interest in the State's aquatic resources, and foster greater awareness of and care for those resources.

This document provides instructions for conducting standard and targeted lake surveys in Minnesota's lakes and reservoirs. A computerized database and reporting system (the Fisheries Survey Module, or FSM) has been developed to store, analyze, retrieve, and report information collected following methods described in this manual. In recognition that a standard survey may not always yield the information needed for each lake situation, the FSM supports a variety of targeted surveys and targeted survey components.

The FSM was designed to function best on field computers, and data collection and entry screens can vary as functionality is added to the program. Paper forms can still be used in the field, and latest versions of field forms can be found on the FSM site; however, the best paper forms will not have all the functions available on FSM screens used on field computers.

Within the FSM there are four main types of information related to any given lake or survey. General Information is information related to the lake itself, and generally does not change from survey to survey. Examples of general information include surface area, maximum depth, legal descriptions, and access information. Target Stations are also lake specific, and are not tied to individual surveys. Target Station information includes the type of sampling gear used at the location, a description of the location, and location coordinates. In the current FSM, once a target station has been established, it cannot be deleted, so staff working on a given survey must be aware of which of the lake's target stations are to be included in the survey. Components are the elements of individual surveys, and are based on the target stations. During a survey, staff may select a target station and add it to the survey as a component. No component can be added until a target station for it has been created. Components contain all the information collected during a survey at the selected target station. For example, a gill net set (GN) component will include all the information related to an individual net set, and the results of that set (all the information related to the catch). Narrative information is observational or descriptive text added to a survey on a variety of subjects. Narratives are simple text, and do not lend themselves well to data queries. Examples of narrative information include a discussion of the fishery based on survey results, general field notes, and notes on fish health.

Several publications describe other sampling methods and techniques used to manage Minnesota's fisheries resource. These include the Lake Management Planning Guide, Special Publication No. 132 (MNDNR 1982), the Large Lake Sampling Guide, Special Publication No. 140 (Wingate and Schupp 1984), the Fisheries Stream Survey Manual, Special Publication No. 165 (MNDNR 2007), and the Fisheries Management Planning Guide for Streams and Rivers in Minnesota, Special Publication No. 170 (MNDNR 2013), and Minnesota Lake Plant Survey Manual (Perleberg et al. 2015). Those surveying Minnesota lakes, or accessing older lake survey data, may also want to refer to previous versions of this manual: the Manual of Instructions for Lake Survey, Special Publication No. 1 (Scidmore 1970) and the Manual of Instructions for Lake Survey, Special Publication No. 147 (MNDNR 1993).

Survey Types

The two broad types of surveys covered by this manual are standard surveys and targeted surveys. Standard surveys are intended to provide a relatively broad overview of the fish community, and some basic water quality information. Targeted surveys are used to address specific aspects of a fish community, fish population, or aquatic ecosystem.

Standard surveys will include, wherever possible, all of these core components: standard gill netting (GN), standard trap netting (TN), and water quality (WQ) sampling that includes measuring Secchi disk transparency and a water temperature-dissolved oxygen profile. Spring night electrofishing (EF) targeting Largemouth or Smallmouth Bass is a fourth core component if the lake management plan designates one or both species as a primary or secondary species. Additional types of sampling covering other attributes of the aquatic system surveyed may, and often will, be added to standard surveys.

On a given lake the core components and timing of standard surveys will be described and defined in the lake management plan. Surveys that do not include those core components, or are not done at the established time of year for standard surveys in that lake, will be targeted surveys.

Targeted fish sampling seeks information on a small number of species, or species assemblages, or specific life stages (i.e., age 0 only, or adults only). Some types of targeted sampling may list specific targeted species or life stages. If a species or life stage is listed as targeted, other species or life stages may be ignored (no effort made to capture them), or may only be subject to minimal data collection. If no targeted species or life stages are listed, equal effort is made to collect all species and life stages encountered, and a certain minimal amount of data is consistently collected for all species.

Targeted surveys must be included and described in management plans. Objectives should be included for each planned targeted survey, and for any targeted sampling that might be included as an added component in a standard survey. Those objectives will drive the amount of sampling effort and desired sample sizes for those surveys.

Standard Surveys done under this manual will be most comparable to the old survey types of Initial Survey, Resurvey, and Population Assessment established in previous manuals (Scidmore 1970, MNDNR 1993). Older surveys referred to as Special Sampling would be considered Targeted Surveys under this manual.

Sampling Considerations for Standard Surveys

Standard Survey Frequency

The frequency at which standard surveys can be completed depends on upon the type of sampling done (and the time required to do it), the number of lakes in a particular management Area, the priority ranking assigned to each lake, and the number that can reasonably be surveyed annually, given all the other demands on Area survey crews. Statewide program needs may also be an important factor driving sampling frequency. Standard survey frequency for a lake should be defined in that lake's management plan, but the sampling needs of all Area waters, other demands on staff time during the sampling season, and statewide needs affecting Area waters, must be considered and balanced when those plans are written.

Statewide programs that may drive survey frequency include the Minnesota Pollution Control Agency's Intensive Watershed Monitoring Program (IWM), the Large Lake monitoring program, and the Sentinel Lakes long term monitoring program. The IWM will be a major driver of sampling frequency. Under this program, major watersheds are assessed approximately every ten years. Within each of the 81 major watersheds, the MPCA's goal is to survey fish communities in most lakes > 500 acres that have public access and that are suitable for Fish Index of Biotic Integrity (IBI) sampling, and in a subset (25-100% depending on the number of lakes in the watershed) of important lakes 100-500 acres in size that meet the same access and sampling criteria. Surveys are to be done within a 5-year window ending on the watershed sampling year. Lakes sampled under the MPCA's watershed monitoring program would be scheduled for a standard survey, plus a targeted survey of the nearshore fish community (IBI survey).

A three-level system should be used when prioritizing lakes for surveys:

A) Long-term monitoring (LTM) lakes. This group includes eleven lakes in the Large Lake program, and eight Tier 1 and 17 Tier 2 Sentinel Lake long term monitoring program lakes. Large Lakes are surveyed annually, Tier 1 Sentinel Lakes are surveyed every one to three years, and Tier 2 Sentinel Lakes are surveyed every three to five years.

Additional sampling may be required on Tier 1 and Tier 2 Sentinel Lakes, depending on the fish communities found in those lakes (*Link to Sentinel Lakes Sampling: Fish Protocols*). Completion of those surveys as scheduled is important in maintaining long term records for those lakes. The Large Lake program (circa 1983) and the Sentinel Lakes long term monitoring program (since 2008) both have statewide sources of funding and are considered critically important pieces of the Section's survey program.

B) Management evaluation lakes. This level includes all lakes where there are clear management evaluations or activities in place. Standard survey frequency would be established according to need, and evaluations would have a defined end date. Sampling methodology would be focused on specific management evaluations and targeted surveys would be common. Categories or types of management activities associated with evaluation lakes include: stocking evaluations, regulation evaluations, habitat evaluations, and lakes of high local importance. The latter group includes managed lakes where evaluations have been completed or are not needed, but where regular and recent survey data is highly desirable to anglers and managers to track population characteristics. Many, if not all, management evaluation lakes would be sampled as part of the MPCA's watershed assessment program, and would therefore be scheduled for a standard survey at least once every ten years. Exceptions would be remote lakes, and lakes under 100 acres.

Some Areas may have a disproportionate number of lakes considered important fishing lakes, and a priority ranking will be needed to determine survey frequency or intensity. However, it is also likely that evaluations on many of these lakes may be accomplished using less time-consuming (or off-season) targeted surveys, reducing the need for frequent standard surveys.

Although many of the evaluations done on management evaluation lakes would be done using targeted surveys, periodic standard surveys of these lakes are still required. Standard surveys place the results of targeted surveys in context with the rest of the fish community, and if habitat and water quality components are included, may place those results in context with the larger aquatic ecosystem. On all management evaluation lakes standard surveys should be completed at least once every ten years. On most of those lakes, that requirement will be met by completing the surveys required for the MPCA's watershed monitoring program.

C) Maintenance (established management) lakes. In most areas this category will include the majority of lakes. These lakes most likely fall into one of two groups: lakes previously in evaluation status that now have established management, or lightly used lakes. Management of evaluated lakes is firmly established based on previous surveys and investigations and benefits from the wealth of knowledge on lake fish communities gained from 60+ years of Section activities. Some may be considered very good fishing lakes. Active management activities on these lakes, such as stocking or special fishing regulations, have been evaluated and no additional surveys are required to continue routine management. As a result, a low sampling frequency or intensity can be applied. Lightly used lakes may be small (e.g. < 200 acres), remote, or low profile (e.g. lack lake associations). Some of these lakes may have simple fish communities dominated by Northern Pike, White Sucker, Yellow Perch, and small panfish. Anglers may not find these lakes highly desirable. Others may have good fishing but poor access limits their use and makes them difficult to reach. Historically they have likely had a low survey frequency (< one per 10 years). On these lakes infrequent standard surveys (once every 10-20 years) would be done to check for gross changes in fish populations or communities. In cases where lakes are small, lightly used, isolated, and well-protected from development, standard or targeted surveys may be done solely on an as-needed basis, in response to changes suspected or reported.

Standard surveys of most maintenance lakes over 500 acres would be completed at least once every ten years as part of the MPCA's watershed monitoring and assessment program. Standard surveys on a few of the most important maintenance lakes 100-500 acres in size would also be done at least once every ten years. Most of the standard survey needs for maintenance lakes will probably be met by watershed monitoring sampling.

Sampling Effort

The 1993 lake survey manual provided guidelines for the number of gill net (GN) and trap net (TN) sets to use in a standard survey, based on lake size (Table 1). For lakes under 100 acres, gill netting was optional, to reduce the potential for removing excessive numbers of fish from small populations. The same numbers are recommended for standard surveys in this revision; however, numbers may be modified (reduced or increased) depending on circumstances in individual lakes. Deviations from these recommendations should be justified in lake management plans.

Table 1. Recommended minimum sampling effort (number of sets) for gill nets (GN) and trap nets (TN) used in standard surveys.

Lake Size (acres)	Number of GN Sets	Lake Size (acres)	Number of TN Sets
< 100	GN not required	< 600	9
100 - 300	6	600 - 1500	12
300 - 600	9	> 1500	15
600 - 1500	12		
> 1500	15		

The number of sets may be reduced below recommended levels if acceptable coefficients of variation (CV) and adequate sample sizes can be maintained for catches of primary or secondary management species. A review of the number of net sets used in lake surveys done in 2012 by DNR Fisheries Research staff suggested that in many cases, where the most important species sampled by gill nets were Walleye, Northern Pike, and Yellow Perch, the number of gill net sets used could be reduced to 12 when 15 had been normally used, or to nine when 12 had been normally used, without unacceptably large increases in CVs for those species. In cases where nine gill net sets had normally been used, and CVs were relatively low, a reduction in the number of sets to eight might have been acceptable. No reductions were recommended in cases where six (or fewer) sets were normally used. Roughly similar reductions were possible in the number of trap net sets used to sample

Bluegill or Black Crappie, in some lake classes. See the full review for more detail on those recommendations (*Link to Recommended Effort Reductions*).

In extreme and rare cases reductions in the number of gill net sets used may be justified by high numbers of fish taken once field work begins. High numbers of bullheads or Yellow Perch may increase the amount of time needed to work nets beyond acceptable levels. If catches of primary or secondary management species are high enough to yield useful sample sizes, or if they are so low that attaining a useful sample is unlikely, even at the recommended effort, the number of gill net sets may be reduced (MNDNR 1993). Reductions in the number of sets used will reduce (and may eliminate) the value of catch per unit effort (CPUE) data obtained during these surveys.

Recommendations for the number of net sets to make, in the 1993 manual and in the later Fisheries Research review, were based on maintaining adequate precision in CPUE, and then only for a short list of fish species. Sample sizes needed for other survey metrics were not considered. More net sets may be needed to produce adequate sample sizes for some analyses. (e.g. age and growth).

Index Sampling

Most of the sampling techniques described in this manual are considered forms of index sampling. Index sampling relies on sampling at a set of sampling stations whose locations are fixed from year to year, with sampling done under similar conditions, at the same time of the year. Index sampling does not provide an absolute measure of abundance, rather, it provides a relative measure – how does the catch in survey A compare to the catch in survey B in the same lake, or how does the catch in survey A compare to some standard for lakes of a similar type (e.g. a lake class median). Results of index sampling are most useful for within-lake comparisons, and are less useful for lake-to-lake comparisons. Index sampling relies on a demonstrated relationship between CPUE for a species in the sampling gear and the population density for that species. If such a relationship has not been demonstrated for a given species, index sampling for that species will not be useful as an indicator of abundance. For example, in Minnesota the relationship between Walleye gill net (GN) catches and Walleye abundance is fairly well understood; however, no such relationship has been demonstrated for bass.

Sampling Stations

On most lakes, in most Areas, fixed sampling stations for gill netting and trap netting in standard surveys (full surveys or population assessments) have already been established. Earlier lake survey manuals provided guidance on selecting those survey stations. Staff were advised to avoid selecting stations they felt were likely to yield the highest catches. Instead, past manuals recommended that gill nets and trap nets be set in a variety of habitats within a given lake so that a variety of fish species were sampled. Truly random site selection was probably very rare, but it is hoped that through some deliberate process, stations covering a variety of habitat were established. Those earlier recommendations still hold for most cases where new sampling stations must be selected.

For some of the sampling gears and methods covered by this manual, more random methods for establishing station locations have been recommended to better provide for representative sampling. Goals for representative sampling are generally to produce a CPUE value that reflects the true abundance of a species, or a size (or age) distribution that reflects the true distribution for the population. Goals of this type are most attainable when sampling targets a single species or life stage. Sampling that yields representative catch or size data for one species may not perform nearly as well for other species taken in the same gear.

Once adequate sampling stations have been established, they should be repeated in subsequent surveys of the same type. Established stations are saved as Target Stations in the Fisheries Survey Module (FSM). When embarking on a survey a field crew will have the list and locations of target stations they will be sampling. However, circumstances can change, and at times new target stations must be established and old stations discontinued. Examples of situations that may require changing a sampling station include anoxic waters at the target station depth, changes in habitat (e.g. an impenetrable weed bed or shoals due to low water) or changes in accessibility (e.g. a channel no longer navigable). Adding sampling stations may be necessary if sampling effort in past surveys was inadequate. Sampling stations may be dropped if past sampling effort was higher than necessary (as described under ''Sampling Effort''). When changing, adding, or dropping sampling stations, an effort should be made to continue sampling the same mix of habitats. Target stations that have been added or dropped should be documented as such in the FSM, through appropriate notation in the description field for the target station. If a target station must be moved, the new location should be entered in the FSM as a new target station, with the new coordinates for that station. Do not keep the old station number and simply assign it to a different location.

It may not always be possible to replicate every target station. With the availability of precise Global Positioning System (GPS) data from handheld devices, sampling station locations can now be replicated more easily, precisely, and accurately than was possible when crews relied on hand-drawn field maps. Nevertheless, variations in sampling station locations will occur, either deliberately (e.g. avoiding an obstruction) or otherwise (e.g. high winds). If a sampling station misses the target location by more than 30 meters, or if it samples a different habitat type, it should be assigned a new station number (not the original target station number). To do so in the FSM, it will have to be added to the target station list. It will be up to the Area to determine whether that location becomes the new target station, or whether subsequent surveys will attempt to sample at the original target site.

Standardized Sampling

Consistency within sampling is essential. Because fish movements and location change seasonally and by life stage, areas should plan sampling schedules such that a particular lake is sampled within the same time frame (within 2-3 weeks) and in a similar manner (gear selection and methods) from survey to survey. Catches in standard gill nets and trap nets for various species are known to vary widely across the sampling season (*Link to Seasonal Catch Rates for GN and TN*; MNDNR 1993). The goal is to sample under similar conditions (e.g. water temperature, day length, stage). Consistent sampling will improve our ability to make year-to-year comparisons within specific lakes. Ideally, all lakes would be sampled at similar times so that lake-to-lake comparisons could also be more readily made; however, areas can only do so many surveys in a short time frame, so lake-to-lake comparisons must be limited to subsets of lakes done under similar conditions and at similar times of the year.

Gear Selectivity

All fish sampling gears are selective, or biased, in some way. The core components of a standard survey will tend to sample only larger fish species. Standard gill nets (GN) were designed to sample adult Walleye and Northern Pike in a fairly representative way, but information they provide on other species is less reliable. Standard trap nets (TN) were developed to sample panfish in nearshore habitats, but their catches can be greatly affected by changes in survey timing as fish go through their spawning cycles. Neither gear samples bass effectively; thus the addition of boom electrofishing as a core component of standard surveys. A wide variety of targeted survey gears and methods are available to help areas collect data that would be missed by standard surveys. Much of this manual is intended to guide Fisheries staff as they select the sampling gear most appropriate for the species of interest, or most likely to provide reliable answers to management questions.

Survey Preparation and Reporting Considerations

FSM Limitations

There are some limitations within the FSM that must be considered when planning a survey season. A unique survey is identified in the FSM by a combination of the lake, the survey type, and the survey date (survey ID). Results of each unique survey are combined in a single standard survey report (not the same as a report for a standard survey). Within that report, catch and effort data for any one sampling gear are combined, even if components for that gear were completed at different times of the year, or for different purposes. For example, if a survey includes ice-out TN sampling components, and summer TN components, those will be combined in a single TN catch report section. The FSM is also unable to distinguish between different types of electrofishing (e.g. day EF versus night EF, or representative versus nonrepresentative), or sampling targeting different species (e.g. spring EF targeting bass versus spring EF targeting Walleye). It will produce a single report section for a gear in a single survey, and will ignore all sampling nuances that may have been recorded for that gear. If separate reporting is required, those different sampling scenarios should be covered under separate targeted surveys. For the scenarios listed above, a standard survey might include gill netting, the summer TN, and the representative night spring EF targeting bass. Spring EF targeting Walleye and ice-out TN sampling could be included in a single targeted survey, since they involve different gears, while day EF and non-representative EF might have to be covered by two additional targeted surveys.

Use of Special Gear Codes

Some Areas have used the ‘‘special’’ codes (SGN, SEF, STN, and SSE) to avoid the need for multiple survey reports; however use of those codes for that purpose should be avoided. Special codes were devised in the initial (1993) version of the FSM, when the only standard gear codes supported were GN, TN, EF, and SE. Since then well-defined gear codes have been developed for many additional types of sampling, and those codes should be used whenever possible. Sampling gears and methods associated with standard gear codes (e.g. GN, S18, LTN) are well documented; a person using survey data can easily find out what those gears are, and how they are normally used. Special codes would have to be defined in each survey, probably in a narrative, and those descriptions do not lend themselves to data queries.

Preparing for the Survey

Before beginning field work, crews should review sampling plans and goals listed for each survey in the current lake management plan so they understand what information is to be collected, and how. This is particularly important for targeted surveys, and for targeted components that may be added to a standard survey.

Prior to field crews leaving the office, staff should look through the target stations available for a given lake in the FSM and identify those that will be used in the coming survey. GIS systems should be used to make sure location data for those targets are correct (no GN locations showing up out in a pasture, for instance). Target location data can then be downloaded to handheld GPS units, or maps showing the active target stations can be provided to the field crew.

Elements of a Lake Survey

General Survey Information

Lake survey reports include a large amount of general information related to the lake. Most has been compiled in the FSM from Geographic Information Systems (GIS) data already available within the DNR, but some can be checked and updated, as needed, during a lake survey.

Lake detail: Once a lake has been selected in FSM, staff will have access to a lake detail data entry screen. On that screen staff can add any missing data, including an alternate name for the lake (if known), littoral acres, maximum depth, mean depth, maximum fetch, shoreline length, and lake class. Shoreline length should not include island shorelines. Maximum fetch is the greatest straight line distance that does not cross islands or other land masses. Values already recorded under lake detail have been derived from the latest lake maps or from current GIS data, and should not be changed unless known to be incorrect. If any errors are noted for those values, work with GIS staff to have them corrected.

Lake access: Lake access information on survey reports is carried forward from the last survey in which access information was recorded. Access information recorded in the FSM includes ownership, availability for public use, access type (e.g. concrete ramp), and location. If no access information is shown on a survey report, or if it is incorrect, one or more access components must be added to the survey. These may be generated by field observations or, if there has been no change in access, from older reports on file. The location description included in the access target station record is what will be displayed on the survey report. Information recorded in the location description for the access component in the survey will be appended to the target station description on the report. Data entered as part of the access component will provide ownership, public use, and access type information for an individual access.

Habitat Evaluation

Habitat evaluations are not required as part of a standard survey; however, a better understanding of habitat, and habitat changes, is often critical to understanding, anticipating, and responding to challenges faced by aquatic systems. Initial or full lake surveys done in the past typically collected information on water levels, inlets and outlets, watershed and shoreline characteristics, aquatic vegetation, shoalwater substrates, erosion or pollution sites, and fish spawning habitat. All are still supported by various components of the FSM, and data collection options for some have been greatly enhanced (Table 2).

In lakes affected or threatened by development or other land use changes, or already adversely affected by current land uses, habitat components should be added to standard surveys on a regular basis. At a minimum, it is recommended that every third standard survey of those lakes include a full suite of habitat components, including a ''Score the Shore'' component, or another aquatic vegetation component the area office deems most useful for that lake. Score the Shore and other methods for conducting vegetation surveys are described in the Minnesota Lake Plant Survey Manual (Perleberg et al. 2015), which should be available at all Area offices.

For lakes that seem well protected and are at low risk of degradation, habitat measurements using current methods should nevertheless be done at least once. All Minnesota lakes will be affected by climate change, and are likely to see some habitat changes as a result. Habitat survey data from low-risk lakes will help identify changes from these broader causes, and may provide useful comparisons with lakes more affected by land use issues.

Habitat measurements should be done when vegetation is well developed – most commonly in July or August if surveying native vegetation is a primary concern. Fish sampling and habitat measurements may be done at different times of the year, but can still be included in the same standard survey report.

Habitat surveys will require some equipment not usually included as part of a standard survey. Additional equipment required may include: a tape measure or ruled staff (stadia rod), a hand or laser level, a stop watch, a flow (or current) meter, a vegetation key, a magnifying lens, a digital camera, sample bags or other containers, sample labels, and a vegetation grapple.

Water levels: Water level information is needed to monitor changes in habitat and to evaluate the effects of water level fluctuations on fish populations (i.e. spawning success, recruitment). Water level measurements are most critical on lakes known to be subject to wide variations, such as reservoirs and flowage lakes. In some of those cases water levels are routinely monitored by other agencies, and their data are usually available for Fisheries use. In others, Fisheries crews may include water level measurements as a routine part of standard surveys, to aid in interpreting survey results. Water level measurements are easy to obtain, but are probably of little value when collected infrequently and at only one time of the year. Water level measurements are not required as part of a habitat evaluation. They may be done if the Area deems them necessary for management of a given lake, or for interpretation of survey results.

Water levels are measured by Area staff at benchmark (BM) or gauge (GA) stations. Benchmarks have been most commonly used; two should be established on each lake, and once established, should be measured together. Benchmarks are valuable even when a system has been gauged; they provide water level data when gauges have been lost, and benchmark data can be used to relate old gauge data to data collected at a new gauge site.

New benchmarks should be established if no benchmarks exist, or if old benchmarks have been lost. If a single benchmark is lost, it should be replaced immediately, lest the second also be lost and the historic record be interrupted. If all the benchmarks on a lake are spikes in trees, at least one more-permanent benchmark should be established. Benchmarks should be unobtrusive, easy to locate, and as permanent as possible. When selecting a benchmark use the most immovable object that can be found. Ideally, benchmark readings should be tied to water elevations as determined from Division of Ecological and Water Resources (EWR) or Minnesota Department of Transportation survey points.

Benchmarks can be hard to describe; it is highly recommended that photos be taken and kept on file of all benchmarks. Locations should be detailed; ‘‘the big rock east of the landing'' may be easily confused with other big rocks east of the landing. UTM coordinates should be recorded every time a new benchmark is established, and every time a water level reading is obtained at an existing benchmark.

Water levels at a benchmark are recorded as vertical feet below (or, rarely) above the benchmark. Water levels below the benchmark are recorded as negative values (e.g. -3.53 ft), while levels above the benchmark are positive (e.g. 3.05 ft). A hand, string, or laser level, and a tape measure or ruled staff are needed to measure water level. The survey crew must measure the vertical distance between the water surface and a horizontal line extended from the benchmark (as indicated by a level). If the water level is above the benchmark (as in a flood), simply measure the water depth from the surface down to the benchmark to get the water level above the benchmark.

Readings at gauges are usually made directly by noting the gauge reading at the water surface, and the direct reading is recorded. When taking a gauge reading, note any problems with the gauge (e.g., damaged or tilting).

When measuring and recording benchmark or gauge water levels, also record whether the water level appeared to have been low, normal, or high at the time of the reading. High water levels might be indicated by flooded terrestrial vegetation; low levels by exposed lake sediments.

If detailed water level fluctuation data are required, water level monitors can be purchased at relatively low cost to provide hourly (or more frequent) readings over a period of months to years. These readings can be related to a few benchmark or gauge readings to yield a continuous record of fluctuations. These data are not currently supported by the FSM, but data and results can be attached to survey reports.

<u>Connectivity (inlets and outlets)</u>: Inlets and outlets often provide critical spawning and nursery habitat for fish, and may connect fish communities in different lakes and streams. They can be conduits for the introduction of invasive or otherwise undesirable species, and pathways for sediment and pollution. It is important to understand the connections that exist between waterbodies.

Information collected on inlets and outlets includes mean wetted width (bankfull width may also be of interest), mean depth, flow (cubic feet per second), velocity (feet per second), location and types of barriers to fish movement or navigation, bottom types, vegetative cover, availability or use of spawning habitat, water temperature, and source of flow. The location and types of any dams on outlets should also be described.

When surveying a lake for inlets and outlets, the entire shoreline should be examined. Small inlets may not be visible on aerial photos or topographic maps. Storm sewers may be important connectors in some systems, but may not be mapped. The locations of all inlets and outlets found should be recorded, and all should be mapped.

Flow should be measured on all major inlets and outlets. Flow in small streams (under a few feet in width) may be adequately measured using the floating chip method; in larger streams use of a flow meter is recommended. Methods for using a flow meter to measure flow are well documented in the hydrology section of the Fisheries Stream Survey Manual, Special Publication No. 165 (MNDNR 2007).

To measure flow using the chip method, use a small, nearly neutrally buoyant float (an orange, or a small vial partially filled with water will work). Select a section of the stream several feet in length (L), with fairly uniform width, depth, and bottom type, and with no obstructions. Determine the mean width (W) and average depth (D) of the section, in feet. Using a stopwatch, measure the time in seconds (T) it takes for the float to pass from the upstream end of the section to the downstream end of the section. At least three float trials should be done, and an average time determined. Determine a roughness factor (R) for the station; use 0.8 if the bottom is rough (rocks, rubble, or coarse gravel), and 0.9 if it is smooth. Flow in feet per second (F) is yielded by the formula:

$$F = (W \times D \times L \times R)/T$$

Stream sections used for flow measurements may not be typical of the stream. Flows are often measured inside culverts, or in other artificial settings where deeper or more uniform channels exist. Average width and average depth for a stream should be determined in a section of ''normal'' channel located near the mouth of the stream. These measurements are intended to provide a rough indicator of the size of the stream; they are not a substitute for the more detailed and representative measurements that would be provided by a stream survey.

If the presence of thermal refuges, or coldwater habitat, is important in a lake, an area should consider placing water temperature monitors in some inlets. These can record water temperatures hourly (or more frequently) for periods of months to years, and provide important insight as to the nature of the lake's inlets.

Watershed and shoreline characteristics: Once recorded as subjective observations by field crews, information on watershed and shoreline topography and land use is best obtained now from GIS data. ''Score the Shore'' surveys referenced elsewhere in this manual will provide the best information on condition and use of shorelines.

Aquatic vegetation: Aquatic vegetation survey methods have evolved and improved considerably since this manual was last revised. Vegetation surveys should be done following guidelines and instructions included in the Minnesota Lake Plant Survey Manual (Perleberg et al. 2015). Four survey types are described in the manual and supported by the FSM or Section of Fisheries GIS products: Score the Shore (a rapid assessment of lakeshore habitat), Floating-Leaf and Emergent Mapping, Plant Species Inventory (transect surveys as done under the 1993 lake survey manual), and Point-Intercept Plant Surveys. Refer to the Minnesota Lake Plant Survey Manual to determine which type of survey(s) will be appropriate for a given lake, and for instructions on how to conduct those surveys.

Bottom substrates (shoal water soils): Shoal waters, and associated bottom substrates, are important fish spawning and nursery areas. For lake surveys, shoal waters are defined as areas of the lake shallower than four feet. Shoal waters can be mapped in the field using GPS equipment, or by marking bottom types on a field map. Neither is currently supported by the Fisheries Section's GIS products or by the FSM; however, staff familiar with GIS programs can produce maps using techniques similar to those used for emergent vegetation mapping. If a shoal water map is produced (by GIS or by hand), it should be attached to the survey report. These shoal water substrate categories are used in lake surveys: ledgerock, boulder (>

10 in), rubble (3-10 in), gravel, sand, silt, clay, muck, detritus, and marl (MNDNR 1993).

Information on shoal waters is also collected during transect and point intercept vegetation surveys, and summary data will be reported by the FSM.

Erosion or pollution: Erosion sites, or evidence of point or non-point-source pollution, may be encountered by crews doing habitat surveys; however, even crews conducting other types of surveys should take note of any problem area observed, and record the location of the site. Photographs should be taken to document sites. Survey crews should be alert to indicators of non-point-source pollution, including intense algae blooms or fish die-offs. Fish kills observed by survey crews must be reported immediately to the Minnesota Duty Officer (1-800-422-0798). The Area Fisheries Supervisor and the Regional Fisheries Manager should also be informed. It is important that kills be promptly reported and investigated. Each area office has a fish kill kit available with supplies and instructions for investigating kills. Make sure survey staff know where to find the kit, and have reviewed sampling procedures.

Fish Spawning Habitat: Information concerning the amount and quality of spawning habitat is important in determining the potential for natural reproduction, as well as providing data to identify and justify protection of critical habitat. When compiling information of fish spawning habitat, two spatial scales may apply. The first is a lakewide description of habitat availability, by species. The second is a site-specific description of known or highly suitable spawning sites. In the latter case, UTM coordinates for the sites should be recorded, and sites should be mapped. Spawning habitat should be described for the major game fish species found in the lake, and for any others in which there might be some present or future interest (e.g. an invasive species, a planned introduction, or an expanding range). Evaluation of spawning habitat should be based on the following ideal conditions:

Largemouth Bass, Bluegill, and Pumpkinseed prefer firm gravel or coarse sand bottoms in two to five feet of water. Often the gravel or sand may be overlain by muck or detritus. Soft, unstable bottoms are not commonly used unless roots or detritus provide a firm substrate. Preferred sites are protected from heavy wave action. Weedy lakes are usually well suited to these species.

Crappie usually spawn in water one-half to three feet deep. Males clear a section of the bottom of sand, gravel, or mud, where there is some vegetation, sometimes where protection is offered by an undercut bank (Scott and Crossman 1973).

Smallmouth Bass prefer clear-water lakes with boulder and rubble areas protected from heavy wave action. Nests are usually found in depths of one to four feet and are often placed where one to three sides are protected by rocks, stumps, or large woody debris.

Northern Pike spawn in shallow, marshy areas, particularly in temporarily flooded meadows or marshlands. Good spawning marshes should have slowly dropping spring water levels, to avoid trapping fry or fingerlings. Northern Pike have also been known to spawn over deep beds of Muskgrass (*Chara*) and Stonewort (*Nitella*). Information on the variety of spawning habitats used by Northern Pike in Minnesota can be found in Northern Pike Ecology, Conservation, and Management History (Pierce 2012).

Walleye prefer clean gravel or rubble shores or shoal areas exposed to wave action. Rivers and streams are also used when available, and when they provide suitable substrates. In streams, successful spawning occurs where the current is moderate, on a variety of substrates free of silt and muck.

Yellow Perch spawn in open, shallow water, usually near rooted vegetation, submerged brush, or fallen trees, but sometimes over sand or gravel.

Lake Trout spawn on clean coarse rubble or boulder bottoms, at depths of one to 40 feet (often deeper than can be evaluated from the surface). Because Lake Trout spawning conditions can be difficult to assess visually, it can usually be assumed (in a natural population) that conditions are good if several age classes are present in the lake.

Channel Catfish prefer firm bottom areas with natural cavities (such as log jams, undercut banks, burrows, etc.) for nest building.

Other information on fish spawning habitat requirements can be found in Northern Fishes (Eddy and Underhill 1974), Freshwater Fishes of Canada (Scott and

Crossman 1973), or Fishes of the Minnesota Region (Phillips, et al. 1982). Fish spawning history and information on known fish spawning sites, can be obtained from Area or Regional records, or by inquiring locally.

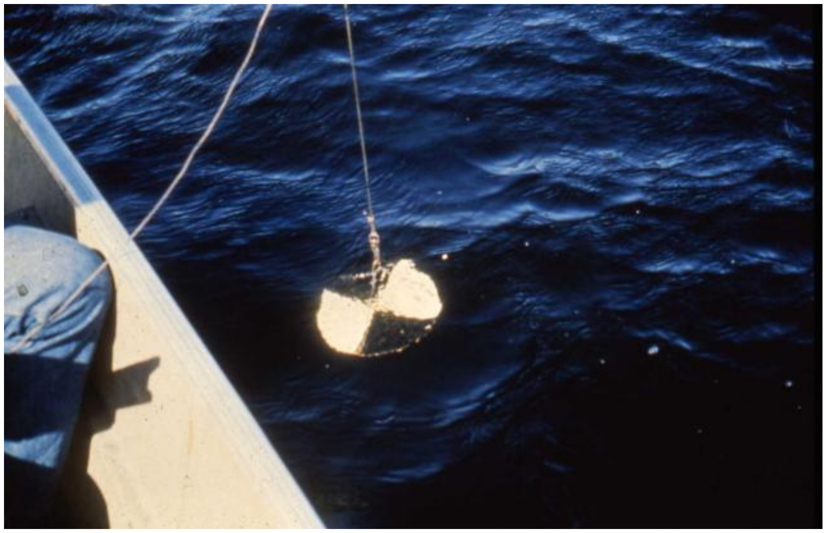

Figure 1. Measuring Secchi Disk transparency.

Water Quality

Some basic water quality sampling is a required part of all standard surveys. During each standard survey, usually on the first day at the lake, the crew should measure a water temperature-dissolved oxygen (TDO) profile, and a Secchi disk transparency, and record water color and the cause of that color. Other possible field measurements include pH and conductivity. Water samples may also be collected for a variety of laboratory analyses. In the FSM, most water quality data are entered and stored as part of water quality (WQ) or special water quality (SWQ) components; however, components for some other types of sampling may include some water quality data. For example, electrofishing components may include water temperature and conductivity data.

Sampling stations: In lakes under 5,000 acres with relatively simple basins, one primary water quality (WQ) sampling station should be selected at a centrally located point at the lake's maximum or near maximum depth. In lakes greater than 5,000 acres, or smaller lakes with complex shapes or distinct sub-basins, two or more sampling locations should be established. The primary station would be located at or near the point of the lake's maximum depth. Secondary stations would be located in the deepest areas of the lake's other major basins. Once established, these stations should be used in all subsequent standard surveys. For many lakes, multiple WQ stations have been established since 1993. Those that are considered primary or secondary stations for standard surveys should be indicated as such on the FSM target station screen, using the ''Station Name'' or ''Description'' fields to guide future field crews.

When to sample: Water quality should be measured during the initial stages of a survey. TDO profile(s) must be completed before gill net sampling to ensure nets are not set in anoxic water. Ideally all water quality field measurements will be completed on the same day.

Water quality changes over the year. Areas have the option of sampling at different times if needed, and in situations where water quality affects management of the fishery, areas should strongly consider additional sampling. For example, in lakes known to support cold-water species, completing an additional TDO profile late in the summer can be critical for defining the amount of cold-water habitat provided by the lake. This additional sampling can be added to any standard survey, or to a targeted survey if no standard survey has been scheduled; it need not be considered a separate targeted survey.

Dissolved oxygen and water temperature: A TDO profile must be completed at each primary and secondary water quality station using an oxygen and temperature meter with enough cable to reach the lake bottom. Meters must be properly maintained and calibrated according to the manufacturer's recommendations.

When sampling, the boat should be securely anchored to ensure the water column is sampled vertically. It may be necessary to use more than one anchor in high winds or rough water to prevent drifting and wild swings. Tying a length of chain to the anchor can help prevent drifting by absorbing the energy from the rising and falling of the boat on the waves.

Record dissolved oxygen and water temperature at 3-ft intervals from the surface to the top of the thermocline, at 1-ft intervals through the thermocline, and at 3-ft intervals from the bottom of the thermocline to the lake bottom. Measurements at 1-ft intervals through the thermocline are needed to more precisely define the amount of cold-water habitat available, and the limits of anoxic waters. The thermocline is defined as a drop in water temperature of more than 1 °C (or 2 °F) per three feet of depth (or per meter). If the lake is not stratified (no thermocline present), record dissolved oxygen and temperature at 3-ft intervals from the surface to the lake bottom. For entry in the FSM, depths should be recorded in feet, water temperature in °C, and dissolved oxygen in parts per million (ppm).

Secchi disk transparency: Water transparency must be measured at each primary and secondary water quality station using a standard Secchi disk (circular plate, 20 cm in diameter, with opposing black and white quarters that hangs horizontally from a calibrated line; Figure 1). Sampling should be done during mid-day if possible. Avoid wearing polarized or other treated glasses that reduce surface glare, as they affect the readings. Slowly lower the Secchi disk over the shady side of the boat until it disappears from view, and record the depth of the disk in feet and tenths of feet. Then lower the disk several more feet, and raise it until it just becomes visible again. Record that depth. The average of the two depths is the Secchi disk reading. If needed, multiple measurements may be done to obtain a better overall average.

Measuring water transparency is strongly encouraged each time the lake is visited. Transparency can change quickly and vary seasonally; several measurements over the course of a year will provide a better understanding of water transparency for specific lakes. If possible, take all Secchi disk measurements at the primary or secondary water quality stations.

Water color and cause: Factors affecting water quality, such as algae blooms, suspended solids, or bog stain, may be indicated by the water color and cause reported by field crews. For example, brown, bog stained water is an indicator of high levels of dissolved organic carbon (DOC), which in turn can be an indicator of inputs from wetlands in the watershed (Gunn et al. 2004).

Alkalinity, pH, and conductivity (field or Area analysis): Alkalinity and pH sampling are required during standard surveys of lakes with a history of total alkalinity < 5 ppm. Low total alkalinity indicates a lake has a reduced capacity to buffer acidic inputs like acid rain. Low pH can limit certain fish species, and low total alkalinity indicates a lake may be at risk of seeing pH fall to those limiting levels. Low pH, and low total alkalinity, are most commonly found in lakes in Northeastern Minnesota.

Conductivity measurements are needed any time standard or targeted surveys are done using electrofishing gear. Conductivity affects the efficiency of electrofishing gear, and so is valuable for interpreting electrofishing results; it is also an indicator of the lake's productivity.

For measuring alkalinity, pH, and conductivity, one surface water sample must be collected from the primary water quality sampling station, using one of these techniques:

Integrated sampling – open and rinse a sample bottle three times. Then, a 1-inch diameter by 6.5-ft-long PVC pipe is rinsed three times, and slowly lowered into the water vertically, with both ends open. The top end is corked, the pipe is retrieved, and the trapped water is emptied into the sample bottle.

Grab sampling – the sample bottle is opened, rinsed three times, inverted, and slowly immersed to elbow depth while being held by the bottom of the bottle. The bottle is then inverted slowly as it fills.

Grab samples minimize contamination, but can be less representative than integrated samples if algal biomass is concentrated near the surface. Once a sample has been obtained, Total alkalinity and pH should be measured as soon as possible. Keep samples refrigerated if they must be held overnight. Total alkalinity should be measured using potentiometric titration. Meters can be used to measure pH and conductivity in the field or at the office. Meters must be maintained and calibrated according to the manufacturer's recommendations. Standards for conductivity call for measurements to be done at a water temperature of 25 ^{o}C; most modern meters measure specific conductivity, which is ambient conductivity adjusted to the value at 25 ^{o}C. When recording conductivity, indicate whether the recorded value is specific conductance (adjusted to the 25 ^{o}C standard).

Water samples for laboratory analysis: When laboratory analyses of water samples are needed as part of a survey, that should be indicated when preparing survey proposals for the upcoming field season. The list of surveys that will be including laboratory analyses will be requested by the survey coordinator before the beginning of the season. Once the statewide list has been compiled, sample bottles, labels, and instructions are distributed to area offices. To avoid overwhelming laboratory capacity, each area has historically been assigned a standard time when sampling should be done, although variations for individual surveys are possible. The FSM currently supports laboratory analyses for total dissolved solids, pH, chlorophyll-*a*, conductivity, total alkalinity, total phosphorus, and sulfate ion. Additional tests can be requested for surveys and should be coordinated with the water quality consultant. For example, calcium ion analysis can be added to help measure a lake's susceptibility to zebra mussel infestation.

Water samples for laboratory analysis should be collected from the primary water quality station using one of the methods described for pH and total alkalinity sampling (integrated or grab). Indicate the collection method used on the sample label and sample submittal form. A dark bottle must be used for chlorophyll-*a* samples. Secchi disk transparency should be measured when water samples are collected.

Water samples should be labeled and be immediately placed on ice or refrigerated. Labels should include the lake name and DOW number (or the stream name and Kittle number), the sampling station number, the date and time at which the sample was collected, the depth at which the sample was taken, the collection method, UTM coordinates for the sample site, and contact information for the Area office. Samples should be transported or shipped to the designated laboratory as soon as possible after collection. Results will be returned to area offices over the following fall or winter.

Additional water samples may be collected from the hypolimnion (near bottom) at the primary sampling station, from inlets, or from other locations of interest. Hypolimnetic sampling can provide information concerning internal nutrient loading (nutrients released from bottom sediments), while water samples from inlets can provide information on water quality problems related to the surrounding watershed. Other chemical parameters (e.g. chloride, total nitrogen, turbidity, fecal coliform) can be measured upon request from the Area office when specific problems are suspected. Contact the Fisheries water quality consultant if you wish to add parameters, as additional bottles may be required. Plan ahead for this additional sampling, adding it to the list of requested samples and analyses when the list is requested before the field season.

Table 2. Habitat and water quality sampling station types use by the Minnesota Department of Natural Resources Fisheries Survey Module.

Station Type	Station Code
Inlet – general information	IN
Inlet – flow measurement	FMI
Inlet – width and depth measurement	WDI
Outlet – general information	OUT
Outlet – flow measurement	FMO
Outlet – width and depth measurement	WDO
Dam – general information	DAM
Access – information on access site	AC
Erosion – non-point source	ENP
Erosion site – point source	ER
Pollution – non-point source	PNP
Pollution site – point source	PO
Resort or campground	RE
Watershed or shoreline observations	WS
Spawning locations – known or favorable	SP
Aquatic vegetation – vegetation/substrate transect	VT
Aquatic vegetation – area or polygon	VA
Aquatic vegetation – point station	VP
Aquatic vegetation – miscellaneous sampling	VX
Benchmark – water level measurement	BM
Gauge – water level measurement	GA
Water quality station	WQ
Water quality station – special type	SWQ
Water quality location - area	WQA

Zooplankton Sampling

An Area may choose to sample zooplankton to better understand forage availability for small fish, to determine the effects of invasive species infestations or management activities (e.g. fry stocking) on the zooplankton community, or to monitor the lake for new invasive species (e.g. zebra mussel veligers or spiny waterflea). The FSM offers only limited support for zooplankton sampling, but a sampling gear (ZO) has been established to cover some sampling efforts. If planning to sample zooplankton, contact Ecological and Water Resources (EWR) staff for gear, method, and sample preservation recommendations. EWR staff may also be available to identify and enumerate zooplankton samples.

The FSM currently lacks any fields for recording methods used for zooplankton sampling. To document methods, Areas should use the 'Location Description' field on the target station or component screens, or describe the method in detail in the 'General Field' narrative. For sampling using towed nets, the net may be described in terms of mesh size (microns) and mouth opening diameter (typically centimeters). The tow itself may be described as 'vertical' or 'horizontal'. Vertical tows are done by lowering the net to a set depth, then pulling it back to the surface slowly. The depth to which the net is lowered should be described (it may vary from station to station). Horizontal tows are done by towing the net behind the boat at some depth below the surface (usually near the surface). The length and depth of horizontal tows should be described. For any tow, the volume of water sampled can be calculated from the diameter of the net mouth and the distance covered by the tow (vertically or horizontally).

Within the FSM, each tow (or other collection site) can be entered as a zooplankton (ZO) component. For each component, staff can enter a catch by selecting a species or group, and entering ''Animals per Liter.'' ''Mean Length (microns)'' can also be entered for each species or group. No catch data can be entered without entering some value for ''Animals per Liter.'' If those values are not available, catch can only be recorded using one of the FSM's narratives. Spreadsheets or other means of recording zooplankton catch can be attached to FSM survey reports if desired.

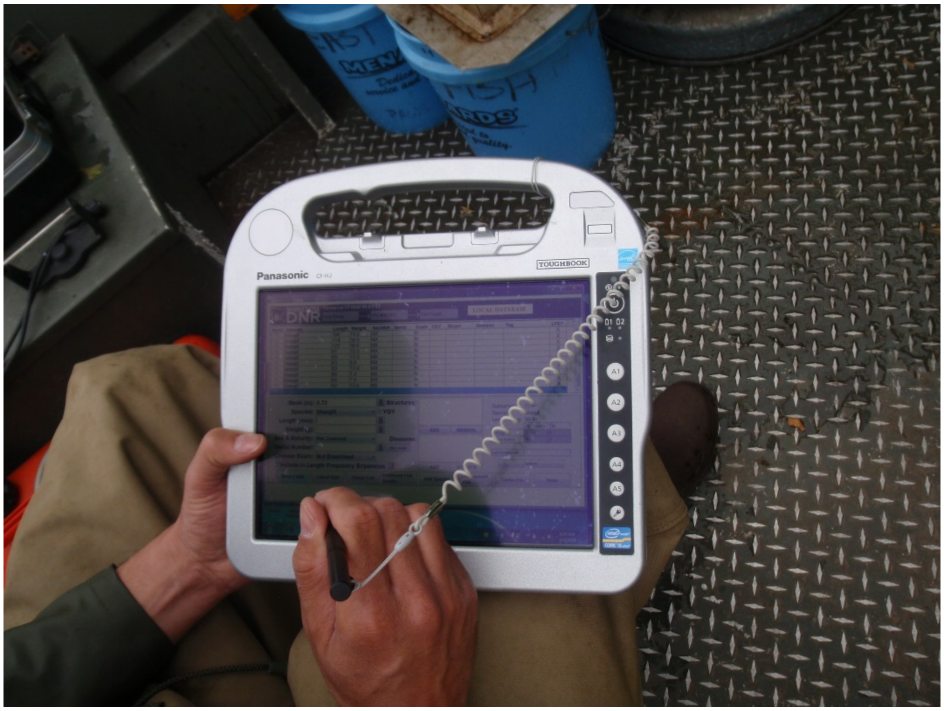

Figure 2. Recording the catch in FSM on a field tablet computer.

Recording the Catch

Information concerning the length, weight, condition, and health of fish is critical to evaluating fish population characteristics. Individual lengths and weights provide data concerning length distribution, age structure, fish condition, fish health, growth, and mortality.

Data collection requirements will vary depending on the sampling gear used and the purpose for a survey. In some cases a target species will be identified, and data collection for non-target species will be minimal, if done at all. The sampling methods section of this manual will provide information related to specific sampling gears and scenarios. The following are general guidelines for fish taken in any of the sampling gears used in standard or targeted surveys (Table 2).

Lengths and weights: When fish are measured, a measuring board (rather than a flexible rule) should be used, and fish length should be measured to the nearest millimeter (mm). Cradles or other specialized equipment may be used for large fish (e.g. Lake Sturgeon or Muskellunge). Fish should be laid on the board with their mouth closed and their snout pressed against the headboard. Their body should be straightened, the caudal fin should be compressed, and their total length (TL) measured at the tip of the caudal fin. Fish that are too damaged to be measured should be entered as unmeasured fish.

When fish are weighed, weights should be recorded in grams (g). When recording a weight, do not exceed the precision of the scale. For example, on a scale marked in 10-g increments, you should be able to read the 10-gram increment, and estimate a weight to one additional significant figure (to the single gram). Survey crews should be equipped with a 1000-g platform scale for fish under 1000 g, and a 12-kg platform scale for fish over 1000 g. Tube scales (in a variety of sizes) may be useful when weight or bulk of platform scales is an issue. Compact electronic scales of various sizes and types can provide good accuracy as well.

Wind and boat movement can seriously affect the precision of weights obtained in the field. Seek a quiet location, or transport fish back to the office if boat movement is excessive.

<u>Calcified structure collections</u>: Calcified structures have typically been collected for aging purposes; however, new techniques also make them valuable as sources of genetic information. Scales and otoliths have been the most commonly collected structures, but fin rays, dorsal spines, cleithra, and opercles have also been taken in many surveys. Otoliths are known to provide the most accurate and precise ages, but to collect them fish must be sacrificed. Scales can be useful when aging young fish, but their value is limited for fish older than ages 5 or 6. Dorsal spines and fin rays can provide somewhat better aging to supplement a scale collection, while not requiring fish to be sacrificed.

Each fish from which a calcified structure is collected should be assigned a unique (within the survey) serial number. Crew members should record the type(s) of structure taken from each fish. Structures should be placed in a paper envelope, and be allowed to dry thoroughly. It may be necessary to clean fleshy structures before using them; cleithra and opercles can be boiled to remove excess skin and muscle.

A new Section of Fisheries aging manual will be available by the winter of 2018. That manual should be consulted for guidelines related to recommended sample sizes for various analyses and techniques for preparing and reading various structures.

Subsampling: Although large sample sizes are typically desirable, it is common to capture so many fish of a given species in a single sampling station that measuring them all is impossible in the time available. In those cases, a method of sub-sampling must be employed to ensure that an adequate number of fish are measured, and that those measurements are representative of the total catch in that station. Fish not selected for measurement are simply counted, with the count recorded as ''unmeasured fish''.

As a general rule, 25-50 fish of each species caught should be measured from each sampling station (or mesh size, in a gill net set), although requirements will vary according to the needs of specific survey types and analyses. Subsampling a catch can easily introduce bias, so if you think the catch lies close to the needed number, it will generally be best to measure them all. If sub-sampling seems necessary, two methods can be used to produce a reasonably representative sub-sample: physical mixing, and systematic selection.

Physical mixing - To create a sub-sample by physical mixing, first sort the catch by species into various tubs and buckets. Large single-species collections are then stirred or mixed, then split into two containers containing roughly equal numbers. Those containers may be further stirred and split until one remains that holds a sub-sample of suitable size. At each stage, fish in containers not selected are counted and released or discarded. This method is not recommended for live fish that could be successfully released, but it avoids some of the selection bias that may creep into systematic selections.

Systematic selection – To create a sub-sample by systematic selection, the crew must first make a rough estimate of the total number of fish caught. That number is divided by the desired sub-sample size to yield a proportion of the catch to be measured. If the estimated catch is (for example) three times larger than the needed sub-sample size, the crew would measure every third fish of that species encountered, and count and release the rest. Care must be taken to avoid any unconscious bias when selecting fish to measure, and the systematic selection must be carried all the way through the sample, even if more (or fewer) fish end up being measured than originally planned.

Any time fish are selected for measurement in a non-random way there are numerous ways to bias those selections. Fish in a container may sort themselves by size as they move, resulting in different size distributions at different levels of the container. The human eye (and hand) can be drawn to larger fish, and those fish may simply be easier to grasp and remove, even if a blind draw is done from the container.

Subsampling exceptions - The FSM does offer a means of handling the occasional large or unusual fish that might otherwise have been skipped for measurement in a sub-sampling scheme. Those fish can be measured and entered in the FSM (or on a field sheet), as not to be included in length frequency distribution expansions done by the FSM. That will ensure that one or two large fish, deliberately selected, will not unduly skew an estimated size distribution that is based on an otherwise valid sub-sampling scheme.

Sex and maturity: Determination of fish sex and maturity can be critical for some survey analyses. Growth rates may differ markedly between sexes, and for mature versus immature fish. Behaviors may also differ, so knowing the sex of fish captured can help in determining whether the catch in a particular sampling gear, or at a particular time of year, was biased towards one sex or another. That said, sex and maturity determinations can be difficult, and often involve sacrificing fish. If sex and maturity are critical pieces of information for a given survey, that survey should be done in a way that will yield the most reliable information. In the survey report, document the method used to determine sex and maturity, particularly whether those determinations were based on internal or external examinations.

Sex and maturity are most reliably determined when gonads are well developed. For spring-spawning fish, determinations are best made between late summer and the following spring's spawning period. For fall-spawning fish it may be possible to reliably determine sex and maturity for fish taken earlier in the summer, through fall spawning.

Fish are considered mature if they have spawned once in their life, or if they are in the process of developing gonads for their first spawning event. Thus, a young Walleye collected in late August that had not previously spawned, but displayed gonad development indicating it would spawn the following spring, would be considered mature. Where these determinations are critical, crews must be trained in advance to be able to correctly identify maturity in the target species.

In the FSM there are several sex and maturity categories available for individual fish. The default for any fish is ''Not Examined.'' Males may be recorded as immature, mature, unknown maturity, ripe, or spent. The latter two categories should be used only if sampling during a spawning run. Females may be recorded as immature, mature, unknown maturity, ripe, green, or spent. The latter three categories should be used only if sampling during a spawning run. Small immature fish for which sex could not be determined may be recorded as ''Unknown Sex, Immature.'' A final category, not yet available in the FSM, that may apply to male or female fish in long-lived or slow-growing populations, where mature fish may not spawn every year, is ''mature, not developing gametes.''

Fish diseases and parasites: Examination of fish for diseases and parasites can at times be an important part of a lake survey, if done systematically. At other times, incidental observations can be indicators of potential problems that might drive more intensive studies in the future. In the FSM, information on diseases or parasites can be entered for any measured fish. More general observations can be recorded using the "Fish Health'' narrative (e.g. ''Most Northern Pike collected were infested with Neascus''). Many of the more common fish diseases and parasites were described in the 1993 Manual of Instructions for Lake Survey and in the 2007 Fisheries Stream Survey Manual (*Link to Common Fish Diseases*; MNDNR 1993 and MNDNR 2007).

The default type of disease exam for most measured fish entered in the FSM will be ''Not Examined'', since recording of disease and parasite information is optional. If a disease or parasite has been observed, options for the type of exam under which it can be recorded are: external, incidental, internal, and lab. Only one of these options can be selected for a single fish, but selecting any one of these options allows adding one or more of the many diseases or parasites supported by the FSM to the record for the fish.

Unless a systematic examination of fish for specific diseases or parasites has been planned in advance and executed as planned during a survey, disease and parasite observations for individual fish should be recorded as ''Incidental.'' Most disease and parasite records in the FSM have little value when it comes to judging the severity of infestations, because those using the data have no way of knowing what examiners were looking for or whether they were recording fish without disease . At best, most can only indicate a disease or parasite was observed in a population.

Selecting ''external'', ''internal'', or ''lab'' should be reserved for cases where there has been a planned, systematic examination of fish for a short list of targeted organisms. Methods used and the rationale for that exam should be documented in the ''Fish Health'' narrative. For example, one might state in the narrative ''All Lake Trout over 300 mm in length were examined internally for bladderworm, all Smallmouth Bass over 250 mm were examined internally for bass tapeworm, and all Yellow Perch over 150 mm were examined externally for yellow grub and neascus.'' If fish are to be examined for both external and internal infestations, select ''Internal'' for the exam type. Select ''Lab'' if fish are to be shipped to another location for examination (e.g. to be tested for VHS), and if you are able and willing to revisit the data entry screen and enter testing results for individual fish after they have been returned.. If the exam type is best entered as ''External'', ''Internal'', or ''Incidental'', but you still plan to ship some fish to a lab for further testing, you can select ''Disease Exam'' from the ''Retained For'' drop-down list on the ''Additional Fish Details'' screen. If you have shipped some fish to a lab for testing, but do not expect to get results back for individual fish, you can use the ''Retained For'' drop-down to document which fish were sent, or you can just enter a more general statement in the ''Fish Health'' narrative (e.g. ''Sixty Northern Cisco were shipped to the University of Minnesota lab to be tested for VHS'').

Other individual fish data: When entering individual fish data in the FSM, several more items are supported on an ''Additional Fish Details'' screen. Crews can enter girth, fork length, and stomach content information, as well as information on individually numbered tags and bulk markings found or applied. Crews can select a reason a fish may have been retained (contaminant testing, disease testing, genetics, or as a voucher), and they can include any other pertinent information using a large comments field. It is important to note that none of the information entered as additional fish details will be included on standard survey reports produced by the FSM. It is up to the areas to do their own analyses of these data.

Unmeasured fish: Fish that have been captured, but not measured, should be recorded as ''Unmeasured Fish.'' For each sampling station, multiple records of unmeasured fish may be added. Unmeasured fish records include the count of unmeasured fish, their bulk weight (optional, and must be only the weight of the counted unmeasured fish), the number vouchered, the number with deformities, erosions (fins), lesions, or tumors (DELTs), mesh size (fill in only for gill nets), and a check box to indicate whether the unmeasured fish recorded were young-of-year (YOY) fish.

Fish observed, but not captured: Fish that have been observed, but not captured, should not be entered in the FSM as unmeasured fish, even if they have been reliably counted. Areas wishing to track such observations must record them in other ways. Observations of fish may be included in FSM narratives, or observational data may be attached to FSM surveys and reports.

Non-fish species: Fisheries and other DNR staff sometimes have an interest in non-fish species taken incidentally in survey gear. Data on non-fish species can be entered for any fish-sampling station through the ''Fish Caught'' entry screen. From that screen one can access a ''Non-Fish Species'' screen where bulk or individual catch data can be entered. For individuals, one can select a species from a long list of turtles, snakes and other reptiles, frogs, toads, and salamanders, mussels, and snails, crayfish, and birds. Do not enter non-fish catch data unless you are sure you have correctly identified the organism. Sex, length, and weight can be entered for each individual. For turtles, measure the carapace length using a standard fish measuring board. For bulk entry, only the species and the number caught can be entered. Summary information on non-fish species taken is included on standard survey reports. If the non-fish catch includes an exotic or invasive species not previously seen in that lake, preserve voucher specimens to confirm the collection.

Narratives

The FSM provides 14 narrative sections that can be included in any given survey. Of those Discussion and Status narratives are required in every survey, standard or targeted. The rest can be used to record observations or interpretations related to different aspects of the survey. Of all the narratives, only the Status section appears on public reports viewable on the MNDNR's LakeFinder site. On standard survey reports (for standard or targeted surveys) all narratives for which the user has added content will be included in the final report. Because all narratives appear in the final report, basic standards for writing them should include use of complete sentences, proper spelling and grammar, and good sentence and paragraph structure. Language should be concise and professional.

Narrative entry fields provide no word-processing tools or aides (no spell-checking). Simple narrative entries can be created directly in the FSM, but users may want to create more complex narratives using an outside word processor, and paste the results into the final narrative. When doing that, users should be aware that the FSM cannot handle special fonts or characters. Text intended for use in the FSM should be simple. Text in narratives can be cut or copied, and pasted into other narratives.

In FSM survey reports, Fish Species, General Field, Discussion, and Status narratives will be found, in that order, near the end of the report. Other narratives will be placed close to the subject matters described by their names. However, it is not necessary to have data or other sampling results for a subject to have a narrative on that topic in the report.

Data, tables, photos, shapefiles, and other items that cannot be included in narratives can still be attached to a survey, although not all would be included in survey reports. The following is a link to guidelines for attaching files to surveys: (*Link to Fisheries Survey Attachment Guidelines*).

Discussion: The target audience for Discussion narratives consists of other natural resource professionals, current management and research staff, and future staff. Anybody reading the Discussion narrative likely has the full survey report in front of them, so it is not necessary to repeat in detail the results of each type of sampling that was done. That can be obtained from the body of the report. Unless it is relevant to interpretation of current survey results, it will usually not be necessary to delve deeply into the survey and management history of a lake when writing a Discussion narrative. That kind of broad historical information is probably better reserved for the lake management plan. There may be some value in briefly describing the management goals for the lake, and, if not covered elsewhere, providing a brief summary of recent management efforts. For the most part, the Discussion narrative is intended to be a place where the results of a single survey are described.

Standards for what should be included in the Discussion narrative vary widely across the state. At the minimum, the discussion should describe what kind of survey was done, why it was done, what the results were, and what the results mean. Results of the survey should be tied to major goals and objectives in the current lake management plan, or to the goals and objectives for the survey itself (particularly important for targeted surveys). In general you are providing an interpretation of the results. Raw numbers are in the report to be read, but how do they relate to results seen in other lakes (medians), or historic results in this lake, or goals set for the lake? What do they say about the success (or failure) of current management efforts? Carefully consider the limitations of the data collected before making statements about what it means. Narratives for targeted surveys may be more tightly focused – what did we do, why did we do it, and what did we learn.

Status: The main target audience for the Status narrative is the general public. Status narratives are included as part of abbreviated survey reports available at the MNDNR LakeFinder site, and they are included on standard survey reports produced for area Fisheries use. Status narratives should use plain language and no Fisheries jargon. Readers at the LakeFinder site will not have access to the full standard survey report, only summary information provided by LakeFinder. As a result, writers should avoid references to results that cannot be seen on LakeFinder, or they should be prepared to more fully describe those results in the Status narrative. Most Status readers will not have access to the lake's management plan, so a brief description of the lake, management goals for the lake, and current management activities should be included, particularly in a Status narrative done as part of a standard survey. A recent change to LakeFinder gives site users access to a full range of historic survey results (in summary form), so a detailed historic summary in the Status is not required. Like the Discussion, the Status should describe what we did, why we did it, what we learned, and how that relates to management goals for the lake. The Status must be tailored to its main audience, be kept as simple and clear as possible, and address angler's concerns as much as it addresses fish manager's concerns. Simply cutting and pasting a Discussion into the Status is not acceptable, except as a starting point.

Until recently, results of targeted surveys (or special assessments) were not available at the LakeFinder site. Targeted surveys can be done for a wide range of reasons, using a variety of sampling gears and methods. The results of targeted surveys are not necessarily comparable to the results of the standard surveys and assessments that the public was used to seeing on the site. Therefore, the Status narrative for a targeted survey should have a statement that explains why you did that survey and that results from the targeted survey should not be compared to results from standard surveys. If a standard survey was done on the same lake that year, the Status for a targeted survey may refer the reader to the standard survey for more complete information. Status narratives for targeted surveys may be quite brief, perhaps limited to what was done and why, with a summary of results if those are not supported by LakeFinder.

General Field: This narrative appears only on standard survey reports, and its target audience will usually be area Fisheries staff, present and future. The narrative can be used to describe sampling methods in more detail (e.g. the type of gill net used in GSU sampling, or the method used to select EF station locations). It is a good place to describe problems encountered during the survey (e.g. TN 4 and 5 were collapsed by high winds), unusual occurrences or phenological events (e.g. loons were observed nesting on Windswept Island), or any other item that doesn't fit well in other narratives. In some areas this narrative has been used to report recent stocking, methods and results for population estimates, stomach contents observed, results of sex and maturity analyses, lists of recaptured fish, or reports received from anglers during the survey.

Other narratives: Other narratives available include Fish Species, Connectivity, Water Level Reading, Water Quality, Pollution Erosion, Spawning Habitat, Riparian Landscape, Vegetation, Substrate, and Fish Health. In most cases the narrative names are good descriptions of suggested content. These narratives all appear only in standard survey reports, and their target audiences are area Fisheries staff, present and future. The Water Quality narrative is a good place to describe general water quality concerns noted by the survey crew, and to list laboratory water quality parameters that were tested for, but fell below reporting thresholds. Although a Preliminary Discussion narrative exists and can be filled in and saved, it does not appear in any reports.

Lake Survey Mapping

Collecting location data is critical to the lake survey program and maps are a product of the lake survey database. Maps are needed to locate sampling stations, identify resorts and other developments, and show locations of dams, access points, erosion or pollution sites, and critical habitats. Handheld Global Positioning Systems (GPS) units and the widespread availability of powerful GIS software have greatly eased mapping.

For most lakes, sounding or bathymetric maps are already available, in lake files or as GIS products, and will be adequate for survey use. If no map is available for a lake, or if the current map is inaccurate or imprecise, new technology and commercial software make it possible for an Area to produce a new map for survey purposes fairly easily. Methods for doing so will not be addressed in this manual; staff are advised to enquire within the Fisheries section for advice on the availability and use of equipment for this purpose.

All maps produced from a given survey should be titled. Included in the title section should be the lake name, lake inventory number (DOW number; Division of Waters 1968), the type of survey information shown (e.g. Sampling Stations, Emergent Aquatic Vegetation), the survey type (Standard or Targeted), the survey ID date, and dates of field work for information shown on the map. Items mapped should always be identified using standard codes or labels from the FSM. If no standards exist for mapped information, the map must include a key to any codes used. Providing this information ties the map to the survey report.

Traditionally, field crews have started each survey with a set of maps showing the sampling stations they plan to replicate, and a set of blank maps on which to record stations as they are sampled. Crews may also have available photos of some past target stations. Even though station locations can now be documented precisely using GPS data and digital photography, field maps are still a useful way for a survey crew to document, in more-or-less real time, their progress on a survey, and any deviations from target locations.

Sampling Station Map

Crews embarking on a survey must have available for field use, electronically or as a paper copy, a map showing locations of the sampling stations they plan to replicate. If they plan to establish new sampling stations, they should have available a map showing pre-selected station locations, to the extent those are known. For any type of representative sampling, station locations should be selected before the crew goes into the field.

All sampling stations used in a survey must be mapped. As long as Universal Transverse Mercator (UTM) coordinates are recorded for each sampling station, it is relatively easy to produce precise maps showing all the stations used in any given survey using GIS software (Figure 3). Once location data have been entered into the FSM, Fisheries GIS staff make them available for Area use as layers or other GIS products. Because those maps can be produced as needed, paper sampling station maps are no longer required as part of a lake survey report when UTM coordinates for stations are known. If UTM coordinates have not been recorded, the field map showing sampling stations must be appropriately titled and attached to the survey report. Field maps used in a survey may be scanned and stored electronically, or may be stored in lake files at the area office.

Other Survey Maps

If the purpose of a survey is to map a specific item, the map or maps produced must be included with the survey report. A wide variety of other maps may be produced by various types of surveys. Hydroacoustic sampling may produce maps showing the distribution and density of pelagic fish, or the distribution, density, and height of submerged aquatic vegetation. Standard methods have been developed for mapping emergent vegetation, and are referenced elsewhere in this manual. Survey maps should be produced using GIS whenever possible; however, Areas may produce maps in other ways, based on their field observations, equipment available, and survey needs. These maps may be georeferenced, or they may simply be produced and stored as hand-drawn paper maps.

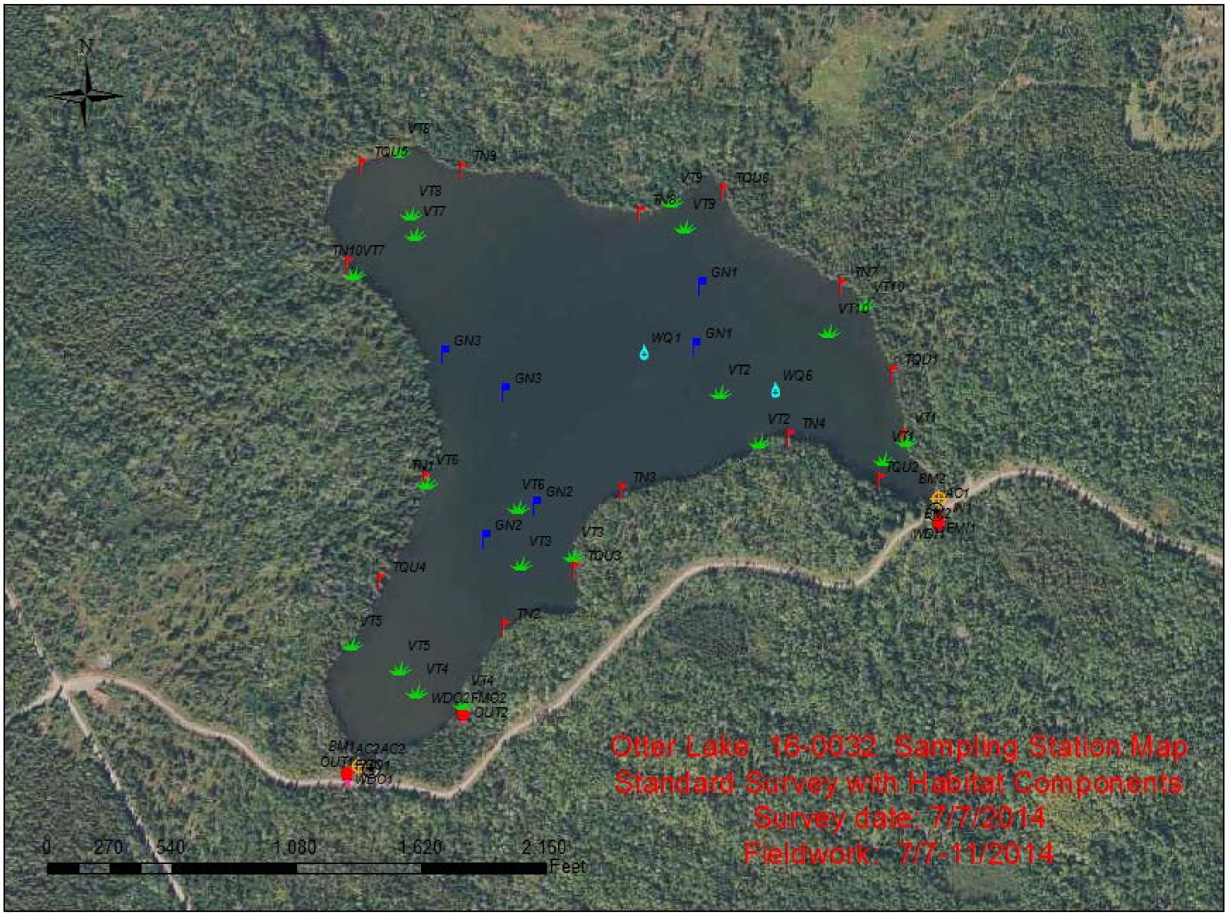

Figure 3. Example of a GIS-generated sampling station map for a standard lake survey.

Table 3. Gears used to sample aquatic organisms during Minnesota Department of Natural Resources Fisheries Lake Surveys.

Gear Code	Gear Type	Description	Unit of Effort[a]
GN	Gill net	Standard graduated-mesh gill net	Set
GDE	Gill net	Deep GN net, in waters colder than 12 °C	Set
GSH	Gill net	Shallow GN net, in waters warmer than 12 °C	Set
GSM	Gill net	Small-mesh (0.375 and 0.5-in-bar) net	Set
GST	Gill net	Short-term sets, monofilament net	Set
GSU	Gill net	Suspended set, any gill net type	Set
GNP	Gill net	Large-mesh (1.5, 2.0, 2.5-in bar) net	Set
FCI	Gill net	Fish Community Index nets (Ontario)	Set
TML	Gill net	Trammel net	Set
SGN	Gill net	Other (special) gill net	Set
GNA*	Gill net	Standard North American gill net	Set
VGN*	Gill net	Vertical gill net	Set
TN	Trap net	Standard 0.75-in-mesh double-frame net	Set
LTN	Trap net	Large-frame (5x6 ft) net	Set
DTN	Trap net	Pair of TN nets, set in double-pot configuration	Set
TQU	Trap net	0.25-in-mesh net	Set
T38	Trap net	0.375-in-mesh net	Set
THA	Trap net	0.5-in-mesh net	Set
T34	Trap net	0.75-in-mesh single-frame net	Set
T1	Trap net	1.0-in-mesh net	Set
STN	Trap net	Other (special) trap net	Set
EF	Electrofishing	Standard Boat electrofishing	Hours
EW	Electrofishing	Fall electrofishing targeting Walleye	Hours
EFB	Electrofishing	Backpack electrofishing	Hours
SEF	Electrofishing	Other (special) electrofishing	Hours

Continued on next page…

Table 3. (cont'd)

Gear Code	Gear Type	Description	Unit of Effort[a]
S58	Seine	50-ft bag seine, 0.125-in mesh	Haul
S18	Seine	15-ft seine, 0.125-in mesh	Haul
SE	Seine	50-ft bag seine, 0.25-in mesh	Haul
SSE	Seine	Other (special) seining	Haul
AIF	Angling	Ice fishing	None
AOW	Angling	Open-water angling	None
TOU	Angling	Tournament angling	None
ATL	Trot line	Normal trot-line configuration	None
STL	Trot line	Other (special) trot line	None
TR	Trawl	Large lake trawl	Hour
STR	Trawl	Other (special) trawl	Hour
EXT	Miscellaneous	Fish collected from or by an external source	None
XXX	Miscellaneous	Fish taken by miscellaneous means	None
MT	Miscellaneous	0.25-in-mesh minnow trap	None
SA	Miscellaneous	Fish spawning trap	None
ZO	Zooplankton	Zooplankton sampling gear	None

[a] Units used by the Fisheries Survey Module when calculating and reporting catch per unit effort.

* Not currently supported by the FSM.

Figure 4. A standard survey in the Boundary Waters Canoe Area Wilderness.

Fish Community and Population Sampling Methods

Standard Surveys

Standard surveys are a form of non-targeted sampling, most often done to obtain basic inventory data, to determine the composition of the fish community, to characterize abundance of various fish species, to determine size and age structures of various fish populations, and to collect samples for age and growth analysis. Gears used for this sampling tend to capture only larger fish species. Most standard lake surveys will use standard gill nets (GN) and standard trap nets (TN) to sample fish. In lakes supporting significant bass populations, surveys may include night electrofishing (EF). In some deep lakes supporting cold-water fish communities, a depth-stratified standard survey may be done, replacing GN sets with a combination of deep standard gill net sets (GDE) and shallow standard gill net sets (GSH).

In some cases, standard surveys may be done using only GN (or GDE plus GSH), or only TN to sample fish. Gill nets may be used alone when access is so difficult that TN nets (and watercraft needed to operate them) cannot be safely transported to the lake. TN gear may be used alone in small lakes (under 100 acres) where even limited use of gill nets might result in excessive mortality for a high-value primary or secondary management species (e.g. stream trout), and where the primary management species is known to be vulnerable to TN sets during the selected sampling period (e.g. fall survey of a stream trout lake). Use of GN or TN alone as a standard survey will be detailed in the lake management plan. Note that this exception does not apply to the use of trap net gear other than TN, or gill net gear other than GN (or GDE plus GSH).

Other sampling gears, including those listed as types of targeted sampling in this document, may be used during a standard survey, and may be included as optional components of that survey, so long as the core components of a standard survey are also used.

These fish sampling gears are core components of a standard survey:

<u>GN (standard graduated-mesh experimental gill nets):</u> Timing for standard GN sampling in a given lake will be established in the lake management plan for that lake. Once established, sampling dates should be replicated whenever possible. Where set locations have been established, they should be repeated in subsequent surveys whenever possible. If establishing new sampling stations, select a variety of habitats, and alternate the orientation of mesh sizes with respect to the shoreline. In lakes known to support, or suspected of supporting a coldwater fish community, GN sets, or portions of GN sets, may be made in waters capable of supporting coldwater fish. If conditions allow, a depth-stratified standard survey may be done, using GSH <u>and</u> GDE instead of GN to sample both warmwater and coldwater fishes.

Data collection standards for specific sampling purposes are discussed elsewhere in this manual. Minimum data collection requirements for the GN (or GSH plus GDE) catch in a standard survey are:

1) record catch by mesh size (measured fish and fish counts)

2) measure all intact gamefish taken (weights are optional; count damaged or partial fish)

3) measure 50 panfish and non-game fish per mesh size (across stations; individual weights are optional), and count unmeasured fish (bulk weights of unmeasured fish are optional). Never bulk-weigh measured fish. Try to include fish from each sampling station in the measured sample. No fish species are exempt from this measuring requirement.

4) for primary management species, collect calcified structures for age and growth analysis from 5-10 fish from each 10-mm length category under 300 mm, and from 10 or more fish in each 25-mm length category over 300 mm. Sample a range of lengths within each length category.

5) collect calcified structures for other species as required by the lake management plan or relevant study plans

6) determine sex and maturity for selected species as required by the lake management plan or relevant study plans

<u>TN (standard double-frame 0.75-in-mesh lake survey trap nets):</u> Timing for TN sampling done as part of standard surveys in a given lake will be established in the lake management plan for that lake. It is usually done at the same time as standard GN (or GSH and GDE) sampling. Once established, sampling dates should be replicated whenever possible. Where set locations have been established, they should be repeated in subsequent surveys whenever possible.

Data collection standards for specific sampling purposes are discussed elsewhere in this manual. Minimum data collection requirements for the TN catch in a standard survey are:

1) measure all intact gamefish taken (weights are optional; count damaged or partial fish)

2) measure 25-50 panfish and non-game fish per station (individual weights not required), and count unmeasured fish (bulk weights of unmeasured fish are not required). Never bulk-weigh measured fish. No fish species are exempt from this measuring requirement.

3) for primary management species, collect non-lethal calcified structures (scales, fin rays, or dorsal spines) for age and growth analysis from 5-10 fish from each 10-mm length

category under 300 mm, and from 10 or more fish in each 25-mm length category over 300 mm. Sample a range of lengths within each length category.

4) collect calcified structures for other species as required by the lake management plan or relevant study plans

When a standard survey is done to provide data to be used in calculating a fish IBI, measurements of fish of <u>all</u> species are critically important. IBI calculations rely on biomass estimates from GN and TN gears, and those cannot be done unless sizes of fish taken in each sampling station, in each gear, are known. Subsampling for length measurements is acceptable, but failing to measure any fish of a given species is not.

<u>GDE (standard graduated-mesh experimental gill nets, set on the bottom in waters colder than 12 °C):</u> If used as part of a temperature-stratified standard lake survey in place of GN, GDE must always be used in conjunction with GSH. In a temperature-stratified standard survey GDE sets sample coldwater habitats suitable for Lake Trout (and other coldwater species), and GSH sets sample warmer waters. If temperature-stratified surveys are the standard practice in a lake, the relative effort devoted to sampling coldwater (GDE sets) and warmwater (GSH sets) fish communities should remain fixed from survey to survey. Before setting gill nets, complete a water temperature-dissolved oxygen profile. GDE sets should be made in waters cooler than 12 °C (54 °F), with dissolved oxygen over 3 ppm. It may be necessary to vary net depths and locations slightly from year to year, based on current temperature-oxygen conditions. Minimum data collection requirements for this sampling are the same as those listed for GN in a standard survey.

<u>GSH (standard graduated-mesh experimental gill nets, set on the bottom in waters warmer than 12 °C):</u> If used as part of a temperature-stratified standard lake survey in place of GN sets, GSH sets must always be used in conjunction with GDE sets. In a temperature-stratified standard survey GDE sets sample cold waters suitable for lake trout (and other coldwater species), and GSH sets sample warmer waters. If temperature-stratified surveys are the standard practice in a lake, the relative effort devoted to sampling coldwater (GDE) and warmwater (GSH) fish communities should remain fixed from survey to survey. GSH sets should be made in waters warmer than 12 °C (54 °F). It may be necessary to vary net depths and locations slightly from year to year, based on current water temperature-

dissolved oxygen conditions and water levels. Minimum data collection requirements for this sampling are the same as those listed for GN in a standard survey.

EF (Boom electrofishing): Although electrofishing is part of a standard survey, unlike other standard survey gears it is used primarily to target bass, as opposed to assessing the fish community. Use of electrofishing is strongly recommended in lakes where bass are a primary or secondary management species, but is optional in other lakes. Standard methods for electrofishing were established by the MNDNR's Bass Technical Committee. Bass electrofishing is used to address two basic objectives: to determine the size structure of population, and to determine the relative abundance of bass (CPUE). Electrofishing done as part of a standard survey is intended to yield valid CPUE data, and so should be done at night, following procedures for representative sampling developed the Bass Technical Committee (*Link to Night Electrofishing for Black Bass*). Refer to those procedures for detailed instructions on how to conduct this sampling in a way that can yield valid CPUE (and size distribution) data.

Data collection standards for specific sampling purposes are discussed elsewhere in this manual. Minimum data collection requirements for the EF catch in a standard survey are:

1) Net all bass. Netting other species is optional.

2) Record catch by sampling station (measured fish and fish counts).

3) Measure all bass taken.

4) For bass, collect calcified structures for age and growth analysis from 5-10 fish from each 10-mm length category under 300 mm, and from 10 or more fish in each 25-mm length category over 300 mm. Sample a range of lengths within each length category.

General Nearshore Fish Community Sampling

Nearshore fish community sampling does not target a specific species but rather attempts to collect a representative sample of the smaller fishes in the community. Nearshore fish sampling components are often completed as part of sampling required to calculate a Fish Index of Biotic Integrity (IBI), but may also be done simply to better understand species diversity within a lake. Sampling described below differs from other nearshore sampling (e.g. standard trap netting using TN gear) that target gamefish populations because the gears used are best suited for sampling small fish. If this sampling is done to collect data to be used by the MPCA for IBI scoring or development, methods and sampling gear detailed in the most recent IBI sampling manual must be used: (*Link to Lake IBI Sampling Manual*). The following gears may be used for general nearshore fish community sampling and may be included as components of a standard survey, or as components of a targeted survey. The use of these gears has replaced the use of 50-ft, 0.25-in-mesh bag seines (SE) as our primary means of sampling the nearshore fish community.

S18 or S58 (IBI bag seines, 15- or 50-ft long, 0.125-in mesh): This sampling should be done between late June and early September. Minimum data required are counts of fish by species in each haul. YOY of fish other than minnows should be counted separately. Do not include YOY fish smaller than 25 mm TL.

EFB (backpack electrofishing gear): This sampling should be done between late June and early September. Minimum data required are counts of fish by species in each set. YOY of fish other than minnows should be counted separately. Do not include YOY fish smaller than 25 mm TL.

TQU (0.25-in-mesh trap nets): Sampling may be done at any time between late June and early-September. In IBI surveys on Lake Class 1–19 lakes, it may be done as a substitute for seining (S18 or S58) at the preset stations – see IBI manual for more details. Minimum data required are counts of fish by species in each set. YOY of fish other than minnows should be counted separately.

Other Sampling Targeting the Nearshore Fish Community

Use of gears other than EFB, S18, S58, and TQU to sample the nearshore fish community would be considered targeted sampling, unless included as a component of a standard survey; however, for this general community sampling no target species would be listed. Generally, this sampling would be done simply to better determine species diversity. However, on some lakes where it has been used historically, Areas may want to continue this type of sampling to retain their ability to identify trends and make comparisons with past results.

SE (bag seine, 50-ft long, 0.25-in mesh): This sampling should be done during August or September. Minimum data required are counts of fish by species in each haul. YOY panfish and gamefish should be counted separately. SE sampling is no longer a required part of a standard survey, but can be an added component.

MT (minnow traps): This sampling should be done between late June and early September, usually in conjunction with the gill netting portion of a survey. This is one of the least effective means of sampling nearshore fishes, and should be used only when other methods are not feasible. Minimum data required are counts of fish by species in each set. YOY panfish and gamefish should be counted separately.

Other trap net gears (T38, THA, T1, T34): These gears are defined by their mesh sizes (0.375, 0.5, 1.0, or 0.75-in bar, respectively). Other details of gear construction (e.g. frame size and number, lead length) should be described in a narrative attached to the survey report. If no target species is listed, minimum data requirements are the same as those listed elsewhere in this manual for standard trap nets (TN). If a target species has been listed, data requirements should be found in the lake management plan, and should be described in a narrative attached to the survey report.

Surveys Targeting YOY or Age-1 Fish

This sampling may be done to determine abundance of YOY or age-1 fish (CPUE), or to determine the average size of YOY fish at a set point during their first growing season. Both could be used as indicators of future year class strength. Sampling must be done when YOY and age-1 fish are large enough to be vulnerable to the gear, and are present in habitats effectively sampled by the gear. In some cases, this sampling can be accomplished in conjunction with other nearshore fish community sampling. Minimum data required for all sampling targeting YOY fish are counts of YOY or age-1 fish of the targeted species, by station, and lengths of YOY or age-1 fish of the targeted species (up to 20 per species per station, minimum of 50 per species per survey). If scale samples must be collected to distinguish between YOY, age-1, and older fish, collect scales from at least 10 fish in each length range where sizes for YOY, age-1, and older fish appear to overlap.

TQU (0.25-in-mesh trap nets) targeting YOY Walleye or YOY Yellow Perch: This sampling is done primarily to obtain comparable CPUEs. Sampling has typically been done between late June and late July. This sampling could be done in conjunction with general nearshore fish community sampling using the same gear.

TQU (0.25-in-mesh trap nets) targeting YOY Smallmouth or YOY Largemouth Bass: The purpose of this sampling is to obtain mean pre-winter lengths for YOY bass. Sampling may be done as a substitute for fall daytime electrofishing targeting YOY of the same species. It should be done in September or October. This sampling may also target Yellow Perch (all ages) and Bluegill (all ages).

EW (boom electrofishing) targeting YOY and age-1 Walleye: This is representative sampling for estimating relative abundance and size structure of age-0 and age-1 Walleye. Sampling gear will be pulsed-DC boom electrofishing conducted along lakeshores at night between sunset and sunrise from late August to early October in most lakes. This sampling targets walleye < 15 in. Refer to ''Fall electrofishing for YOY or age-1 walleye'' for full instructions on how to do this sampling, and for a complete list of references (*Link to Fall Electrofishing for YOY or Age-1 Walleye*).

EW (boom electrofishing) targeting YOY Walleye for determining the need for stocking of advanced-stage Walleye: This non-representative sampling is done primarily to determine need for stocking of advanced-stage (fingerling or yearling) Walleye in fall or following spring. Sampling gear will be pulsed-DC boom electrofishing conducted along lakeshores at night between sunset and sunrise from late August to early October in most lakes. This sampling targets age-0 Walleye (total lengths usually < 12 in). Refer to ''Fall electrofishing for YOY walleye to determine stocking needs'' for full instructions on how to do this sampling, and for a complete list of references (*Link to Fall Electrofishing for YOY Walleye to Determine Stocking Needs*).

EF (boom electrofishing) targeting YOY Smallmouth or YOY Largemouth Bass: The purpose of this sampling is to obtain mean pre-winter lengths for YOY fish. Sampling is done during the day in September or October. This sampling may also target Yellow Perch (all ages) and Bluegill (all ages). Sampling procedures would be the same as those developed for fall EW sampling.

SE (50-ft, 0.25-in-mesh bag seine) targeting YOY of certain species: Some Areas have a history of assessing natural reproduction of one or more fish species using seine hauls made at a standard times and locations. The purpose has been documenting reproduction (yes or no), obtaining a CPUE for YOY fish, and obtaining a mean length of YOY fish. The latter two measures may provide an indication of future year class strength. The value of these data must be determined on a case-by-case basis.

TR (trawling) targeting YOY, age-1, and age-2 fish of certain species: This is the balloon trawl described in the Large Lake Sampling Guide (Special Publication 140). In Large Lakes it has primarily been used to sample young Walleye and Yellow Perch to obtain CPUEs (fish/hour) and mean lengths at capture by age class for YOY, age-1, and age-2 fish, as a supplement to large lake seining.

Fall Surveys Targeting Bluegill, Black Crappie or Yellow Perch of All Ages

The purpose of this sampling is to estimate relative abundance and size structure of the target species, or to better determine their length and age at maturity. Sampling is done in the fall to avoid biases associated with summer sampling, and, if age or length at maturity are sampling objectives, to allow gonads to mature enough for reliable sex and maturity determinations. Sampling should be done in September through mid-October (water temperature range 55 to 70 ^{o}F, or 13 to 21 ^{o}C). . Sampling should be done using trap nets (TN) or day time electrofishing (EF). Small-mesh trap nets (TQU; 0.25-in mesh) may be used for sampling Yellow Perch if EF is impractical or ineffective and if all fish large enough to be vulnerable to TN gear are mature. Once sampling stations have been established, they should be repeated in subsequent assessments, whenever possible. Identify YOY fish, and measure 25-50 fish (all ages) from each sampling station. Scale samples and otoliths should be collected, and sex and maturity should be determined, for at least 10 fish in each 10-mm size category.

TN targeting crappie: This sampling is done to estimate relative abundance and size structure of crappies. To meet this objective, standard trap netting must be done in fall about when aquatic plants begin their senescence. Unlike June or July assessments, fall trap netting appears to provide useful data on relative abundance of larger Black Crappies. Refer to ''Fall TN targeting black crappie'' for full instructions on how to do this sampling, and for a complete list of references (*Link to Fall TN Targeting Black Crappie*).

TN targeting Bluegill: This sampling is done to estimate relative abundance and size structure of Bluegill. This sampling could be done in conjunction with fall sampling using TN gear to target crappie. Refer to ''Fall TN targeting bluegill'' for full instructions on how to do fall Bluegill sampling, and for a complete list of references (*Link to Fall TN Targeting Bluegill*).

TQU (0.25-in-mesh trap nets) targeting Yellow Perch: The purpose of this sampling is to obtain a mixed-age sample of Yellow Perch to be used to determine mean length and age at maturity. Yellow Perch can mature at very early ages and at very small sizes; samples collected using standard 0.75-in-mesh trap nets (TN) may not include any immature perch. The same gear and timing may be used to sample YOY Largemouth and Smallmouth Bass (see Surveys Targeting YOY and Age-1 Fish). We do not know whether CPUE or size-distribution data obtained in this type of survey reflect true abundance or size distribution for the population, so results must be interpreted cautiously.

EF targeting crappie, Bluegill, or Yellow Perch: Sampling gear will be pulsed-DC boom electrofishing conducted along lakeshores during the day between sunrise and sunset. Refer to ''Day electrofishing for black bass'' for general instructions on sampling station selection for this type of sampling (*Link to Day Electrofishing for Black Bass*).

Spring Surveys Targeting Pre-Spawn Panfish

This is targeted sampling, intended to yield an index of abundance (CPUE; for in-lake or within-area comparisons only), size and age distributions, and sometimes growth rate data, for panfish populations. Timing for the most effective (least biased) sampling may vary by target species; the intent is to sample fish before they commence spawning activity that might bias catch results. Timing of these surveys may vary from year to year, depending on water temperature. Minimum data collection requirements for spring sampling targeting bluegill or crappie are:

1) measure 25-50 Bluegill or crappie per station (individual weights not required), and count unmeasured fish (bulk weights of unmeasured fish are not required). Never bulk-weigh measured fish.

2) collect non-lethal calcified structures (scales or dorsal spines) for age and growth analysis from 5-10 fish from each 10-mm length category under 300 mm, and from 10 or more fish in each 25-mm length category over 300 mm. Sample a range of lengths within each length category. If required by the lake management plan or relevant study plans, sacrifice these fish to collect otoliths and to determine sex and maturity.

Several gears can be used in spring surveys targeting pre-spawn panfish:

TN targeting crappie or Bluegill: The objective of this sampling is to estimate relative abundance and size structure of crappies or Bluegill. Standard trap netting must be done in spring relatively soon after ice out but before crappies or Bluegill begin spawning (water temperatures range from 50 to 60 ^{o}F, or 10 to 16 ^{o}C). Unlike June or July assessments, spring trap netting appears to provide useful data on relative abundance of larger Black Crappie. Sampling at this time should reduce biases on size structure linked with spawning. For further information on this type of sampling, and for more detailed instructions, refer to ''Spring TN targeting crappie'' or ''Spring TN targeting bluegill'' (*Links to Spring TN Targeting Black Crappie and Spring TN Targeting Bluegill*).

EF targeting crappies: Spring electrofishing of crappies should be conducted at night and begin when water temperatures reach 57 ^{o}F (14 ^{o}C), and should be completed before water temperatures exceed 70 ^{o}F (21 ^{o}C).

EF gear targeting Bluegill: Spring electrofishing of Bluegill should begin when water temperatures reach 50 °F (10 °C), and should be completed before water temperatures exceed 68 °F (20 °C). Similar to bass, catchability of sunfish varies between day and night and catches should be treated separately.

Figure 5. A spring survey targeting Muskellunge.

Spring Surveys Targeting Spring-Spawning Species

This is targeted sampling, intended to yield size and age distributions, and (in some cases) relative abundance and growth rate data, for the adult population of the targeted species. This sampling allows a fisheries manager to capture adult fish of the target species in greater numbers, and with lower mortality, than might be possible during standard GN and TN sampling. Since these sampling techniques are non-lethal, fish can be marked or tagged for mark-recapture or depletion estimates of adult population size. Timing for the most effective (or least biased) sampling may vary by target species; the intent is to sample fish while they are congregated on, or moving actively in search of, spawning habitat. Timing of these surveys may vary from year to year, depending on ice conditions or water temperature. Minimum data collection requirements for spring sampling targeting spring-spawning species are:

1) measure 25-50 fish of the target species per station (individual weights not required), and count unmeasured fish (bulk weights of unmeasured fish are not required). Never bulk-weigh measured fish.

2) if age or growth data are required (specified in the lake management plan), collect non-lethal calcified structures from the target species (scales, fin rays, or dorsal spines) for age and growth analysis from 5-10 fish from each 10-mm length category under 300 mm, and from 10 or more fish in each 25-mm length category over 300 mm. Sample a range of lengths within each length category.

3) if required by the lake management plan or relevant study plans, sacrifice some or all of the fish from which calcified structures have been collected to confirm sex and maturity.

Several gears can be used in spring surveys targeting spring-spawning species:

TN, T1, or LTN targeting Northern Pike: Spring trap netting of Northern Pike should begin as ice is going out, as soon as nets can be set. Netting should be discontinued when water temperatures reach 55 °F (13 °C). Trap net sets may be fished multiple days at the same location, but should be lifted each day.

TN or T1 targeting White Sucker: Spring trap netting of White Sucker should begin when water temperatures reach 45 °F (7 °C), and can be continued until water temperatures reach 60 °F (16 °C). Trap net sets may be fished multiple days at the same location, but should be lifted each day.

EF targeting adult Walleye: Objectives of this sampling are to estimate relative abundance and size structure of Walleye ≥ 254 mm (10 in), estimate size-structure of Walleye ≥ 254 mm, or capture Walleye ≥ 254 mm for marking/recapture in population estimates. Sampling gear will be pulsed-DC boom electrofishing conducted along lakeshores at night between sunset and sunrise soon after ice out. Refer to, refer to ''Spring night electrofishing for walleye'' for complete instructions for this type of sampling (*Link to Spring Night Electrofishing for Walleye*).

LTN targeting Muskellunge: Guidelines for Muskellunge sampling were produced by the Muskellunge Technical Committee (MTC) in 2017. Any area managing Muskellunge populations should follow those guidelines when setting up a survey or evaluation program in management plans for Muskellunge waters. Full text of the guidelines can be found in: (*Link to Muskie Sampling Guidelines*). The following is a brief summary.

The MTC described LTN as the primary gear for sampling Muskellunge. Muskellunge population assessments are intended to provide a mark-recapture population estimate and a representative size distribution of the mature adult population. The goal for this sampling is to catch, measure, and mark as many Muskellunge as possible. CPUE from this gear is not a good indicator of relative abundance and should not be used to characterize abundance. Set locations should be standardized and replicated in subsequent assessments, although two or more years of sampling may be required to identify a list of standard sites. Individual net lifts (number of 24 hour sets) may vary between assessments based on the progression of spawning. In a normal spring nets should be set 7-10 days after ice-out; sets may be made sooner in a late spring. Scheduling needs to be fluid, based on current water temperature and weather forecast. Approximate timing is when surface temperature reaches 46 °F (8 °C) and continued warming is predicted; however, optimal timing can vary depending on the strain present. Lengths should be measured for all Muskellunge. Weights (to the nearest 100 g) should be measured for all fish captured for the first time (not needed for recaptured fish). Sex, maturity, and state of ripeness should also be determined (by external observation; see guidelines) for each fish. All fish should be marked to allow identification of recaptured fish during initial sampling, and for population estimates. See the full sampling guidelines for recommendations for additional sampling needed for population estimates. Options include electrofishing (SEF), angling (AOW or TOU), LTN sampling in following years, and Schnabel estimates based on same-year LTN daily catches.

Night EF targeting Largemouth or Smallmouth Bass: Although this type of electrofishing is part of a standard survey, it may also be done as a stand-alone targeted survey. This sampling is used to address two basic objectives: to determine the size structure of population, and to determine the relative abundance of bass (CPUE). Refer to ''Night electrofishing for black bass.doc'' (*Link to Night Electrofishing for Black Bass*) for detailed instructions on how to conduct this sampling in a representative way that can yield valid CPUE and size distribution data. Walleye may also be targeted during this type of sampling; for more information on targeting Walleye while conducting night electrofishing for bass refer to ''Spring night electrofishing for walleye'', and look for the section titled ''Sampling walleye while electrofishing bass'' (*Link to Spring Night Electrofishing for Walleye*).

Daytime EF targeting Largemouth or Smallmouth bass: The objective for this sampling is to estimate size structure of Smallmouth Bass or Largemouth Bass. Sampling gear will be pulsed-DC boom electrofishing conducted along lakeshores during the day between sunrise and sunset when black basses spawn. Refer to ''Day electrofishing for black bass'' for detailed instructions on how to perform this type of sampling (*Link to Day Electrofishing for Black Bass*).

Night EF targeting crappie (or sampling crappie while doing night EF targeting bass): The objective of this sampling is to estimate relative abundance and size-structure of crappies. Sampling gear will be pulsed-DC boom electrofishing done in spring, at night, and when water temperatures range from 57 to 77 °F (14 to 25 °C). This sampling is usually done concurrently with black bass electrofishing. Refer to ''Night electrofishing for crappie'' and ''Night electrofishing for black bass'' for detailed instructions on how to conduct this type of sampling (*Links to Night Electrofishing for Crappie and Night Electrofishing for Black Bass*).

AOW targeting bass: Bass on nests can be very vulnerable to angling. The most common use of AOW will be determining the size and age structure of the targeted population. Use of AOW may provide some insight into the sizes and ages of fish available to anglers, without the cost of a full creel survey. May be used to sample fish non-lethally for studies requiring marking or tagging fish, or as an alternate gear for recapturing tagged or marked fish. Comparable CPUEs are not a realistic goal for this sampling.

SA targeting spawning Walleye or White Sucker: Traps on major spawning sites collect adult fish for egg production. Data collected from fish taken can be used to determine size and age distributions for the spawning population. Fish taken at SA sites may also be marked for mark-recapture population estimates. CPUE for SA gear should be used with great caution, even for within-site comparisons, because the length and intensity of the fish run will be determined by water temperature and photoperiod, while effort may be determined by State-wide production needs. To obtain length data that are representative of the run, all the fish, or a sub-sample of fish (25 – 50), of each sex should be measured each day that the net is deployed. To obtain age-distribution data, a sub-sample should be selected for bony structure collections from each sex. Sub-samples may include 10–20 fish per sex per day, or may be based on standard 25-mm length bins for each sex. The method of sub-sampling lengths and aging structure should be determined by length of run and the purpose of your sampling.

General Coldwater Fish Community Sampling

This sampling is intended to provide information on the composition of the coldwater fish community (no target species would be listed), and to provide more detailed information on the population characteristics of some of the species comprising that community. Fish species comprising the coldwater fish community sampled may include Lake Trout, other trout species, Burbot, Cisco, Lake Whitefish, or Rainbow Smelt. The following gears may be used for this sampling.

GN (standard graduated-mesh experimental gill nets): In a lake that supports a coldwater fish community, or where such a community may exist, some GN sets, or portions of some GN sets, may be placed at depths where water temperatures and dissolved oxygen levels are suitable for the coldwater fish in question. If Cisco or Lake Whitefish are present or suspected, waters colder than 18 ^{o}C (65 ^{o}F) should be sampled. If Lake Trout may be present, waters colder than 12 ^{o}C (54 ^{o}F) should be sampled. Avoid setting nets in waters with less than 3 ppm dissolved oxygen. GN may be used to sample the coldwater fish community in lakes where the use of depth-stratified sampling (using GDE and GSH sets) has not been a standard practice, or where lake contours and temperature-oxygen profiles typically make it very difficult to set nets entirely within depth ranges capable of supporting coldwater fish, or where surveys are typically done when the lake is not thermally stratified. Once some sampling of coldwater habitats has been established, subsequent surveys should employ similar levels of effort (number of sets, or amount of net) dedicated to sampling those habitats. It may be necessary to vary net depths and locations slightly from year to year, based on current water temperature-dissolved oxygen conditions, to maintain a similar mix of warmwater and coldwater sampling. Minimum data collection requirements for this sampling are the same as those discussed elsewhere in this manual for standard surveys using GN gear.

GDE (standard graduated-mesh experimental gill nets, set on the bottom in waters colder than 12 ^{o}C): GDE sets are typically used in conjunction with GSH sets, as part of a temperature-stratified standard survey; however, GDE sets may be used alone to sample just the coldwater fish community in a targeted survey. GDE sets are typically used when the lake is thermally stratified (mid June through mid September). GDE sets should be made in waters cooler than 12 ^{o}C (54 ^{o}F), with dissolved oxygen over 3 ppm. It may be necessary to vary net depths and locations slightly from year to year, based on current temperature-oxygen conditions. Minimum data collection requirements for this sampling are the same as those discussed elsewhere in this manual for standard surveys using GN gear.

FCI (Fish Community Index Nets: Fish community index netting (FCIN) was the standard coldwater fish community sampling method developed and used on Lake Nipigon in Ontario, Canada. This gear was adopted for use in evaluating the 2000 water level regulation changes for operators of the dams on Rainy Lake and the Namakan Reservoir system; specifically to provide information on Lake Whitefish and Cisco populations. Other species vulnerable to and commonly taken in the gear include Burbot, Walleye, Northern Pike, and Rainbow Smelt. Netting should be carried out in July or August when the lake is thermally stratified. Nets should be set along a flat or gradual slope and not within 100 meters of shoreline or exposed shoals. Net orientation is selected randomly and sampling location usually follows a stratified, random design. Sampling location is stratified by sector (area) and depth (depending on lake size and depth ranges).

Surveys Targeting Coldwater Fish Species

This targeted sampling is intended to provide specific information on one or more coldwater fish species that may not be adequately sampled during a standard survey. Coldwater species typically targeted include Cisco, Lake Whitefish, sculpins, Rainbow Smelt, Lake Trout, Rainbow, Brook, or Brown Trout, Splake, or Burbot. The following gears may be used for this sampling.

GDE (standard graduated-mesh experimental gill nets, set in waters colder than 12 °C): Since GDE sets are defined as bottom sets made in waters cooler than 12 °C (54 °F), they are typically used to target Lake Trout. Use of GDE nets is considered targeted sampling if they are not being used with GSH sets as part of a depth-stratified standard survey. Other coldwater species that can be targeted using GDE include Cisco, Lake Whitefish, and Burbot. GDE sets are used when the lake is thermally stratified (mid June through mid September). GDE sets should be made in waters cooler than 12 °C, with dissolved oxygen over 3 ppm.

GSM (small-mesh gill nets): GSM sets are typically used to target smaller coldwater fishes. Originally designed and employed to sample Rainbow Smelt, they have also effectively sampled dwarf (or juvenile) Cisco, sculpin, and juvenile Lake Whitefish. They do not appear to sample juvenile Lake Trout effectively, although some will occasionally be caught. To sample smelt and other coldwater fishes, GSM sets should be made in waters colder than 18 °C (65 °F), with dissolved oxygen exceeding 3 ppm. Minimum data collection requirements for this sampling are the same as those discussed elsewhere in this manual for standard surveys using GN gear. GSM nets use two mesh sizes (0.375-in and 0.5-in bar), and catch should be recorded by mesh size. Any sub-sampling required should also be done by mesh size.

GSU (gill nets suspended off the bottom): GSU sets are used to sample fish suspended in the water column, and can be used to effectively sample pelagic coldwater species, including Cisco or Rainbow Trout. The type of net used should be documented in the survey report. Suspended sets may be more effective than bottom sets when coldwater habitat is limited to a very narrow range of depths. When used to sample coldwater fish species, they should be set in waters colder than 18 °C (65 °F), with dissolved oxygen exceeding 3 ppm. To meet those criteria, it may be necessary to vary net depths and locations from year to year, based on current water temperature-dissolved oxygen conditions. If no particular species has been targeted, minimum data collection requirements for this gear would be the same as those discussed elsewhere in this manual for standard surveys using GN gear. If a target species has been designated, required data collection will be detailed in the lake management plan, and should be described in a narrative attached to the survey report.

VGN (vertical gill nets): VGN sets are best used to sample fish suspended in the water column and can be used to effectively sample pelagic coldwater species. They can be used to identify depths occupied by various species and sizes of fish, and to relate that information to water temperature-dissolved oxygen profiles or hydroacoustic data. Minimum data collection requirements for this gear would be the same as those discussed elsewhere in this manual for standard surveys using GN gear. In addition, the depth at which each fish was taken should be recorded. If a target species has been designated, data collection requirements will be detailed in the lake management or study plan, and should be described in a narrative attached to the survey report. See ''Vertical Gill Netting Description and Protocol'' for more detail on VGN sampling (*Link to Vertical Gill Netting Description and Protocol*).

Spring or Fall GST (short-term monofilament gill net sets): Species that could be targeted by this gear include Lake Trout, Cisco, and Lake Whitefish. Standards for this sampling are not well established within DNR Fisheries. One of the benefits of this sampling is minimized mortality of high-value fish. Since mortality is usually low, GST sampling can be used to capture fish for marking or tagging studies. Monofilament-mesh gill nets with a variety of mesh sizes would typically be used. Nets are set, then lifted after a fairly short time period (30 minutes to two hours). Nets used and the timing and duration of sets must be described in a narrative attached to the survey report. GST sampling has typically been done in the spring or fall, when surface water temperatures are low enough to be tolerable for coldwater fish. If no particular species has been targeted, minimum data collection requirements for this gear would be the same as those discussed elsewhere in this manual for standard surveys using GN gear. If a target species has been designated, minimum data collection includes daily surface water temperatures, depths of sets, set and lift times, measured lengths for all fish of the target species, and counts of non-target species caught. All catch data should be recorded by mesh size. Additional data collection requirements should be detailed in the lake management plan.

Late-fall GN (standard graduated-mesh experimental gill nets) targeting spawning Cisco: Timing may vary from year to year due variations in water temperature. Nets are set overnight at standard historically chosen stations located in water depths of 5-7 ft along bars, points, or shoal areas with predominantly boulder/rubble substrates where cisco have historically spawned. This type of sampling can be used for determining the Cisco netting opener date for lakes, obtaining male/female age and growth information, length frequency data, condition factors and historical comparisons of relative abundance of spawning Cisco for a particular lake. The advantage of using the standard lake survey net is that all sizes of spawning Cisco can potentially be sampled. Disadvantages of this sampling technique are the catch biases that can be caused by the size-selectivity of the various mesh sizes used in GN nets, and variations in catch caused by water temperature differences and differences in spawning activity from year to year.

MT (minnow traps): Wire or plastic minnow traps can be used to target sculpins in deep water (Schmidt 2013). Results are limited to determining the presence of a given species, since we do not have a history of this type of sampling to allow us to use CPUE as an index of abundance, and we do not know to what extent size distributions of the catch may be biased. Glow sticks can be placed in the trap to attract fish, or traps may be baited with dog food or other slowly-dissolving baits. Minnow traps can be attached to anchor lines at either end of deep gill net sets (GN, GDE, GSM, or VGN), or be set on their own. Methods for setting the traps, trap construction and dimensions, and baits or other attractants used, should be described in a narrative attached to the survey report. Minimum data required are counts of fish by species in each set.

Spring or Fall TN (double-frame 0.75-in-mesh standard lake survey trap nets): TN may be used to target stream trout in lakes when surface water temperatures are at or below 21 ^{o}C (70 ^{o}F). Even cooler water temperatures may be desirable to maximize survival of fish. Catch data may provide an index of abundance (CPUE), age and size distributions, and growth rate data. Most surveys using TN gear to target stream trout would be done in May, early June, late September, or October. Fish stocked the preceding fall may not be fully vulnerable to TN sets in an early spring assessment. Catches in fall assessments can be affected by the timing of fall stocking, and by heavy harvest of spring-stocked fish over the preceding summer. If no target species are listed for this sampling, minimum data requirements are the same as those listed elsewhere in this manual for standard trap nets (TN). If a target species has been listed, data requirements should be found in the lake management plan, and should be described in a narrative attached to the survey report.

Spring or Fall sampling with other trap net gears (T38, THA, T1, T34): Other trap net gears may be used to target stream trout in lakes when surface water temperatures are at or below 21 °C (70 °F). Even cooler water temperatures may be desirable to maximize survival of fish. Catch data may provide an index of abundance (CPUE; for in-lake or within-area comparisons only), age and size distributions, and growth rate data. Most surveys using trap net gears to target stream trout would be done in May, early June, late September, or October. Some of the problems associated with full recruitment of fall-stocked trout to TN nets used in surveys done the following spring can be avoided by the use of smaller-mesh trap nets in the spring; however, catches in smaller mesh nets in the fall are more likely to be affected by the timing of fall stocking. If no target species is listed for this sampling, minimum data requirements are the same as those listed elsewhere in this manual for standard trap nets (TN). If a target species has been listed, data requirements should be found in the lake management plan, and should be described in a narrative attached to the survey report.

Angling (AOW or AIF): Angling in the spring, fall, or winter can be used as a means of non-lethally sampling Lake Trout and stream trout in lakes. Angling can be used to determine whether any fish from stocked year classes are present. It may provide an indication of sizes of fish available to anglers, without the expense of a creel survey. Angling can be used to capture fish for marking, or as an alternative means of recapturing fish, in mark-recapture population estimates. Angling, at the level of effort typically possible for DNR Fisheries crews, will not yield useful CPUE values.

Spring Surveys Assessing Winterkill

Winterkills often occur in lakes where high biological oxygen (BOD) demand during winter months results in decreasing dissolved oxygen (DO) available to aquatic life as a result of prolonged ice and snow cover that reduces or eliminates photosynthesis within the lake. Some Minnesota lakes have aeration systems that can at times reduce the occurrence of winterkill by creating openings in areas of the ice to have wave action oxygenate surface water. However, in harsh winters aeration systems can be insufficient to eliminate all winterkill. The severity of the winterkill can be unpredictable, with species affected and reductions in their abundances variable. Occasionally, winterkills can be partial (individuals or size groups of some species eliminated), moderate (some species entirely eliminated), or complete (all species eliminated) depending on conditions found in the lake at the time of the kill.

Winterkill sampling is a targeted survey which should be conducted when a winterkill is suspected. Areas should have a protocol for inspecting susceptible winterkill lakes through the winter months with periodic dissolved oxygen readings done during ice cover. At a minimum, DO should be sampled at two or more locations on the lake every 3 to 4 weeks to document changes in DO during ice cover. Additional observations should be noted if a winterkill is suspected based on winter DO including collecting additional water quality parameters (such as pH, CO_2, alkalinity, etc.) and noting physical observations (smell of sulfur, dead organisms) during ice cover or during ice off.

After ice-out, the lake should be observed to determine the extent of the kill by estimating the number of dead fish per 100 feet of shoreline and species composition by percentage along shorelines and among fish observed floating. Transects based on prevailing conditions (wind, decomposition state of fish, etc.) can be conducted to count the number of floating fish and the species composition if needed. Based on initial observations, a targeted survey with the appropriate gear selectivity can be proposed to effectively sample all species. Goals for the targeted survey are determining which fish species remain, and whether adequate broodstocks have survived. Sampling should be done at or immediately following ice-out. Sampling locations should be areas where fish have been known to concentrate during ice-out, although sampling a range of habitats could help maximize the number of species observed. Lengths should be measured for a representative sample of each species taken, following guidelines given in this manual for standard surveys. Lengths of fish sampled can be used to determine whether enough healthy broodstock-sized fish remain, or if stocking will be required restore some populations. A complete protocol for examining suspected winterkill lakes can be found in: (*Link to Winterkill Sampling Protocol*). Recommended sampling gears include:

TN or T34: used to sample nearshore species like Northern Pike and White Sucker, but may not effectively sample Walleye or Yellow Perch, or other fish species that remain off shore. Recommended sampling effort is five sets for lakes under 600 acres and seven sets for 600-1500 acre lakes. For larger lakes a full standard survey should be considered.

T38 or TQU: Used to sample smaller non-game species, or for greater catchability of the species of interest. A minimum of two sets should be made (in addition to the trap nets described above).

GN: standard graduated-mesh gill nets may be used to sample off-shore species. Their use is optional, and only one or two sets (depending on lake size) may be needed.

EF: boom electrofishing gear (used day or night) may be a good alternative to netting to determine presence of certain species, and to gather a sample for measurements, in a fairly short time. Electrofishing may capture a wider range of species than either trap or gill netting alone. For lakes under 600 acres 30 minutes of effort may be enough. For larger lakes 60 minutes is recommended. For lakes over 1500 acres a full standard survey should be considered.

Other Targeted Sampling

Many other types of targeted sampling may be done, either as separate targeted surveys, or as components added to a standard survey. The following methods have been described for this manual, but this is not meant as a complete list of possibilities.

GNP targeting Northern Pike: This is targeted sampling to characterize the relative abundance and size and age distributions of Northern Pike, and to collect samples for age and growth analysis. Mesh size of GNP gear limits its effectiveness for sampling pike less than 18 inches, which may render the tool ineffective in lakes dominated by small, slow growing pike. GNP nets may be set in conjunction with the standard survey, or at another time. In lakes that stratify, GNP nets should be set when water temperatures are less than 21 °C (70 °F) and pike are active in the littoral zone. Once established, sampling dates should be replicated whenever possible. Where set locations have been established, they should be repeated in subsequent surveys whenever possible. If establishing new sampling stations, select a variety of littoral habitats, with most nets in or close to vegetated areas. Other applications of the gear are possible, including targeting larger Walleye, cisco, or other species.

Minimum data collection requirements for GNP include:

1) Record catch by mesh size (measured fish and fish counts)
2) Count all panfish and non-game fish taken in each mesh size, and record as unmeasured fish.
3) Collect scales and cliethra from all Northern Pike.
4) Determine sex and maturity for all Northern Pike.
5) More detailed or intensive data collection for species other than Northern Pike may be done as recommended in the lake management plan.

TOU (tournament angling): It is expected that the sampling of tournament-caught fish will be done or supervised by Fisheries staff. Angling is done under open-water or ice conditions. Comparable CPUEs are not a realistic goal for this sampling. The most common use will be determining the size and age structure of the targeted population. Use of TOU may provide some insight into the sizes and ages of fish available to anglers, without the cost of a full creel survey. Tournament caught fish will likely be biased towards the largest fish available. TOU may be used to sample fish non-lethally for studies requiring marking or tagging fish, or as an alternate gear for recapturing tagged or marked fish.

DTN (double-pot trap nets): May provide an effective non-lethal means of sampling off-shore fishes in lakes too shallow to effectively gill net, or in shallow mid-lake habitats (reefs or flats). DTN is likely to target the same species (and suffer the same biases) as TN gear.

VGN (vertical gill nets) targeting warm or coolwater fish species: VGN sets can be used to effectively sample pelagic species. Warmwater fish are usually captured above the thermocline, coolwater fish near the thermocline, and coldwater fish below the thermocline. Since VGN nets have smaller mesh sizes than standard gill nets, they also provide information on smaller fish. Small Yellow Perch appear to make extensive use of the pelagic zone of lakes (usually just above the thermocline) and VGN might be a useful gear for assessing that species at ages and sizes not typically seen in standard GN or TN nets. VGN nets can be used to identify depths occupied by various species and sizes of fish, and to relate that information to temperature-oxygen profile or hydroacoustic data. Minimum data collection requirements for this gear would be the same as those discussed elsewhere in this manual for standard surveys using GN gear. In addition, the depth at which each fish was taken should be recorded. If a target species has been designated, data collection requirements will be detailed in the lake management or study plan, and should be described in a narrative attached to the survey report.

GST (short-term monofilament gill net sets) targeting Walleye or Northern Pike: Standards for this sampling are not well established within DNR Fisheries. One of the benefits of this sampling is minimized mortality of high-value fish. Since mortality is usually low, GST sampling can be used to capture fish for marking or tagging studies. Monofilament-mesh gill nets with a variety of mesh sizes would typically be used. Nets are set, then lifted after a fairly short time period (30 minutes to two hours). Nets used and the timing and duration of sets must be described in a narrative attached to the survey report. GST sampling targeting Walleye or Northern Pike would typically be done in the spring or fall, when surface water temperatures are cool enough to help minimize mortality. Using GST in the spring may be a useful means of recapturing fish marked during spring EF targeting adult Walleye, or Northern Pike marked during ice-out trap netting.

Fish Sampling Gear Descriptions and Usage

General Recommendations for Setting Gill Nets and Trap Nets

Unless otherwise indicated for a specific gear or sampling method, follow these general recommendations when setting gill nets and trap nets of all types:

Standard Gill Net Set: The net is set on the bottom, with brails and anchors at each end of the net to hold it taut and open (Figure 6). A rope harness with some added flotation at the top may be substituted for a brail. A standard set is overnight, about 24 hours in duration. Where set locations have been established, they should be repeated in subsequent surveys whenever possible. If establishing new sampling stations, select a variety of habitats, and alternate the orientation of mesh sizes with respect to the shoreline. Where possible, nets should be set perpendicular to shore. Where possible, avoid sets in waters shallower than nine feet to avoid encounters with outboard motors. Prior to setting gill nets, complete a temperature-oxygen profile. Nets should not be set in anoxic waters, and established locations may be changed as needed to avoid anoxic waters.

Gill Net Brails or Harnesses: Use of brails or harnesses has varied across the state. Brails used for gill nets have ranged from three to six feet in length, and their construction has varied from area to area. Some areas, in some situations at least, have used no brails, and have instead relied on rope harnesses to keep their nets taut and extended. The following are offered as suggestions, and are not intended to imply that any method now in use is wrong and must be changed. Rather than an eyebolt set at some point in the brail, the brail should be attached to the anchor line by a bridle consisting of two lines, one from the top and one from the bottom, with the brail and the bottom line at right angles, and the line to the top of the brail forming the hypotenuse of a right triangle. Brails and harnesses should be made so that most of the force on the net during the process of setting runs through the lead line. Otherwise, tension may tend to pull the float line towards the bottom and keep it there when the net is fishing. A small extra float near the top of the brail, or where the harness meets the net, will help keep the brail from toppling or the harness from collapsing.

Gill Net Setting Technique Notes: In shallow water (under 20 ft), anchors may be tied to, or close to, the brails. Pay nets out of the boat slowly, maintaining some tension in the net to ensure a taut set. In deeper water, the anchor at the start of the net (the first end to enter the water) should be tied a distance away from the brail equal to or greater than the water depth, so that the anchor hits bottom before the net begins to pay out. Otherwise the net may twist as it is lowered. Braided, rather than twisted, line is preferred for deep sets (also to avoid twisting). In deep waters the net must be payed out very slowly, and be kept under constant tension, to avoid having it settle in an arc. In deep sets the anchor on the end of the net can be tied to or close to the brail, but must also be lowered slowly, as the boat backs away, maintaining tension until the anchor hits the bottom. For a deep gill net set, ropes measuring a minimum of three times the water depth will be required (first buoy to first anchor, first anchor to first brail, last brail and anchor to last buoy.

Standard Trap Net Set: The lead is tied to shore, or (if that is not possible) anchored at the edge of heavy vegetation, and the net is set back perpendicular to shore. The net should be set in water deep enough to submerge both throats. If possible the net should be set with the frame at depths of 8 ft or less. The net may be set at an angle, or the lead may be shortened, if necessary to avoid a sharp drop-off that might collapse the lead or cause the frame to tip. A standard set is overnight, about 24 hours in duration.

General Recommendations for Seining

Unless otherwise indicated for a specific gear or sampling method, follow these general recommendations and use one of these methods when doing any type of seining:

Parallel - At the beginning of the station the seine is extended into the lake on a line perpendicular to the shore. It is then hauled along the shore, on a line parallel to the shore (Figure 7). At the end of the station, the outer end of the seine is swept in an arc toward the shoreline, and the seine is pulled up to the shoreline and lifted out of the water.

Perpendicular - Both ends of the seine are carried into the lake an equal distance (50 to 100 ft out from shore, if possible). The seine is stretched parallel to shore, facing the shoreline, and is hauled back to the shore. This method may be used when vegetation, rocks, or other obstructions limit the use of the parallel method.

Fixed Pole - one end of the seine is fixed in place on shore. The other is either walked down the shore or out perpendicular to the shore until the seine is fully extended. The seine is then swept in an arc (180 or 90 degrees) around the fixed end. This method may be used when only a small area can be seined.

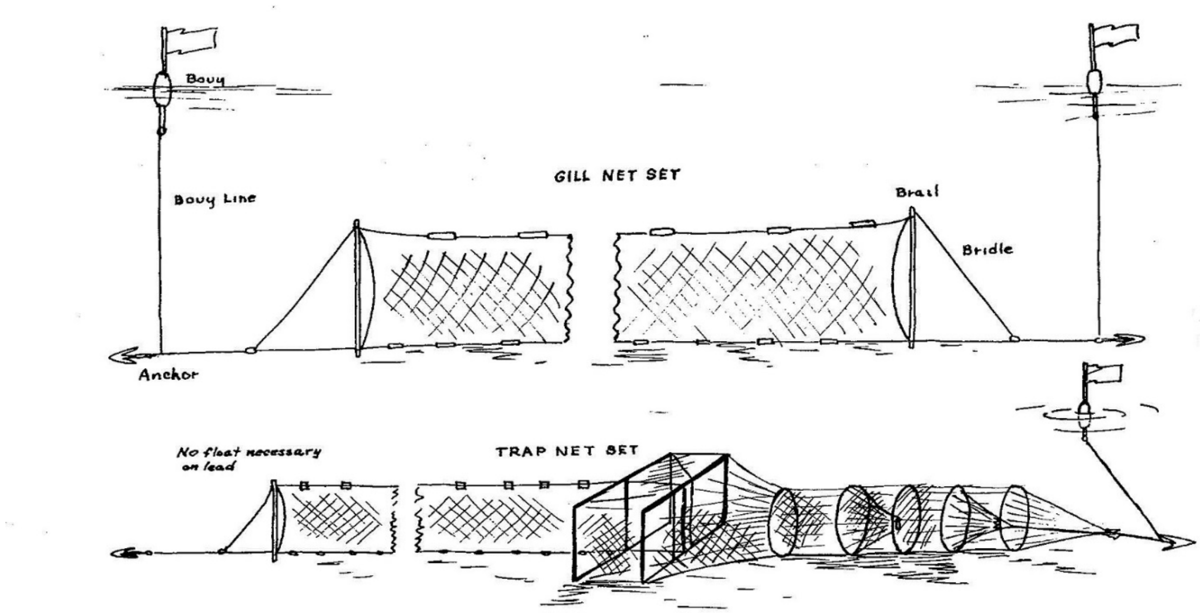

Figure 6. Diagram of typical gill net and trap net sets (Scidmore 1970).

Figure 7. Example of a parallel seine haul.

GN - Standard Graduated-Mesh Lake Survey Gill Nets

Gear description: Gill nets, 250 ft long by 6 ft deep. Constructed of five 50-ft-long panels of white multifilament knotted-nylon mesh, with mesh sizes ordered from small to large. Mesh sizes used are 0.75-in, 1.0-in, 1.25-in, 1.5-in, and 2.0-in (all bar measure). Nets are constructed using #104 nylon twine for all mesh sizes. The mesh is hung on the 1/2-basis. Nets should be untreated, although treated nets (1 part net set to 4 parts solvent) may be used if there is a history of using treated nets in a given lake.

Gear uses: Standard GN sets are an integral part of almost all standard surveys. GN gear may also be used for general coldwater fish community sampling and when targeting coldwater species (including Cisco, Lake Whitefish, Burbot, and Lake Trout). GN gear has also been used in assessing winterkills.

GDE - Standard Graduated-Mesh Gill Nets, Set in Waters Colder Than 12 ºC

Gear description: GDE gill nets are identical to standard GN gill nets.

Standard set: GDE sets are typically used when the lake is thermally stratified (mid June through mid September). GDE sets should be made in waters cooler than 12 C, with dissolved oxygen over 3 ppm. It may be necessary to vary net depths and locations slightly from year to year, based on current temperature-oxygen conditions.

Gear uses: In a depth-stratified standard survey, a combination of deep (GDE) and shallow (GSH) gill net sets can replace GN sets. GDE sets may be used on their own (unaccompanied by GSH sets) in targeted surveys of the coldwater fish community. Coldwater species vulnerable to, and commonly taken in the gear, include Lake Trout, Cisco, Lake Whitefish, and Burbot.

GSH - Standard Graduated-Mesh Gill Nets, Set in Waters Warmer Than 12 ºC

Gear description: GSH gill nets are identical to standard GN gill nets.

Standard set: GSH sets are typically used when the lake is thermally stratified (mid June through mid September). GSH sets should be made in waters warmer than 12 C. It may be necessary to vary net depths and locations slightly from year to year, based on current temperature-oxygen conditions.

Gear uses: In a depth-stratified standard survey, a combination of deep (GDE) and shallow (GSH) gill net sets can replace GN sets.

GSU - Suspended Gill Nets

Gear description: Any gill net type designed for use as a bottom set can also be set as a suspended set. The type of gill net used should be described in the survey report. The FSM supports recording of the depth of the lead line in a suspended set, and the bottom depth, for each end of the net.

Standard set: Nets are suspended at a target depth by tying floats with lines of appropriate length at intervals along the float line of the net. Floats should be tied close enough together to avoid appreciable sag in the net between floats (often at every other gill net float). If brails are used at the ends of the net, they must have a neutral or slightly positive buoyancy, and remain upright when deployed. Large floats are used at each end of the net to counteract tension from anchor lines. A standard set is overnight, about 24 hours in duration. Where set locations have been established, they should be repeated in subsequent surveys whenever possible. If establishing new sampling stations, select a variety of habitats, and alternate the orientation of mesh sizes with respect to the shoreline. Where possible nets should be set perpendicular to shore. Prior to setting suspended gill nets, complete a temperature-oxygen profile.

Gear uses: GSU sets are used to sample pelagic fishes. They may also be used where anoxic conditions in the hypolimnion make it difficult to set a standard gill net on the bottom and keep it out of anoxic waters.

GSM – Small-Mesh Gill Nets

Gear description: Gill nets, 200 ft long by 6 ft deep. Constructed of two 100-ft-long panels of white multifilament knotted-nylon mesh, one panel 0.375-in (bar) and one panel 0.5-in (bar) mesh. Nets should be untreated, although treated nets (1 part net set to 4 parts solvent) may be used if there is a history of using treated nets in a given lake.

Gear uses: Small-mesh gill nets can effectively sample smaller fish in off-shore habitats, including Rainbow Smelt, dwarf or juvenile Cisco, juvenile Lake Whitefish, sculpin, and small Walleye, Yellow Perch, and Lake Trout.

GST - Short-Term Gill Net Sets

Gear description: Any gill net set for recurring short periods of time (0.5-2.0 hours) would be considered a GST net. There are no standards for construction of these nets, although mesh is usually monofilament to maximize catch. Nets may be constructed of a graduated series of mesh sizes, or several nets of different mesh sizes may be used. Details of net construction and net handling must be included in a narrative of any report for a survey using GST sets.

Standard set: There is no established standard; netting methods and the duration of sets should be described in detail in the survey report. Most often, the net is set on the bottom, with brails and anchors at each end of the net to hold it taut and open. Nets may be set for intervals of 0.5 to two hours, and are then lifted and reset, at the same location or at a new location. If using GST sets to provide an index of abundance, initial set locations should be selected randomly around the lake shore, at a variety of depths. If the sampling goal is large sample sizes, effort can be targeted at known areas of fish concentration or movement. Where set locations have been established, they should be repeated in subsequent surveys whenever possible, if sampling goals remain the same.

Setting technique notes: Catches in these nets are often low, and it usually possible to fish two or more sets at the same time by staggering set and lift times.

Gear uses: Short-term gill nets sets provide a relatively non-lethal means of sampling off-shore habitats impossible to sample effectively with electrofishing gear or trap nets. They can be used when there is a need for high survival rates among sampled fish, as might be the case when marking fish for a population estimate. Short-term gill net sets have been used to sample Lake Trout, Cisco, Lake Whitefish, Walleye, and Northern Pike.

GNP – Pike Gill Nets

Gear description: Gill nets, 300 ft long by 6 ft deep. Constructed of three 100-ft-long panels of white multifilament knotted-nylon mesh, with mesh sizes ordered from small to large. Mesh sizes used are 1.5-in, 2.0-in and 2.5-in (all bar measure). Nets are constructed using untreated #104 nylon twine, hung on the 1/2-basis.

Standard set: Nets are generally set in littoral habitats. Where set locations have been established, they should be repeated in subsequent surveys whenever possible. If establishing new sampling stations, select a variety of habitats, and alternate the orientation of mesh sizes with respect to the shoreline. Where possible, nets should be set perpendicular to shore. Where possible, avoid sets in waters shallower than nine feet to avoid encounters with outboard motors.

Gear uses: Pike gill nets were developed to sample Northern Pike in lakes where standard GN sets were heavily biased towards Walleye sampling, such as the large lakes. Since there are no small mesh panels, these nets cannot be used to replace standard GN in a standard survey. Rather, they are supplemental and targeted. While designed for sampling fast growing Northern Pike, other applications can also be imagined. The larger panels may serve to increase sample sizes of larger Walleye or other species for which selectivity has dropped off in standard GN. Nets may also be fished suspended (as GSU sets) if Cisco are listed as a targeted species, although YOY and age-1 Cisco are too small to be caught in these meshes.

GNA – Standard North American Gill Net

Gear description: The ''standard'' North American gill net is recommended by the American Fisheries Society (Standard methods for Sampling North American Freshwater Fish; Bonar and Humbert, Eds, 2009). Constructed with clear, uncoated monofilament, these sinking gill nets are 24.8 m long x 1.8 m deep with eight 3.1 m long mesh panels, one (1) each of: 19, 25, 32, 44, 51, 57 and 64 mm mesh (bar), hung on a 0.5 ratio. Mono-filament diameters are 0.28 mm for 10-32 mm mesh; 0.33 mm for 38-51 mm mesh and 0.40 mm for 57 and 64 mesh. Mesh order should be 38-57-26-44-19-64-32-51. Net shall have lead-core lead-lines and foam-core float lines. These nets are listed on the MNDNR's current (2012-2017) state gill net purchasing contract.

Standard set: Nets are set on the bottom, perpendicular to shore. In large lakes, two or three sets may be ganged together. Nets are set overnight. CPUE is calculated based on the number of sets fished, with each net in a ganged set counted separately.

Gear uses: Use of GNA gear is not currently supported by the FSM, and experience with the gear in Minnesota has been very limited. Because these are small, light-weight nets they may have some value in sampling small remote lakes where use of GN nets is not practical, or not desirable at useful levels of effort. Although we have no comparable CPUE data for Minnesota waters, Boner and Humbert (2009) do provide regional summaries for several common fish species. Until more experience with this gear has been amassed, its main value in Minnesota may be collecting adequate fish samples for length and age distributions.

FCI – Fish Community Index Nets

Gear description: Gill nets, 450 ft long by 8 ft deep, constructed of nine 50 ft-long panels of green monofilament mesh. Mesh sizes range from 0.5-in to 2.5-in bar measure and panels are in the following order: 1.0-in, 2.25-in, 0.75-in, 1.5-in, 2.5-in, 1.75-in, 0.5-in, 2.0-in, and 1.25-in mesh.

Standard set: The net is set on the bottom with a yoke system attaching the ends of the net to an anchor. Brails are not typically used with these nets. The yoke system is usually comprised of a piece of parachute cord tied to the upper and lower loops on the end of the net which come together and attach to an anchor. A rope and buoy are then attached to the anchor to mark the location of the end of the net. A standard set is overnight, about 24 hours in duration. Sampling is carried out in July or August and is usually set up with a stratified, random sampling design. Sampling is stratified by sector (area) and depth. Nets should be set along a flat or gradual slope and not within 100 meters of shoreline or exposed shoals. Net orientation is selected randomly. Before setting FCI nets, complete a temperature-oxygen profile to confirm adequate oxygen where nets are to be set.

Setting technique notes: These nets should be set in a fashion similar to standard gill nets in deep waters.

Gear uses: This is an Ontario coldwater sampling gear and method, developed for use on Lake Nipigon, but also used on some Minnesota-Ontario border waters. Species commonly taken in this gear include Lake Whitefish, Cisco, Burbot, Walleye, Northern Pike, and Rainbow Smelt.

TML – Trammel Net

Gear description: Nets are 100-ft long by 6-ft deep. They are constructed of three 100-ft-long panels of white multifilament knotted-nylon mesh, two 100X6-ft panels of 12-in bar mesh net in # 9 nylon twine with one 100X8-ft panel of 2-in bar mesh net in #104 nylon twine sandwiched between them. The mesh is hung on the 1/2-basis.

Drifted trammel nets are often fished with a set of mules (floating constructions that use the force of the current to keep the net spread as if floats downstream (Figure 8).

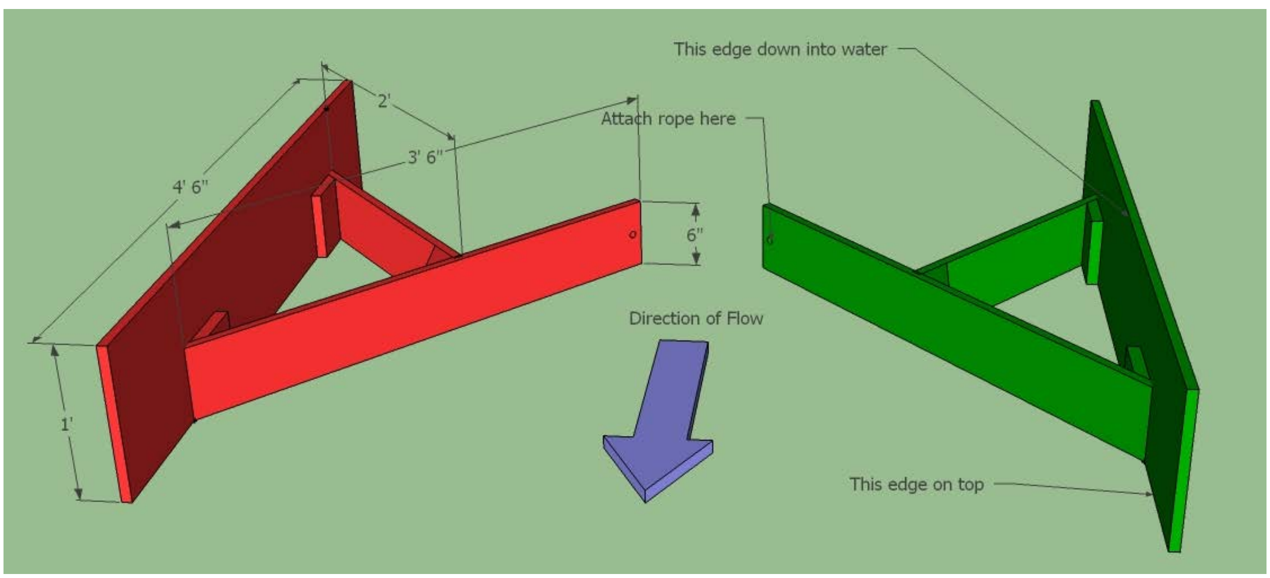

Figure 8. Trammel net "Mules" or spreader boards.

Standard methods: None have been established. Trammel nets are currently being used as a targeted gear only, but may be drifted or dead set at any level of the water column from surface to bottom. Drifted nets require the reporting of both the time fished, distance drifted if a catch per unit effort is desired.

Gear uses: Trammel nets have primarily been used to capture certain large river species like Paddlefish, Blue Sucker, Lake Sturgeon, and Shovelnose Sturgeon, for specific purposes ranging from population or contaminant studies to kids events. As of 2015 East Metro fisheries was fishing a variety of trammel net dimensions as part of their invasive carp monitoring efforts.

SGN – Special Gill Nets

Gear description: This is a general term for any gill net used in a non-standard way, or constructed or modified in a way that differs from an established gear type. Every effort should be made to use one of the other gill net codes first, using other fields, such as Targeted Species and dates set and lifted, to describe the type of set. Examples of SGN gear designation applied to an existing gill net type might include: a GN net with the 0.75-in-mesh removed, or a normally 24-hr GDE set left fishing for two or more nights. Time of year of use, or target species, should not drive SGN designation.

Gear uses: The SGN designation should most often be used for new gears and usages under development. Once standards have been established for the construction and use of an SGN gear, contact the Survey Coordinator to have a gear code established and added to the FSM for that gear.

VGN – Vertical Gill Net

Gear description: Vertical gill nets consist of seven 60m deep panels of monofilament webbing (bar-measure mesh size x panel width): ⅜'' x 0.9m, ½' x 0.9m, ¾'mm x 1.5m, 1'' x 1.5m, 1¼' x 3.0m, 1½' x 3.0m, 1¾' x 3.0m). The ⅜'' and ½' panels are sewn together vertically into one net, as are the ¾'and 1'' panels. The 1¼', 1½', and 1¾'panels are used individually for a total of five separate vertical nets. Each net is ganged together by a 12' connecting rope for a total of five vertical gill nets with 7 different mesh panels. Mesh sizes are ordered smallest to largest. The webbing is hung on a ½basis and the monofilament is clear and not treated. Twine diameters are relatively fine and consist of 0.12mm for ⅜'', 0.15mm for ½', 0.20mm for ¾', 0.23mm for 1'' and 1¼', and 0.28mm for 1½' and 1¾' meshes. Vertical gill nets are marked at 1 meter intervals. Species, mesh size, depth of capture (to the nearest 1m marker), length, and weight (optional) are recorded for each fish. Nets are rolled up on custom made axles.

Standard set: VGN sets are typically used when a lake is thermally stratified (mid-June through mid-September). The net is set from the bottom to the surface, covering the entire water column in the deepest portion of a basin. A standard set is overnight, about 24 hours in duration. Where set locations have been established, they should be repeated in subsequent surveys whenever possible. A temperature-oxygen profile is measured at each set (and is critical information because the vertical distribution of fish is largely dependent on stratification of temperature and oxygen). One gang is usually set in simple lake basins with only one deep area. Two gangs are set in lakes with two distinct deep basins. A maximum of three gangs are set in complex lake basins with multiple deep areas. Details on standard sets and setting procedures can be found in: (*Link to Vertical Gill Netting Description and Protocol*).

Setting technique notes: Boats need custom-made brackets to hold the vertical gill net axles. Vertical gill nets are set as a gang, connected to each other, and anchored at the gang ends. Order the gang from smallest to largest mesh.

Gear uses: VGN gear is suitable for targeting pelagic coldwater fish such as Cisco in mesotrophic lakes that have anoxic hypolimnia. VGN gear also samples the pelagic fish community that exists beyond and above traditional bottom-set gill nets. Warmwater fish are usually captured above the thermocline, coolwater fish near the thermocline, and coldwater fish below the thermocline. These vertical distributions of fish can be distinct in sharply stratified lakes. Since VGN nets have smaller mesh sizes than standard gill nets, they also provide information on smaller fish. Small Yellow Perch appear to make extensive use of the pelagic zone of lakes (usually just above the thermocline) and VGNs might be a useful gear for assessing that important species at ages and sizes not typically seen in standard gill nets. VGN gear is also useful as auxiliary gear for hydroacoustic assessments. Hydroacoustics use sound to sample the water column and can provide information on depth, size, location, and abundance of pelagic fish. However, hydroacoustics does not provide species information and similar-sized species have similar return signals. Therefore, vertical distribution, length, and weight data from VGNs are necessary to interpret hydroacoustic data so that species-specific estimates of pelagic density, biomass, and whole-lake populations can be generated.

TN - Double-Frame 0.75-Inch-Mesh Standard Lake Survey Trap Nets

Gear description: Trap nets with two rigid frames, 6 ft wide by 3 ft tall. A vertical 40-ft-long by 3.5-ft-deep weighted lead is attached to the middle of the frame. The hoop section consists of six 30-in hoops, with a square throat on the first hoop and a fingered throat on the second hoop. The fingered throat has an opening approximately 5 inches in diameter. Mesh on the lead and the body of the net is 0.75-in (bar) knotless nylon. Mesh should be treated (1 part net set to 4 parts solvent).

Gear notes: This gear samples shallow, shoreline-related habitats, and can be selective towards cover-seeking, mobile species. Trap nets sample species that are often not well represented in GN catches, including crappie and Bluegill. Hamley and Howly (1968) and Latta (1959) reported trap nets were more efficient at collecting larger fish, which could be a source of bias when using those catches to estimate fish size structure and abundance. Escapement, water temperature, turbidity, dissolved oxygen, depth, and fish spawning activity can all influence the size and species of fish caught in TN gear.

Gear uses: TN gear is a required component in standard lake surveys, sampling the nearshore component of the community of larger fish species. Additional uses include fall surveys targeting Bluegill, Black Crappie, or Yellow Perch of all ages, spring or fall surveys targeting coldwater fish species, spring surveys targeting pre-spawn panfish or adults of spring-spawning species, and spring surveys assessing winterkill.

DTN – Double-Pot Trap Net Sets

Gear description: These are standard TN nets (see TN for construction details), set off-shore in a double-pot configuration. DTN sets are not an acceptable substitute for TN or GN gear in standard surveys.

Standard methods: Nets are set off-shore, on the bottom, with no suggested orientation. Sets are overnight, roughly 24 hours in duration. Net leads are tied together at their ends, so that the total distance between frames is 80 ft. If nets are set in waters shallower than six feet, additional buoys should be added to the leads to warn boaters of the net's presence. Coordinates are recorded for each end of the net. The catch is recorded for the two pots combined, the unit of effort is the pair of pots (e.g. four DTN sets would have eight pots, but effort would be four sets).

Setting technique notes: Because the second pot must be pulled taught, an over-sized anchor may be needed on the first pot to keep the set from moving as the second pot is set out. Poles or posts may also be used, if properly signed or marked as hazards.

Gear uses: Double-pot trap net sets may provide an effective non-lethal means of sampling off-shore fishes in lakes too shallow to effectively gill net, or in shallow mid-lake habitats (reefs or flats).

TQU - Quarter-Inch-Mesh Trap Nets

Gear description: Trap nets with a single rigid frame, 6 ft wide by 3 ft tall. A vertical 40-ft-long by 3.5-ft-deep weighted lead is attached to the middle of the frame. The hoop section consists of five 30-in hoops, with a square throat on the first hoop and a fingered throat on the second hoop. Mesh on the lead and the body of the net is 0.25-in (bar) knotless nylon. Mesh should be treated (1 part net set to 4 parts solvent), unless there is a history of using untreated nets in a given lake.

Gear uses: TQU gear may be used to sample the nearshore fish community, as part of Index of Biotic Integrity (IBI) sampling, or simply to build a more complete species list for the lake. This sampling may also target YOY fish of some species. Other uses include surveys targeting YOY Walleye or Yellow Perch in late June or July, surveys targeting YOY Smallmouth or Largemouth Bass in September or October, and fall surveys targeting Bluegill, Black Crappie or Yellow Perch. The gear may also be used in spring winterkill assessments.

LTN - Double-Frame 0.75-Inch-Mesh Large-Frame Muskellunge Assessment Nets

Gear description: These are double-frame nets constructed of 0.75-in (bar) knotless nylon mesh (#147). Frames are 6 ft wide by 5 ft tall. A vertical 100-ft-long by 5-ft-deep weighted lead is attached to the middle of the frame. The hoop section consists of four 60-in hoops, with a 9x9-inch square throat on the first hoop and an 8x8-inch square throat on the second hoop. ''Fingered'' throat strings are not used on standard Muskellunge nets to avoid entanglement of large fish.

Gear notes: This gear samples shoreline habitat, five feet deep or less, and is used specifically to target Muskellunge during pre-spawn and spawning periods. Catch rates (CPUEs) for this sampling method are strongly influenced by the progression of spring warming, and cannot be used as indicators of abundance. Individual net lifts produce relatively few individuals so net set locations are run multiple days usually spanning 1-2 weeks. Setting in too early, or significant cooling after netting is initiated, can significantly lower mean catch per net lift. This sampling method specifically targets the mature adult portion of the population and provides no indication of juvenile abundance or size.

In some instances gear modification is acceptable to maximize sample size. Lead extensions can be added to better cover extensive shallow flats. Small frame nets (with modified pockets) can be substituted in some near shore shallow water areas. *Substituting standard survey trap nets is not advised due to throat string entanglement issues*. Double sets using two nets connected lead to lead can be used to sample off shore structure. Any net modifications or application should be clearly identified in the survey component type list.

Standard set: The net lead is staked on shore, or (if that is not possible) at the edge of heavy vegetation, and the net is set perpendicular to shore. The ideal set location has the top of the net frame at the water surface when the lead is fully extended (five feet deep-100 feet from shore). The minimum water depth must be deep enough to submerge both throats. Muskellunge do not trap well in water deeper than five feet where the net frame and part of the lead are submerged. Muskellunge tend to rise and swim over the lead rather than follow the lead laterally. The net may be set at an angle, or the lead may be shortened, if necessary to keep the frame at a suitable water depth.

Gear uses: LTN gear is used almost exclusively to sample adult Muskellunge in spring surveys.

THA (0.5-in), T38 (0.375-in), T34 (0.75-in; single-frame), and T1 (1.0-in) Trap Nets

Gear description: These gears are defined only by their mesh sizes (0.5, 0.375, 0.75, and 1.0-in bar). All consist of one or two rigid frames (frame sizes vary), with a lead and a variable number of hoops (of various sizes). The gear T34 describes single-frame 0.75-in-mesh trap nets. Details of gear construction (e.g. frame size and number, lead length) should be described in a narrative attached to the survey report. Mesh may or may not be treated (1 part net set to 4 parts solvent), depending on the history of using treated or untreated nets of a given type, in a given lake or area.

Gear notes: Like TN gear, these nets sample shallow, shoreline-related habitats, and can be selective towards cover-seeking, mobile species. Size of fish sampled will depend to some extent on the mesh size used in the net. In addition, the size and species of fish caught will likely be influenced by escapement, water temperature, turbidity, dissolved oxygen, depth, and fish spawning activity in the same ways those factors affect TN catches. None of these gears are acceptable substitutes for TN nets in a standard survey.

Gear uses: THA, T38, T34, or T1 gear may be used in spring or fall surveys of trout lakes. THA or T38 nets may be used in the same way that TQU nets are used to sample smaller species that are part of the nearshore fish community; however, they are not acceptable substitutes for seining, electrofishing, or quarter-inch-mesh trap netting in general near shore fish sampling intended for use as part of an IBI. Any of these trap net types may be used to assess winterkill, while T38 and THA have commonly been used to harvest Walleye rearing ponds.

STN – Special Trap Nets

Gear description: This is a general term for any trap net used in a non-standard way or constructed or modified in a way that differs from an established gear type. Every effort should be made to use one of the other trap net codes first, using other fields, such as Targeted Species and dates set and lifted, to describe the type of set. Examples of an STN gear designation applied to an existing trap net gear type might include TN nets set with the frame and hoops on shore and the lead extending toward deep water, or TQU nets with lead ‘wings’ added off the frame corners. Time of year of use, or target species, should not drive STN designation.

Gear uses: The STN designation should most often be used for new gears and usages under development. Once standards have been established for the construction and use of an STN gear, contact the Survey Coordinator to have a gear code established and added to the FSM for that gear.

EF and EW – Boom Electrofishing

Gear description: The basic set up of a boom electrofishing boat includes either a relatively large aluminum boat (16 feet or longer) with two parallel booms projecting off the bow, or a large aluminum boat with a single boom projecting off the bow. The boat hull serves as the cathode, and anodes either consist of a spider array suspended off the end of each boom in two-boom configurations or a single sphere suspended off a single boom. Generators provide at least 5 KW of electric power, and control boxes or control box/generator combinations produce pulsed-DC waveforms. These control boxes or control box/generator combinations are rated to operate efficiently within the range of water conductivities encountered among all accessible lakes or reservoirs within an Area.

Gear notes: This gear effectively samples shallow habitat in lakes and reservoirs, usually five feet deep or less along shorelines. Catchability of fishes is higher with the two-boom configuration than with the single-boom configuration; however, size structure estimates probably do not differ between configurations (MNDNR, unpublished data; Miranda and Kratochvil 2008).

Standards: For two-boom configurations, booms should be spaced about 6 feet apart. Anodes placed too close together act as a single large anode; anodes placed too far apart cause boom shockers to act as two rather than one shocker (Miranda and Kratochvil 2008). The single sphere in one-boom configurations should be suspended in the front and center of the boat. The standard power setting is that which elicits the desired electroshock response in the fish species being sampled (fish are sufficiently immobilized for easy netting; fish recover within 1-min after being released in the live well). Electroshock response in fish is a function of electric power transferred from water to fish, and power requirements to elicit this response increases with increasing mismatch between ambient water conductivities and effective conductivities (lowest water conductivity when fish elicit desired electroshock response) (Reynolds and Kolz 2012). Power transfer from water to fish is also affected by fish size. Fish > 6 in require similar power for immobilization regardless of size, but power requirements increase with decreasing fish size for fish < 6 in (Dolan and Miranda 2003).

Gear uses: Boom electrofishing targeting bass (EF) will be a core component of many standard surveys. Additional uses include spring surveys targeting Smallmouth or Largemouth Bass, spawning adults of several species, and pre-spawn panfish, spring surveys to assess winterkill, fall surveys targeting YOY or age-1 Walleye (EW), Smallmouth Bass, or Largemouth Bass, and fall surveys targeting Bluegill, crappie, or Yellow Perch of all ages. In addition, boom electrofishing gear may be used (day or night) for non-targeted sampling (no target species listed) during late summer (August to early September). The purpose of the latter sampling is to compile species lists and estimate size structure of numerous fish species including Bluegill, Largemouth Bass, and Yellow Perch. The gear is designated EW only when used in fall surveys targeting YOY or age-1 Walleye.

EFB – Backpack Electrofishing

Gear description: This gear type includes any backpack electrofishing gear, whether it is carried, or operated from a boat. Most units are battery powered. Anodes generally consist of one or two rings mounted on hand-held wands, with a kill switch on each wand. The cathode is usually a trailing bare cable (a rattail). Refer to the current IBI Sampling Manual for details on how to safely and effectively conduct EFB sampling (*Link to Lake IBI Sampling Manual*).

Standard methods: Two basic methods are used: wading along the shoreline, or shocking from a boat. Wading is the preferred method whenever it is possible. EFB electrofishing is done during the day. This sampling can be done from late June to early September when part of an IBI survey. When wading, the standard station length is 100 ft. The first pass through the station should be done as close to the shoreline as possible; while the second pass (returning to the boat) should be done slightly further from shore. Because shocking from a boat is less efficient, the standard station length is increased to 200 ft when shocking from a boat. As when wading, sample as close to shore as possible on the first pass, and a little further offshore on the second.

Gear uses: EFB gear has been used for general nearshore fish community sampling, to determine species diversity, evaluate non-game species, and assess natural reproduction for selected species. It is a core component of an IBI nearshore survey. Backpack shockers are selective for species that are small, slow-moving and that inhabit the extreme shoreline areas. In particular, backpack shockers often sample small benthic dwellers not sampled with other gears. Large, strongly swimming fish are better able to escape the field.

SEF – Special Electrofishing

Gear description: Any non-standard use of electrofishing gear, or non-standard electrofishing gear. Backpack electrofishing units operated from a boat are considered EFB, not SEF (or EF). Since the descriptions given for EF (or EW) and EFB are fairly broad, the SEF code is not expected to be used very often. Every effort should be made to use EF, EW, or EFB first, using other fields, such as Target Species, Daylight Sampling, and sampling dates to describe and define the usage. Examples of appropriate use of the SEF code might include use of a stationary electrode array, use of an ''electric seine'', or use of a wholly non-standard method, as in using two EF boats to drive fish into each other's arrays.

Gear uses: If new equipment or methods come into regular use contact the Survey Coordinator to have a gear code created.

SE - 50-ft, 0.25-Inch-Mesh Bag Seine

Gear description: SE seining is done using a 50-ft-long, 5-ft-deep, 0.25-in (bar) mesh bag seine. Seines are selective for species that are small, slow-moving, and associated with smooth-bottom, shoreline habitats. Large, strongly swimming fish are better able to escape seine hauls, and very small fish may not be captured by the 0.25-in mesh used in an SE seine.

Standard methods: Once a sampling date has been selected, it should be repeated in subsequent surveys (provided the purpose for the sampling has not changed). Previously established sampling stations should be repeated when possible. If sites have not been established, select a variety of areas that are representative of shoreline habitats found in the lake, and that are relatively undisturbed. Seine hauls should have a maximum length of 100 ft, although historic stations with longer lengths should be repeated. When using SE gear, the parallel method is preferred where its use is possible

Gear uses: SE gear can be used to sample small fishes in the nearshore fish community, and in targeted sampling of YOY or age-1 Walleye and Yellow Perch. SE gear has been used to determine species diversity, evaluate non-game species, and assess natural reproduction for selected species.

SSE – Special Seine

Gear description: Any type of seine used in a non-standard way or a seine construction that doesn't have a code listed. Every effort should be made to use one of the other seine codes first. Examples of an SSE would be any of the small seines used by anglers (and sometimes DNR crews) to collect minnows. These smaller, often more compact seines may be used by DNR staff in remote settings. Examples of use of an established seine gear in a way that would merit SSE designation would be laying an S18 seine out on the bottom in deeper water, and pulling it vertically to the surface, or using two boats to 'trawl' with an SE seine in an off-shore setting.

Gear uses: SSE is also used for large lake seining using a 100'X6' bag seine, ¼' mesh liner.

S18 – 15-ft Bag Seine, 0.125-Inch Mesh

Gear description: S18 seining is done using a 15-ft-long, 5-ft-deep, 0.125-in-mesh (bar) bag seine.

Standard methods: When used as part of an IBI survey, equally spaced nearshore sampling stations are determined for a lake based on the acreage of the lake. Seining may be completed at fewer sites on Northeast Minnesota lakes in lake classes 1 – 19 (see IBI Sampling Manual). For IBI sampling, use of the 50-ft seine (S58) is preferred. If there are items in the water or deep water that prevent seining with the 50 foot seine, the 15 foot seine (S18) should be used and station sampled using multiple seine pulls if necessary. An IBI seining station is 100 feet along shore and 50 feet lakeward or to the maximum wadeable depth, whichever is less.

Seining is completed following the parallel seining protocol whenever possible attempting to go 50 feet from shore or as far away from shore as water depth allows at the deep end of the seine. The shallow end should be at or near shore when conditions permit. In some cases, for example in a small open area of emergent vegetation or deep water, perpendicular seining or fixed pole seining may be used. This sampling can be done from late June to early September when part of an IBI survey.

Gear uses: S18 gear has been used for general nearshore fish community sampling, to determine species diversity, evaluate non-game species, and assess natural reproduction for selected species. It is typically as part of an IBI nearshore survey. Seines are selective for species that are small, slow-moving, and associated with smooth-bottom, shoreline habitats. Large, strongly swimming fish are better able to escape seine hauls. S18 seining can capture very small fish such as least darters that may not be captured by the 0.25-in mesh used in an SE seine.

S58 – 50-ft Bag Seine, 0.125-Inch Mesh

Gear description: S58 seining is done using a 50-ft-long, 5-ft-deep, 0.125-in-mesh (bar) bag seine.

Standard methods: When used as part of an IBI, equally spaced nearshore sampling stations are determined for a lake based on the acreage of the lake. Seining may be completed at fewer sites on Northeast Minnesota lakes in lake classes 1–19 (see IBI Sampling Manual). For IBI sampling, use of the 50-ft seine is preferred over use of the 15-ft seine (S18). If there are items in the water or deep water that prevent seining with the 50 foot seine, the 15 foot seine should be used and station sampled using multiple seine pulls if necessary. An IBI seining station is 100 feet along shore and 50 feet lakeward or to the maximum wadable depth, whichever is less. This sampling can be done from late June to early September when part of an IBI survey

Seining is completed following the parallel seining protocol whenever possible attempting to go 50 feet from shore or as far away from shore as water depth allows with the deep end of the seine; the shallow end should be at or near shore when conditions permit. In some cases, for example in a small open area of emergent vegetation or deep water, perpendicular seining or fixed pole seining may be used.

Gear uses: S58 gear has been used in general nearshore fish community sampling to determine species diversity, evaluate non-game species, and assess natural reproduction for selected species. S58 gear is typically as part of an IBI nearshore survey. Seines are selective for species that are small, slow-moving, and associated with smooth-bottom, shoreline habitats. Large, strongly swimming fish are better able to escape seine hauls. S58 seining can capture very small fish such as least darters that may not be captured by the 0.25-in mesh used in an SE seine.

AIF - Ice-Fishing

Gear description: This gear is intended for sampling done or supervised by Fisheries staff. Angling is done through the ice, using whatever methods are most effective for the species targeted.

Standard methods: None have been established. The number of anglers, the total number of lines, fishing method, and amount of time spent fishing (angler-hours) should be recorded and reported.

Gear uses: Comparable CPUEs are not a realistic goal for this sampling. The most common use will be determining the size and age structure of the targeted population. Use of AIF may provide some insight into the sizes and ages of fish available to anglers, without the cost of a full creel survey. This gear may be used to sample fish non-lethally for studies requiring marking or tagging fish, or as an alternate gear for use in recapturing tagged or marked fish. It can also be used to collect fish for disease or contaminant testing.

AOW - Open-Water Fishing

Gear description: This gear is intended for sampling done or supervised by Fisheries staff. Angling is done under open-water conditions, using whatever methods are most effective for the species targeted.

Standard methods: None have been established. The number of anglers, fishing methods, and amount of time spent fishing (angler-hours) should be recorded and reported.

Gear uses: Comparable CPUEs are not a realistic goal for this sampling. The most common use will be determining the size and age structure of the targeted population. Use of AOW may provide some insight into the sizes and ages of fish available to anglers, without the cost of a full creel survey. This gear may be used to sample fish non-lethally for studies requiring marking or tagging fish, or as an alternate gear for recapturing tagged or marked fish. AOW has been used to sample trout in stream trout lakes. Trout angling should be done in the spring or fall, when waters are cool, to reduce stress for released fish. Angling in the fall seems to be more effective than spring angling in stream trout lakes. AOW is an effective gear for collecting Lake Trout concentrated on known spawning reefs (early to mid October). It is also an effective means of capturing adult Smallmouth Bass when they are building or guarding nests.

TOU – Tournament Angling

Gear description: This gear is intended for fish caught during fishing tournaments by contest participants. It is expected that the sampling or measuring of tournament-caught fish will be done or supervised by Fisheries staff. Angling is done under open-water or ice conditions. Tournament formats include fish brought to weigh-in stations or the increasingly common catch-measure-release format used by tournaments that do not have an on-shore weigh-in at a central location. Fish are caught by whatever methods are allowed by the fishing contest for the species targeted.

Standard methods: None have been established. The number of anglers, fishing methods, and amount of time spent fishing (angler-hours) should be recorded. The most commonly available fish metric is likely to be individual measured length, though individual weight is likely available from most contests.

Gear uses: TOU angling has been used to sample bass and catfish from rivers to collect length-frequencies and to mark or recapture for mark-recapture population estimates. Comparable CPUEs are not a realistic goal for this sampling. The most common use will be determining the size and age structure of the targeted population. Use of TOU may provide some insight into the sizes and ages of fish available to anglers, without the cost of a full creel survey. However, tournament-caught fish will be biased towards the largest fish available. TOU angling may be used to sample fish non-lethally for studies requiring marking or tagging fish, or as an alternate gear for recapturing tagged or marked fish. It may serve to save significant staff time and resources collecting angling caught fish.

ATL – Trotline

Gear description: Any trotline used to sample fish in lakes. Use this gear code for the type of trotline normally used in the Area, or in the lake in question. Statewide standards for trotline use in lakes have not been established, so the type of trotline used, and methods for its use, should be described in the survey report. One type commonly used is 150 ft long, with a 340-lb test main line, with 25 4/0 hooks (usually large ring hooks) baited with cut bait.

Gear uses: Trotlines have mainly been used for sampling large rivers, where they have targeted Flathead and Channel Catfish. In lakes they have most often targeted Channel Catfish. Trotlines may capture larger catfish that are not effectively sampled in standard survey gear. Because the numbers of hooks per line may vary, catch may be reported in terms of fish/hook rather than fish/line.

STL – Special Trotline

Gear description: No standard has been established for trotline use in lake surveys. If a standard is eventually developed, the STL code would be used for any use of trotlines that do not conform to that standard.

TR – Trawling, Large Lake

Gear description: Trawl dimensions have varied through time due to changes in vendors supplying the trawls, and that builders use proprietary designs for their trawls. Generally, the trawls used are shrimp trawls, typically used in the Gulf of Mexico shrimp fishery. A generic description is a four-seam, semi-balloon trawl, with approximately a 25-foot headrope, and a 32-foot footrope. The body of the trawl is 0.75-inch (bar measure) mesh (#9 thread), with a 0.5-in mesh (#15 thread) cod end, lined with a 0.25-inch woven mesh liner. The entire net (except the cod end liner) is treated with synthetic green ‘‘net dip’’. Floats are attached to the headrope, and a chain is used to weight the footrope.

Standard methods: Sampling site selection is critical when considering trawling as a sampling gear. Trawls work best on smooth, flat, soft (no rocks) bottom. Start to deploy the trawl by tossing the cod end off to the side of the boat, so that it is not affected by turbulence behind the boat. As the cod end drifts behind the boat, tension will allow the rest of the trawl to be deployed. Feed out the doors, and a short amount of towing line, and allow the doors to take a set behind, and slightly off to each side, of the boat. When the doors have set, continue to feed the towing lines out. Boat speed can be increased while the lines are being fed out. The appropriate amount of line to use is approximately three times the depth of the water being sampled. Letting out too much line will cause excessive drag on the towing lines, and the net will not spread, while letting out too little line will also prevent the net from spreading.

Gear notes: The direction the boat is travelling is strongly influenced by the wind, as even a fairly light wind will cause the boat to circle down-wind. Try to take a heading into or with the wind, and hold a straight course, rather than trying to follow a depth contour. If trying to follow a pre-determined depth contour, the operator may be able to overcome the effects of a cross wind by adjusting the throttle. Start timing the run when the towing lines have been secured. The amount of time to tow is based on the size of the sample that is expected to be caught. In very productive systems, a tow time of 5 minutes may produce an adequate sample, while less productive waters will require longer tow times to reduce the likelihood of a zero catch. Timing of the run is ended when the doors break the water surface, as the trawl is being retrieved, or when the throttle is cut, depending on trawling practices within the Area. The mouth of the trawl is held open by hydraulic pressure, so boat speed is critical to correct opening of the mouth of the trawl. The trawl is spread horizontally by pressure on the doors, while the vertical opening is controlled by floatation of the floats on the headrope, and weight on the footrope. Excessive boat speed will increase drag on the body of the trawl and on the towing lines. In combination these will reduce the size of the opening of the mouth of the trawl. The appropriate boat speed is typically 3 to 3.5 mph.

Bottom debris can render trawling ineffective, even if there are no rocks. For example, trees and Zebra Mussels have both caused problems when conducting trawling operations. Trawling is a specialized gear, and may not be suitable for all situations. However, making adjustments on the doors can influence how much they dig into the bottom and/or spread. Experimenting with different settings should be done prior to standardizing to a particular suite of settings. If developing a new trawling station on a lake, trawl runs in the first year or two of sampling may be used to clear major debris from the station.

Gear uses: In the large lakes, trawling has been used to sample YOY, and age-1 Walleye, Sauger and Yellow Perch. It has been done as an extension of seining to better determine abundance and in-season growth of those species. Walleye tend to move off-shore through the summer, and may not be vulnerable to seines later in the summer. Trawl CPUE is reported as number/hour.

STR – Special Trawling

Gear description: Any trawl with a design or use that differs significantly from the large lake trawl (TR) would be considered special trawling. Examples may include various mid-water trawls, or the Missouri trawl. The design of the trawl, and its method of use, must be defined in the lake survey report.

Gear uses: Mid-water trawling may be another tool that could be used to validate hydroacoustic records. Other uses may be developed over time.

EXT – Fish Collected Externally

Gear description: This code specifies the source of a collection, and is not intended to describe any sampling gears used. Catches recorded under the code EXT could have been taken by any means. If the method is known, in should be described in the survey report.

Gear uses: This code is used to document catches reported by commercial fishers, other agencies, holders of scientific collector's permits, or other parties that may be collecting fish.

XXX – Fish Collected Miscellaneously

Gear description: This code is used when recording fish taken opportunistically. It is not considered a form of sampling. It may be used to record fish taken or found in a wide variety of settings, including, but not limited to, found on a beach, captured in a dip-net, or found in the stomach of another fish. There is no standard method.

Gear uses: The value of recording these fish lies primarily in documenting new introductions, or adding to the species list for a lake. It provides no information on the abundance or size distribution of those fish.

MT - Minnow Traps

Gear description: Minnow traps are usually relatively small and cylindrical (12-30 inches in length, 6-12 inches in diameter). They are often constructed of rigid wire or plastic mesh, 0.25-in (bar) or smaller, with a rigid funnel at one or both ends. Minnow traps usually have no lead. Minnow traps may be set baited or unbaited. Baits may include dog food or other slowly-soluble bait, or attractors like tin foil or glow sticks. This is not a well-defined gear, so dimensions and construction of traps used should be described in a narrative attached to the survey report. Baits used (if any) should also be described in the report narrative.

Standard set: A minnow trap is set on the bottom, held in place by its own weight, with a buoy to mark its location. Minnow traps are usually set in near-shore habitats, but orientation with respect to the shore is not standardized. The trap may or may not be set perpendicular to shore; there is no standard orientation. A standard set is overnight, about 24 hours in duration. Anglers are allowed to use minnow traps, and private traps may be set in the same areas fished by DNR traps. To allow trap ownership to be determined by

Enforcement officers, a tag should be attached to each DNR trap or trap buoy indicating it is owned by DNR Fisheries, and showing the Area office address.

Gear uses: Minnow traps may be used to sample small nearshore fishes, although they are one of the least effective means of doing so. Minnow traps are not an acceptable substitute for seining, electrofishing, or quarter-in-mesh trap netting (TQU) in IBI nearshore surveys. Minnow traps can also be used to target sculpins in deep water (Schmidt 2013).

SA - Fish Spawning Trap

Gear description: These are large stationary traps, usually set in streams or rivers. They consist of a holding pen attached to a funneling configuration with long leads extending out on each side. The leads will extend out in a way to force the fish to swim into the funneling configuration and be trapped in the holding pen. This net is used to capture fish for fish spawning activities. No standard net configuration has been designed.

Standard method: None have been established. Each fisheries station that operates an egg take operation has a unique net configuration and dock setup around the net openings. The main purpose is to funnel all the fish into a holding pen so they can be sorted. This net will be set near inlet/outlets of lakes in which fish congregate for spring spawning. The length of fish spawning trap deployment is based on water temperature/photoperiod or the status of the statewide egg take operations. CPUE in SA gear should be used with great caution, even for within-site comparisons, because the length and intensity of the fish run will be determined by water temperature and photoperiod, while effort may be determined by statewide production needs. Nets are set in areas known to hold concentrations of the fish species of interest.

Setting techniques notes: In some cases the leads are set up prior to sunset and lifted during the daylight to allow day movement of fish during the day.

Gear uses: Fish spawning traps may be used to target spring-spawning species, including Walleye and White Sucker.

Glossary

Accuracy. A measure of the closeness of a statistic obtained by sampling to the true value of the population parameter (Zale et al. 2012).

Bag seine. A seine with an added bag of mesh that increases capture efficiency. The bag is usually located midway between the two ends of the seine (Bonar et al. 2009).

Bar measure (mesh). The distance between adjacent knots in netting. Also known as square measure. Half the length of stretch measure (Zale et al. 2012).

Basis. See Hanging Ratio.

Bycatch. Those organisms unintentionally captured in addition to the target organisms or species (Bonar et al. 2009).

Catch per unit effort (CPUE). The number or weight of organisms captured with a defined unit of sampling or fishing effort (Zale et al. 2012).

Cod end. The closed end of a fyke or trap net, or trawl, or similar entrapment gear that holds the captured fish (Bonar et al. 2009).

Coldwater fish. Fish species that survive grow, and reproduce best in cold water. They generally spawn at water temperatures below 13° C (55° F) and do not survive at water temperatures exceeding approximately 21° C (70° F; Bonar et al. 2009).

Community composition. The species present and their relative proportions in an assemblage of organisms (Bonar et al. 2009).

Coolwater fish. Fish species that survive, grow, and reproduce best in cool water. They generally spawn at water temperatures between 4° C and 16° C (40° F and 60° F) and do not survive well in waters exceeding approximately 32° C (90° F; Bonar et al. 2009).

Fingered throat. A type of trap or hoop net throat in which a series of finger strings tied to a set of main beam strings are used to create a long tapered entry to the pot. Fish must pass between the finger strings to enter the pot.

Gamefish. For the purposes of this manual, these fish are considered gamefish: Walleye, Northern Pike, Largemouth Bass, Smallmouth Bass, Muskellunge, trout (all species), salmon (all species), catfish (all species other than bullheads), Lake Sturgeon, Shovelnose Sturgeon, Paddlefish, and Sauger (MNDNR 1993).

Hanging ratio. The length of a net divided by the stretched length of the original netting (Zale et al. 2012). The hanging ratio is equivalent to a net's basis. If 100 ft of stretched net has a final length of 50 ft when hung, the final net has a hanging ration of ½ and is said to be hung on a ½basis.

Index sampling. Sampling designed to yield a value, often a ratio (e.g. fish/net) used in lieu of the actual number; for example, the number of fish caught per hour electrofishing used as an index of fish density (Bonar et al. 2009).

Nongame fish. Fish species that are not harvested for recreational purposes; fish that are legally described as nongame species (Bonar et al. 2009). For the purposes of this manual, fish not identified as gamefish or panfish are considered nongame fish (MNDNR 1993).

Otter trawls. An active capture device for aquatic organisms in which the mouth of the trawl is maintained in an open position by weighted boards called otter boards (Bonar et al. 2009).

Panfish. For the purposes of this manual, these fish are considered panfish: Bluegill, Black Crappie, White Crappie, Yellow Perch, Pumpkinseed, other sunfishes, White Bass, and Rock Bass (MNDNR 1993).

Precision. The amount of variation in the data used to compute an estimate. It is most often expressed as a standard deviation or standard error (Bonar et al. 2009).

Relative abundance. Information obtained from samples or observations and used as an index to population abundance; often based on catch per unit of sampling effort in fisheries (Bonar et al. 2009).

Representative sampling. Obtaining a sample the characteristics of which do not differ significantly from the characteristics of the population.

Selectivity (Gear). The bias of a gear leading to misrepresentation of taxa, sizes, or life stages in samples relative to actual occurrence. Gear selectivity is undesirable if an unbiased sample is wanted. It can be useful if only certain sizes or kinds of fish are sought (Zale et al. 2012).

Target species. Fish or other aquatic species intentionally sought for capture (Zale et al. 2012).

Throat. In a hoop or trap net, a funnel-like restriction that guides fish into the pot end of the net, while making it difficult for them to find their way back out.

Trawl. An active sampling gear. It is a funnel-shaped net that is dragged along the lake bottom behind a boat. The mouth of the trawl is held open laterally through hydraulic pressure on doors (otter boards), and vertically by floatation and weights attached to the headrope and footrope, respectively. Note that other types of trawls exist (mid-water trawls and beam trawls), but these types have been used only experimentally, or not at all, in Minnesota. (Hayes et al. 2012)

Trotline. Passive angling gear composed of a horizontal main or ground line strung at intervals with short vertical drop lines, each with a baited hook (Zale et al. 2012).

Voucher. A specimen, sample, or product thereof, and its associated data that documents the existence of an organism at a given place and time in a manner consistent with disciplinary standards to ensure the repeatability of research that otherwise could not be adequately reviewed or reassessed (Zale et al. 2012).

Warmwater fish. Fish species that survive, grow, and reproduce best in warm water. They generally spawn at water temperatures above 16° C (60° F; Bonar et al. 2009).

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This is a list of references cited in the Manual of Instructions for Lake Survey, as well as other useful references pertaining to topics addressed in the manual. Additional references are included in sampling protocols attached as appendices to this manual.

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Manual of Instructions for Lake Survey

APPENDICES

Appendix 1 – Protocol: Night Electrofishing for Black Bass

Method: Night boom electrofishing to estimate size structure of smallmouth bass and largemouth bass

Objectives: estimate relative abundance and size structure of smallmouth bass and largemouth bass

To meet these objectives, the sampling gear will be boom pulsed-DC electrofishing conducted along lakeshores at night between sunset and sunrise when these two species spawn. Spawning of black basses usually occurs when water temperatures range from 54 to 70 ^{o}F (12 to 20 ^{o}C), and initiation of spawning usually occurs within a two week period between mid-May to mid-June (Coble 1975; Heidinger 1975; Carlander 1977; J.R. Reed, MNDNR, personal observation). Electrofishing catch per unit effort (CPUE; either number per time or number per shoreline length) of black basses during these conditions increased with increasing population density within water bodies among years, among strata within water bodies, or among water bodies (Hall 1986; McInerny and Degan 1991; Coble 1992; Hill and Willis 1994; McInerny and Cross 2000; Schoenebeck and Hansen 2005). Boom electrofishing in spring captures a wider range of lengths of both bass species than standard gill netting or standard trap netting (MNDNR lake survey database). Catchability of largemouth bass with boom electrofishing exceeds catchability in either type of standard netting in nearly all lakes; however, gill netting captures more smallmouth bass than boom electrofishing in many lakes (MNDNR lake survey database).

Sample segment selection:

Ideally, the entire shoreline of the lake should be electrofished; however, shoreline lengths of many lakes will be too long to practically accomplish this. Therefore, the entire shoreline should be electrofished if shoreline lengths are less than three miles (the equivalent of 2 hours of continuous on-time effort) (McInerny and Cross 2000). For lakes with longer shorelines, a total of at least 3 miles of shoreline, partitioned in segments equally distributed around the lake, should be electrofished. Sampling segments should be at least ½ mile in length (the equivalent of about 20-min continuous on-time of effort), and all segments within a lake should be equal in length. Assuming that black basses exhibit patchy spatial distribution patterns in lakes, longer segment lengths reduce station to station variability and reduce odds that catch per segment will be excessively high or zero (Miranda et al. 1996). Once selected, UTM coordinates of start and stop points should be entered into the Lake Survey module so that the same segments are sampled during each subsequent assessment.

To increase odds that CPUE and size structure estimates of bass are representative of CPUE and size structure of the entire lake shoreline, a stratified-random sampling protocol will be used to select sampling stations. The basic design includes six strata with equal shoreline lengths (the entire shoreline length/6), and within each stratum one station with a shoreline length of ½ mile will be randomly selected for electrofishing. Equidistant points will be assigned to each ½ mile of shoreline. From each of the six strata, one point will be randomly chosen (through various methodologies) that represents the midpoint of the selected station. If the randomly selected point is less than ¼ mile of an adjacent stratum, that point will be the starting end of the station.

Spatial heterogeneity in morphometry, habitat, or other physical features that affect spatial distribution patterns of bass within lakes becomes more likely as lake size increases; thus, other stratified random strategies should be considered in order to provide more cost-effective estimates of CPUE and size structure than the above protocol used for sampling smaller (shoreline length < 6 miles). These strategies should also be customized to fit the particular lake because criteria for defining strata boundaries will likely differ. Sampling segments within strata will be selected randomly, at least two segments must be sampled per strata, and at least a total of three miles of shoreline must be sampled per lake. Odds are high that initial assessments in these lakes will require electrofishing more than 6 miles of shoreline because criteria for establishing strata should be based on electrofishing catches. Stratified random sampling should be adopted for a given lake if segment to segment variability in CPUE within strata is consistently below segment to segment variability among segments within the entire lake. If not, then the stratified-random sampling method recommended for smaller lakes is more appropriate.

Shoreline lengths of each sampling stations per lake may need to be extended if sample size goals for size structure estimates have not been met; it is recommended that lengths be extended by a short distances (i.e., 1/8 of a mile). Sample sizes of 100 to 150 are approximate minimums required for estimating accurate (within 10% of true estimate 80% of the time) mean length and proportional size distributions of black basses (Gilliland 1986; Miranda 2007). Random sampling increases odds that each catchable life stage of largemouth bass is sampled because each life stage requires different habitat types (Annett 1996). Furthermore, size structure estimates made from randomly selected segments differ from those in which segments were selected subjectively (i.e., sampling only segments perceived to provide high catches of bass) within the same water bodies (Hubbard and Miranda 1987).

Sampling procedures:

Only pulsed DC waveform is to be used, and optimal electroshock response in bass $\geq$ 6 in (15 cm), not control box settings, will define the standard power setting for each assessment. Optimal electroshock occurs when bass are sufficiently stunned for netting coupled with fast (< 1 min) recovery in holding tanks. Electroshock response in fish is a function of peak power (not voltage or amperage) transferred from water to fish, and optimal power changes with changing water conductivity (Reynolds and Kolz 2012). This standard power setting should be determined before sampling the first station. It is recommended that initial power settings be relatively low; then voltage or duty cycle settings be gradually increased until fish of any species at least 6 in in length display optimal shock responses. Power transfer from water to fish is affected by fish length; disproportionately more power is required to stun fish of decreasing length when shorter than 6 in (Dolan and Miranda 2003). Using shorter fish to optimize shock response increases odds of injury and death of longer bass, lengths that boom electrofishing most effectively captures (McInerny and Cross 1996; Reynolds and Kolz 2012; MN DNR lake survey database).

Electrofishing should begin within 30 minutes after sunset and end before sunrise the following morning. Winds should be calm. (One or two yet to be determined) individuals will net stunned bass, and this number will remain constant. Electric power is to be applied as continuously as possible. Boat paths during electrofishing will be parallel to shore at depths of at least 2 feet but not more than 6 feet. A boat speed of approximately 1 to 2 mph should be maintained.

All bass captured will be identified to species, measured (total length in mm) and all length data be recorded. Other ancillary information that should be recorded include sampling date, on-time (in seconds), start and stop times, water temperature, water conductivity, wind conditions, anode configuration, control box manufacturer, control box settings appropriate for the particular type of control box (i.e.; voltage, voltage range settings, % of voltage range, amperage, pulse frequency, duty cycle).

Standard electrode configuration on boats:

Standard electrofishing boats will consist of a metal hull which serves as the cathode, and boats will be equipped with two booms with 4-6 cable arrays as anodes. When deployed, terminal ends of booms should be about six feet apart, which ensures sufficient catchability coupled with minimal injury to fish (Miranda and Kratochvil 2008). Because it is cost-prohibitive to purchase new boats for those Areas lacking boats with standard electrode configurations, side-by-side comparisons should be made between these standard boats and those with differing electrode configurations so that correction factors for CPUE can be developed.

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Appendix 2 – Protocol: Day Electrofishing for Black Bass

Method: Daytime boom electrofishing to estimate size structure of smallmouth bass and largemouth bass 9-2-14 version

Objective: estimate size structure of smallmouth bass or largemouth bass

To meet this objective, the sampling gear will be boom pulsed-DC electrofishing conducted along lakeshores during the day between sunrise and sunset when black basses spawn. Spawning of black basses usually occurs when water temperatures range from 54 to 70 ^{o}F (12 to 20 ^{o}C), and initiation of spawning usually occurs within a two week period between mid-May to mid-June (Coble 1975; Heidinger 1975; Carlander 1977; J.R. Reed, MNDNR, personal observation). Catchability of smallmouth bass and largemouth bass in many relatively turbid (Secchi depth < 6 ft) lakes appears high enough so that sufficient samples can be caught to estimate size structure (McInerny and Cross 1996). Boom electrofishing in spring captures a wider range of lengths of both bass species than standard gill netting or standard trap netting (MNDNR lake survey database). Day electrofishing samples similar length ranges of largemouth bass as night electrofishing, but slightly larger proportions of smaller largemouth bass are caught with day electrofishing (McInerny and Cross 1996; MN DNR unpublished data).

Sample station selection

Random sampling during spawning in relatively turbid lakes coupled with either a sample size target of 100 to 150 would provide data to meet this objective. It is recommended that the entire shoreline be electrofished if shoreline lengths of the entire lake is less than three miles (the equivalent of about 2 hours on-time; McInerny and Cross 2000). For lakes with shorelines exceeding 3 miles, shoreline segments of equal distance should be selected randomly because each life stage of largemouth bass require different habitats, and size structure estimates made from randomly selected segments differ from those in which segments were selected with bias (segments perceived to provide high catches of bass) within the same water bodies (Hubbard and Miranda 1987; Annett 1996). Electrofishing at randomly selected stations should continue until target sample sizes are reached or if at least 3 miles of shoreline have been electrofished. Sample sizes of 100 to 150 are approximate minimums required for estimating accurate (within 10% of true estimate 80% of the time) mean length and proportional size distributions of black basses (Gilliland 1986; Miranda 2007). Because the objective is to determine size structure, shorelines consistently failing to yield any bass in consecutive assessments should be identified and omitted from future sampling.

Sampling procedures:

Electrofishing should occur when black basses are spawning; water temperatures range from 54 to 70 ^{o}F (12 to 20 ^{o}C) (Carlander 1977). Power should be set so that optimal shock response in bass > 6 in occurs, which is when bass are sufficiently stunned for netting coupled with quick recovery times (< 1 min) after being placed in holding tanks. Electroshock response in fish is a function of peak power (not voltage or amperage) transferred from water to fish, and power thresholds increase disproportionately with decreasing fish length when less than 6 in (Dolan and Miranda 2003; Reynolds and Kolz 2012). Power should also be applied continuously, not intermittently. Water clarity is too high for day electrofishing if the netter(s) observes bass consistently avoiding the anodes and boat.

All bass captured should be measured (total length in mm) and all length data be recorded. Water temperature and sampling date should be recorded; however, recording of other ancillary information such as anode configuration, control box settings, number of dip-netters, etc. are optional.

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Appendix 3 – Protocol: Electrofishing for YOY or Age-1 Walleye

Method: Fall electrofishing to estimate size structure and relative abundance of age 0 and age 1 walleye

Objective: estimate relative abundance and size structure of age 0 and age 1 walleye

To meet these objectives, the sampling gear will be boom pulsed-DC electrofishing conducted along lakeshores at night between sunset and sunrise from late August to early October in most lakes, and this sampling targets walleye < 15 in. Fall electrofishing catch per unit effort (CPUE) at night derived from representative sampling methods crudely reflects population density of age 0 and age 1 walleye within lakes over time or among Iowa and Wisconsin lakes (Larscheid et al. 2001; Hansen et al. 2004; Madsen 2008; Hansen et al. 2012). However, CPUE of age 1 walleye appeared better than CPUE of age 0 walleye for predicting strengths of the same cohort at age 3 in Escanaba Lake, Wisconsin, the lake with the better methods of estimating population size (Madsen 2008). However, because electrofishing catchability of age 0 and age 1 walleye decreased with increasing population density, electrofishing CPUE becomes a poor indicator of population density when densities become high (Larscheid et al. 2001; Hansen et al. 2004). Both age 0 and age 1 walleye are caught with day electrofishing, catchability is much higher at night (McInerny and Cross 2004). Lastly, measuring for total length appears important because stronger year-class strengths of walleye occurred in Lake of the Woods, Leech Lake, and Lake Vermillion when average lengths of age 0 walleye caught with fall boom electrofishing were higher (Ward 2014; T. Heinrich, MNDNR, personal communication; D. Williams, MNDNR, personal communication).

Sample station selection

Depending on lake size, either the entire shoreline or sampling stations selected via representative sampling methods will be electrofished. The entire shoreline was usually electrofished in those Iowa and Wisconsin studies (Larscheid et al. 2001; Hansen et al. 2004; Madsen 2008; Hansen et al. 2012). However, electrofishing the entire shoreline becomes more impractical with increasing lake size; therefore, at least a total of 3 miles of shoreline (the equivalent of about 120 minutes of continuous on-time effort; McInerny and Cross 2000) should be electrofished. Electrofishing at least 3 miles of shoreline will be sufficient for most lakes; however, more effort could be needed in our largest lakes.

In lakes with more than 3 miles of shoreline, a representative sampling scheme will be used to select electrofishing stations if the entire shoreline will not be electrofished. The entire shoreline will first be partitioned into strata of equal shoreline length; the number of strata will equal the number of sampling stations deemed necessary for that lake. Each stratum will be divided into as many segments as possible that equal the chosen station length, and one segment per stratum will be selected randomly.

Length of sampling stations will depend on spatial distribution patterns of age 0 and age 1 walleye; these patterns will be determined from prior fall electrofishing. If spatial distributions appear rather uniform, then sampling stations can be 1/8 mile (the equivalent of 5 min continuous on-time effort) or longer. If spatial distribution patterns appear patchier, then station lengths should be at least ½ mile (the equivalent of 20 min continuous on-time effort). Longer station lengths provide CPUE with lower station to station variability because of lower odds of selecting stations yielding excessively high or zero catches of fish (Miranda et al. 1996). Regardless of spatial distribution patterns, lengths of stations must be the same within a particular lake. Once selected, UTM coordinates of start and stop points of each sampling station should be entered into the LSM, and these same stations should be electrofished in all subsequent electrofishing assessments.

Sampling procedures:

Electrofishing must be done at night, at water temperatures when optimal catchability occurs, and as close as practical (within one week) during the same week of the year as prior assessments. In most lakes, these temperatures range from 50 °F (10 °C) to 68 °F (20 °C), but in some lakes the highest CPUE of age 0 walleye occurred at temperatures above 68 °F (Borkholder and Parsons 2001). Conversely, in man-made or alluvial reservoirs, electrofishing should be done when water temperatures are 46 to 52 °F (8 to 10 °C); temperatures at which the highest CPUE of age-0 walleye at Cannon and Upper Sakatah lakes (man-made reservoirs) and Lake Pepin (alluvial reservoir) occurred (Borkholder and Parsons 2001; A. Stevens, MNDNR personal communication). Once sampling dates are established, electrofishing in later assessments should be conducted during the same week of the year.

To minimize noise in CPUE estimates, one dip netter will be used, electric power is to be applied continuously (foot pedal depressed at all times) not intermittently, and the 'standard settings' is the electroshock response of walleye and not control box settings. Continuous power application is recommended because it is repeatable; no studies appear available that address possible differences in catchability between these two power application strategies. Electroshock response in fish is a function of peak power (not voltage or amperage) transferred from water to fish, power needed to elicit optimal electroshock response increases with increasing differences between water conductivity and effective conductivity (lowest conductivity of water when electroshock response could occur) (Reynolds and Kolz 2012). Optimal shock response occurs when walleye are sufficiently stunned for netting coupled with quick recovery times (< 1 min) after being placed in the holding tank. Before beginning electrofishing the first station, it is recommended that power be set based on electroshock response of other fish species at similar sizes as age 0 to age 1 walleye.

At least 50 randomly selected walleye from each sampling station should be measured. Aging structures known to provide reliable age estimates should also be removed from a subsample of walleye (see age-growth section of this manual) if length frequency distributions (1-cm length bins) fail to distinguish age 0 from age 1 walleye, and age 1 from age 2 and older walleye.

The following information should be recorded after electrofishing each station: sampling date, total on-time (seconds), water temperature, water conductivity, wind effect (calm: negligible disturbance of water surface caused by wind; breezy: wind disturbance of surface affects water clarity), electrode configurations, and control box details (manufacturer and model, voltage or percent voltage, amperage, duty cycle (if available), or pulse frequency).

This sampling methodology meets basic requirements for representative sampling; thus, should be recorded as such. This is also targeted sampling; thus, the appropriate target species (age 0 walleye, age 1 walleye, or both age 0 and 1 walleye) must be selected.

Standard electrode configuration on boats:

Standard electrofishing boats will consist of a metal hull which serves as the cathode, and boats will be equipped with two booms with 4-6 cable arrays as anodes. When deployed, terminal ends of booms should be about six feet apart, which ensures sufficient catchability coupled with minimal injury to fish

(Miranda and Kratochvil 2008). Because it is cost-prohibitive to purchase new boats for those Areas lacking boats with standard electrode configurations, side-by-side comparisons (research project) should be made between these standard boats and those with differing electrode configurations so that correction factors for CPUE can be developed.

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Appendix 4 – Protocol: Electrofishing for YOY Walleye to Assess Stocking Needs

Method: Fall electrofishing for age 0 walleye for determining the need for stocking of advanced-stage walleye.

Objective: determine need for stocking of advanced-stage walleye in fall or following spring

To meet this objective, the sampling gear will be boom pulsed-DC electrofishing conducted along lakeshores at night between sunset and sunrise from late August to early October in most lakes, and this sampling targets age 0 walleye (total lengths usually < 12 in). Fall electrofishing at night provides useful data for determining spawning success, success of fry stocking, and if habitat is adequate for supporting a self-sustaining walleye populations (Hansen et al. 2004). However, to meet this objective, catchability should be optimized so that odds are best that age 0 walleye will be caught if present, and reduce odds of concluding that age 0 walleye do not exist when in fact they do. Therefore, electrofishing must be done at night and at water temperatures when highest catches are likely to occur (McInerny and Cross 2004). This procedure is an example of non-representative sampling, and is discouraged for use if past evaluations suggest that data collected did not provide useful information to determine if stocking is needed.

Sample segment selection:

Assuming that they provided reliable data, past sampling stations should be sampled during each assessment. If this is the first time a lake is sampled, preliminary sampling is recommended to determine where in lakes age 0 walleye appear most likely to be caught. Catches of age 0 walleye appear best along sandy or gravely shorelines lacking submergent aquatic plants.

Sampling procedures:

Electrofishing must be done at night and should occur at water temperatures when optimal catchability occurs. In most lakes, these temperatures ranged from 50 ^{o}F (10 ^{o}C) to 68 ^{o}F (20 ^{o}C), but in some lakes the highest catch occurred at temperatures above 68 ^{o}F (Borkholder and Parsons 2001). In man-made or alluvial reservoirs, electrofishing should be done when water temperatures are 46 to 50 ^{o}F (8 to 10 ^{o}C); the highest catch rates of age-0 walleye at Cannon and Upper Sakatah lakes (man-made reservoirs) and Lake Pepin (alluvial reservoir) occurred at these water temperatures (Borkholder and Parsons 2001; A. Stevens, MNDNR personal communication). Ideally, preliminary sampling in each lake is recommended to determine temperatures when catch rates appear optimal. After optimal temperature ranges and sampling stations have been selected, it is recommended that subsequent sampling occur at these same temperatures (similar sampling dates) and locations.

Criteria for electrofishing (timing, locations, number of netters, continuous vs intermittent application of power, etc.) shall be determined by the Area, but should be consistent each outing. It is recommended that age of some individuals of each 1-cm length group be determined because age 0 walleye sometimes exhibit bimodal length frequency distributions (fry-stocked lakes with natural reproduction; M.C. McInerny, MNDNR, personal observation). Other ancillary information including sampling date, on-time (in seconds), start and stop times, water temperature, water conductivity, wind conditions, anode configuration, control box manufacturer, control box settings appropriate for the particular type of control box (i.e.; voltage, voltage range settings, % of voltage range, amperage, pulse frequency, duty cycle) should be recorded.

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Appendix 5 – Protocol: Spring Night Electrofishing for Walleye

Method: Night boom electrofishing in spring to estimate relative abundance and size structure of adult (mature) walleye or to capture walleye for estimating population size

Objectives: estimate relative abundance and size structure of walleye ≥ 10 in (254 mm), size-structure of walleye ≥ 10 in, or capturing walleye ≥ 10 in for marking/recapture in population estimates

To meet these objectives, the sampling gear will be boom pulsed-DC electrofishing conducted along lakeshores at night between sunset and sunrise soon after ice out. Walleye ≥ 10 in TL appear most vulnerable to spring electrofishing in Minnesota lakes when water temperatures ranged from 42 to 52 ^{o}F (5 to 11 ^{o}C); temperatures when adults are spawning (B. Borkholder, Fisheries Biologist, Fond du Lac Band of Lake Superior Chippewa, personal communication; Ney 1978). Electrofishing catch per unit effort (CPUE; number per shoreline length) of walleye ≥ 15 inches TL during spring and at night increased with increasing population density among Wisconsin water bodies (Hansen et al. 2000; Schoenebeck and Hansen 2005).

Representative sample station selection for estimating relative abundance (CPUE) and size structure:

Ideally, the entire shoreline of the lake should be electrofished; however, shoreline lengths of many lakes will be too long to practically accomplish this. Therefore, the entire shoreline should be electrofished if shoreline lengths are less than three miles (the equivalent of 2 hours of continuous on-time effort) (McInerny and Cross 2000). For lakes with longer shorelines, a minimum of three miles of shoreline should be electrofished.

For lakes with three miles or less of shoreline, Areas have the option of creating sampling stations of equal length. The endpoints of each station are also the beginning of the next. Establishing stations could provide some useful information on distribution of walleye during spawning. Station lengths should also equal or exceed ¼ mile; shorter station lengths increase odds of zero or greatly excessive catches that could lower precision of CPUE estimates.

When electrofishing CPUE is to be used as an index of walleye abundance, a representative sampling protocol must be used to select sampling stations in most lakes with total shoreline lengths exceeding three miles. Areas may use established bass electrofishing stations if available but only if those stations were selected via representative sampling protocols. If representative electrofishing stations for bass have not been established, or if new representative stations are desired for walleye sampling, then the following procedure should be followed to establish sampling stations. First, Areas must decide on the length of sampling stations, which in turn, is needed to determine the number of stations to be sampled in the appropriate lake. Keys for this selection process are that station lengths must be equal, and the sum of all station lengths within the appropriate lake must equal or exceed three miles. After these decisions are made, then use ArcMap (or similar software) to generate equidistant points along the shoreline equaling the number of sampling stations necessary to electrofish a total of three miles. These points become the starting points of each electrofishing station. End points are the desired distance from start points, and the direction from start to end points (either clockwise or counterclockwise) must be the same for each station. Thus, not only will station lengths be equal, distances between stations will also be equal. Shoreline lengths of each sampling stations per lake may need to be extended if sample size goals for size structure estimates have not been met. For example, an Area decides it wants to establish 3/8 mile (15 minute) sampling stations on their lake of interest. Thus, a total of eight stations must be established so that the minimum of three miles of shoreline are electrofished. Next, use ArcMap to generate locations of eight points along the lake's shoreline that are the same distance apart. These eight points become the start points of each electrofishing station. End points are 3/8 of a mile from the start point. Once selected, UTM coordinates of start and stop points should be entered into the Lake Survey Module so that the same segments are sampled during each subsequent walleye assessment.

Expanded representative sampling or proportional sampling will likely be needed for the largest or morphometrically complex lakes because 3 miles of effort will be inadequate to assess walleye populations in these lakes. Extended representative sampling should be considered for those lakes that cannot be practically stratified based on physical features; these lakes lack obvious bays, arms, or significant islands, and other habitat types appear relatively homogenous. Selection of sampling stations for these relatively simple, but larger lakes should follow the same procedures for selecting representative stations in smaller lakes except that more sampling stations will be selected or lengths of sampling stations be increased. Once selected, UTM coordinates of start and stop points should be entered into the Lake Survey Module so that the same segments are sampled during each subsequent assessment.

Proportional sampling can be considered for large and morphometrically complex lakes, especially if odds are good that the distribution of walleye show strong links with strata or that a representative approach will miss relatively small sections of shoreline in which walleye show strong preferences. Lakes can be partitioned into strata based on physical features of the lake; these lakes could possess obvious bays or arms, significant islands, could possess both deep and shallow basins, or shorelines could possess at least two differing habitat types that can be partitioned into strata. **The proportion of sampling effort within a stratum equals the proportion of the shoreline length of the stratum as a function of the shoreline length of the entire lake.** For example, if Stratum A is one mile and the entire shoreline length is 10 miles, then $1/10^{th}$ of the total sampling effort occurs in Stratum A. When using proportional sampling, criteria used for establishing strata, and methods used for distributing sampling stations among and within strata should be documented in the Lake Management Plan, and in the General Field Notes section of the lake survey report. For each sampling station, the stratum to which it belonged should be documented in the location description for the target station, or the location description recorded for the component. Once selected, UTM coordinates of start and stop points should be entered into the Lake Survey Module so that the same segments are sampled during each subsequent assessment.

This sampling should be viewed as representative for both CPUE and size structure estimates, and the appropriate identifiers in the Lake Survey Module be selected.

Representative sample station selection for estimating size structure only (not CPUE)

If estimating size structure is the primary sampling objective and if sampling segments selected for CPUE estimates consistently fail to provide sufficient sample size for estimating size structure, use the following segment selection procedure. In this case, shoreline segments clearly lacking walleye should be eliminated from the possibility of being selected. If the total length of the remaining shorelines where walleye are likely to be captured is less than three miles, then all of the remaining shoreline should be electrofished. If the remaining shoreline exceeds three miles, then total sampling effort should equal three miles (or two hours) and distributed proportionately among the remaining shorelines that will yield walleye for sampling. For example, your lake has six miles of shoreline, but past experiences show that walleye were never caught among shorelines equaling two miles. Now, a total of four miles of shoreline remain that merits sampling. Past experience suggests that walleye were consistently caught among three stretches of continuous shoreline (these three stretches can now be defined as strata). Stratum A equaled two miles, and strata B and C equaled one mile each. Thus, 1.5 miles (1 hour of effort) of shoreline needs to be sampled in stratum A, and 0.75 miles (1/2 hour of effort) need to be sampled in strata B and C each. Start points within each stratum can be one end of the stratum, be selected with a random sampling method, or a stratum can be treated as a lake and representative sampling protocols can be applied. Once selected, UTM coordinates of start and stop points should be entered into the Lake Survey Module so that the same shoreline segments are sampled during each subsequent assessment.

This sampling should be viewed as representative for size structure but not for CPUE; the appropriate identifiers within the Lake Survey Module should be selected.

Sample station selection for estimating population size

Sampling objectives for estimating population size include catching and examining or marking as many walleye as possible; thus, sampling should focus on those shorelines in which odds are good that walleye will be caught with boom electrofishing. The appropriate lake management plan or mark-recapture sampling designs should be used as a guide for selecting the type (i.e. random, historical, etc.) of sampling stations. Samples from this type of sampling can be viewed as representative for size structure if the entire shoreline is sampled or if all shorelines known to have walleye based on past experiences are sampled. Samples from this type of sampling can be viewed as representative for estimating CPUE if the entire shoreline is sampled, one netter is used, and if the boat traveled at a constant speed parallel to shore and in water 2 to 6 ft. deep. The appropriate identifiers within the Lake Survey Module must be selected in order to determine representativeness.

Supplemental (non-representative) sampling

This may include sampling of traditional 'index' stations that were selected historically to target certain habitats, and sampling of additional stations to improve sample sizes (number of fish captured) for various analyses. Stations sampled in this way should not be considered representative. Ideally, results from these stations would be reported separately from results from representative stations sampled during the same survey. If these results cannot be separated by the Lake Survey Module reporting system on the basis of representative status, it may be necessary to report them as a separate targeted survey.

Sampling walleye while electrofishing bass

Standard electrofishing for bass can also be used to assess walleye populations if netters also net stunned walleye in addition to netting stunned bass. If sampling stations for bass electrofishing were selected via representative sampling protocols, then samples of walleye can be viewed as representative for size structure and CPUE if one netter is used and if the number of species netted did not exceed two (i.e., if netters attempted to capture all species observed, odds increase that gear saturation would occur and cause density dependent decreases in catchability). However, because catchabilities of walleye differ between early spring (42 to 52 ^{o}F water temperatures) and late spring (55 to 70 ^{o}F water temperatures), comparisons of CPUE and size structure collected during bass electrofishing should only be compared with CPUE and size structure from other samples collected during bass electrofishing, and not with samples collected soon after ice out. Labeling protocols must be followed to ensure that end users of data collected with this procedure know the pertinent methodology, ensuring no confusion between this method and the early ice out method of electrofishing for walleye.

Sampling procedures:

Only pulsed DC waveform is to be used, and optimal electroshock response in walleye ≥ 10 in (25 cm) TL, not control box settings, will define the standard power setting for each assessment. Optimal electroshock occurs when walleye are sufficiently stunned for netting coupled with fast (< 1 min) recovery in holding tanks. Electroshock response in fish is a function of peak power (not voltage or amperage) transferred from water to fish, and optimal power changes with changing water conductivity (Reynolds and Kolz 2012). This standard power setting should be determined before sampling the first station. It is recommended that initial power settings be relatively low; then voltage or duty cycle settings be gradually increased until fish of any species at least 6 in in length display optimal shock responses. Power transfer from water to fish is affected by fish length; disproportionately more power is required to stun fish of decreasing length when shorter than 6 in (Dolan and Miranda 2003). Using shorter fish to optimize shock response increases odds of injury and death of longer fish, lengths that boom electrofishing more effectively captures (Reynolds and Kolz 2012).

Electrofishing should begin within 30 minutes after sunset and end before sunrise the following morning in spring soon after ice out when water temperatures range from 42 to 52 ^{o}F (5 to 11 ^{o}C). Winds should be calm when estimating CPUE, but sampling can occur during windy conditions as long as it is safe when estimating size structure or just capturing walleye for population estimates. Two people will net all walleye stunned during early spring electrofishing, and one person will net stunned walleye when sampling is in conjunction with bass electrofishing using representative sampling to estimate CPUE, but one or two netters can be used when estimating size structure. Electric power is to be applied as continuously as possible. Boat paths during electrofishing will be parallel to shore at depths of at least 2 feet but not more than 6 feet. A boat speed of approximately 1 to 2 mph should be maintained.

All walleye will be measured (total length in mm) and all length data be recorded; refer to the appropriate lake management plan for gathering other data including age, sex, and maturity. Other ancillary information that should be recorded include sampling date, on-time (in seconds), start and stop times, water temperature, water conductivity, wind conditions, anode configuration, control box manufacturer, control box settings appropriate for the particular type of control box (i.e.; voltage, voltage range settings, % of voltage range, amperage, pulse frequency, duty cycle).

Standard electrode configuration on boats:

For estimating CPUE, standard electrofishing boats will consist of a metal hull which serves as the cathode, and boats will be equipped with two booms with 4-6 cable arrays as anodes. When deployed, terminal ends of booms should be about six feet apart, which ensures sufficient catchability coupled with minimal injury to fish (Miranda and Kratochvil 2008). Because it is cost-prohibitive to purchase new boats for those Areas lacking boats with standard electrode configurations, side-by-side comparisons should be made between these standard boats and those with differing electrode configurations so that correction factors for CPUE can be developed. Anode configurations do not need to be standardized for estimating size structure

References:

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Appendix 6 – Protocol: Night Electrofishing for Crappie

Method: Night boom electrofishing to estimate relative abundance and size structure of crappies.

Objective: estimate relative abundance and size-structure of crappies.

To meet these objectives, the sampling gear will be boom pulsed-DC electrofishing done in spring, at night, and concurrently with black bass electrofishing. Both crappie species spawn at water temperatures ranging from 57 to 77 ^{o}F (Siefert 1968; Hanson and Qadri 1984; Mitzner 1991; Pope and Willis 1997), which strongly overlaps with spawning temperatures of black basses (54 to 70 ^{o}F). Furthermore, these species spawn at depths ranging from 0.1 to 6 m (Edwards 1982; Phelps et al. 2009; Reed and Pereira 2009); thus, some crappies appear vulnerable to capture with boom electrofishing. Sex ratios suggest that males dominate the electrofishing catch in most lakes. About 89 to 95% of black crappies caught concurrently with largemouth bass during spring boom electrofishing in Heilberger, Molly Stark, and Beers lakes, Ottertail County (spring 2002) were sexually ripe males (M.C. McInerny, personal observation). However, when targeting just black crappies in bulrush stands, males composed at least 70% of black crappie electrofishing catch in Hubert Lake, Crow Wing County, but sex ratios in nearby Upper Mission Lake were near 50:50 males: females (Isermann et al. 2010a). Among five Minnesota lakes, males grew slightly faster than females, but sometimes lengths of males exceeded female lengths by over a centimeter (Isermann et al. 2010b). Therefore, sex could need to be determined.

Selecting sampling segments

Because odds are high that the primary sampling objective is to determine relative abundance and size structure of black basses, the same sampling stations will be electrofished as those selected for sampling black basses.

Sampling procedures:

Immobilized crappies should not be netted during electrofishing unless water temperatures ranges between 57 and 70 ^{o}F (temperatures when crappies and bass should be spawning). Otherwise, methodology is identical to that described for night boom electrofishing for bass. Dipnetting crappies while electrofishing for bass should not affect size structure estimates of bass, but relative abundance estimates of both bass and crappies will be become less valuable with increasing aggregate catch (too many stunned fish to net) (Twedt et al. 1992; McInerny and Cross 2000; Schoenebeck and Hansen 2005).

Crappies should be identified to species (hybrids?), sexed, and measured (TL in mm). During the spawning season, sex of black crappies can be reliably determined in the field. The combination of hand-stripping for gametes, examining for color (males are darker), and examining for body shape (ripe females possess distended abdomens; males do not) yielded accurate (>93% for black crappie $\geq$ 153 mm TL; 98% for black crappies $\geq$ 200 mm TL) estimates of sex (Isermann 2010).

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Twedt, D.J., W.C. Guest, and B.W. Farquhar. 1992. Selective dipnetting of largemouth bass during electrofishing. North American Journal of Fisheries Management 12:609-611.

Appendix 7 – Protocol: Spring Trap Netting (TN) Targeting Black Crappie

Method: Spring trap netting to estimate relative abundance and size structure of crappies

Objective: estimate relative abundance and size structure of crappies

To meet this objective, standard trap netting must be done in spring relatively soon after ice out but before crappies begin spawning. Unlike June or July assessments, spring trap netting appears to provide useful data on relative abundance of larger black crappies because catch per trap net lift (CPUE) of black crappies $\geq$ 200 (7.9 in) mm TL in April and May increased with increasing population density among seven lakes in south central Minnesota (McInerny and Cross 2006; M.C. McInerny, MNDNR, unpublished data). However, CPUE of black crappie 150 to 199 mm did not reflect population density among these same lakes (McInerny and Cross 2006); thus, CPUE estimates should exclude individuals < 200 mm TL. Catchability of black crappies in spring exceed that in fall (McInerny and Cross 2006; M.C. McInerny, MNDNR, unpublished data). White crappies are also captured with spring trap netting, and smaller white crappies appear more vulnerable to trap netting than smaller black crappies (Jackson and Bauer 2000). Thus, relative abundance estimates of white crappie could include smaller individuals. However, it is not known if CPUE of white crappie reflects population density. Lastly, sampling in spring reduces effects on catchability caused by spawning in late spring or early summer and by changing aquatic plant densities occurring throughout the summer.

Selecting sampling stations:

Sampling stations should be the same as those used during summer assessments. If this is the first time trap netting of any type has been done on a given lake, consult the standard trap netting procedure for selecting sampling stations.

Sampling procedures:

Standard double-frame trap nets will be set one day and lifted the next. Trap netting should occur in April and May when water temperatures range between 50 and 60 ^{o}F (10 to 16 ^{o}C) (M.C. McInerny, unpublished data). Spring trap netting of crappies should be curtailed when evidence of spawning appears.

All crappies should be identified to species (hybrids?) and measured (TL in mm). Total length of the targeted species should be measured (TL in mm). Subsampling of crappies is discouraged because odds are high that most of the catch occurs in one or two nets (McInerny et al. 1993; MNDNR sentinel lakes dataset). If catches appear excessive, about 100 black crappies need to be measured per net for precise estimates of mean length (MNDNR sentinel lakes data set).

References:

Jackson, J.J., and D.L. Bauer. 2000. Size structure and catch rates of white crappie, black crappie, and bluegill in trap nets with 13-mm and 16-mm mesh. North American Journal of Fisheries Management 20:646-650.

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Appendix 8 – Protocol: Spring Trap Netting (TN) Targeting Bluegill

Method: Spring trap netting to estimate relative abundance and size structure of bluegill

Objective: estimate relative abundance and size structure of bluegill

To meet this objective, standard trap netting must be done in spring relatively soon after ice out but before bluegills begin spawning (water temperature range = 50 to 65 ^{o}F (10 to 18 ^{o}C). It is not known if trap net catch per unit effort (CPUE) of bluegill in spring reflects population density. However, trap netting in spring could provide more consistent data on relative abundance and size structure than standard trap netting because spawning is not occurring and submerged aquatic plant densities appear minimal. During standard trap netting (June through August), the highest CPUE of bluegill $\geq$ 150 mm TL occurred when gonadosomatic indices were highest, and day of year explained 66% of biomass, 63% of CPUE of bluegill $\geq$ 150 mm TL, and 40% of CPUE of bluegill of all lengths (Cross et al. 1993). Bluegills begin spawning when water temperatures exceed 66 ^{o}F (19 ^{o}C) (Becker 1983).

Selecting sampling stations:

Sampling stations should be the same as those used during summer assessments. If this is the first time trap netting of any type has been done on a given lake, consult the standard trap netting procedure for selecting sampling stations.

Sampling procedures:

Standard double-frame trap nets will be set one day and lifted the next. Trap netting should occur in April and May when water temperatures range between 50 and 65 ^{o}F (10 to 18 ^{o}C) (M.C. McInerny, unpublished data). Spring trap netting of bluegill should be curtailed when evidence of spawning appears.

All bluegill should be counted and at least 25 randomly selected bluegill be measured (TL in mm) per net. About 50 bluegills need to be measured for precise estimates of mean length (MNDNR sentinel lakes data set).

References:

Becker, G.C. 1983. Fishes of Wisconsin. University of Wisconsin Press, Madison.

Cross, T.K., M.C. McInerny, and D.H. Schupp. 1995. Seasonal variation in trap-net catches of bluegill in Minnesota lakes. North American Journal of Fisheries Management 15:382-389.

Appendix 9 – Protocol: Fall Trap Netting (TN) Targeting Black Crappie

Method: Fall trap netting to estimate relative abundance and size structure of crappies

Objective: estimate relative abundance and size structure of crappies

To meet this objective, standard trap netting must be done in fall about when aquatic plants begin their senescence (water temperature range = 55 to 70 ^{o}F (13 to 21 ^{o}C)). Unlike June or July assessments, fall trap netting appears to provide useful data on relative abundance of larger black crappies because catch per trap net lift (CPUE) of black crappies $\geq$ 200 (7.9 in) mm TL in September and October increased with increasing population density among seven lakes in south central Minnesota (McInerny and Cross 2006; M.C. McInerny, unpublished data). However, CPUE of black crappie 150 to 199 mm did not reflect population density among these same lakes (McInerny and Cross 2006). Thus, CPUE estimates of black crappie should exclude individuals < 200 mm TL. However, trap net catchability in September and October was lower than catchability in April or May. White crappies are also captured with fall trap netting, and smaller white crappies appear more vulnerable to trap netting than smaller black crappies (Jackson and Bauer 2000). Thus, relative abundance estimates of white crappie could include smaller individuals. However, it is not known if trap net CPUE of white crappie reflects population density. Lastly, sampling in fall eliminates effects on catchability caused by spawning and reduces effects on catchability caused by changing aquatic plant densities occurring throughout the summer.

Selecting sampling stations:

Sampling stations should be the same as those used during summer assessments. If this is the first time trap netting of any type has been done on a given lake, consult the standard trap netting procedure for selecting sampling stations.

Sampling procedures:

Standard double-frame trap nets will be set one day and lifted the next. Trap netting should occur in September through early October when water temperatures range between 55 and 70 ^{o}F (13 to 21 ^{o}C) (M.C. McInerny, unpublished data).

All crappies should be identified to species (hybrids?) and measured (TL in mm). Total length of the targeted species should be measured (TL in mm). Subsampling of crappies is discouraged because most of the catch usually occurs in one or two nets (McInerny et al. 1993; MNDNR sentinel lakes dataset). If needed, subsample size should be about 100, the minimum needed for precise estimates of mean length (MNDNR sentinel lakes data set).

References:

Jackson, J.J., and D.L. Bauer. 2000. Size structure and catch rates of white crappie, black crappie, and bluegill in trap nets with 13-mm and 16-mm mesh. North American Journal of Fisheries Management 20:646-650.

McInerny, M.C., and T.K. Cross. 2006. Factors affecting trap-net catchability of black crappies in natural Minnesota lakes. North American Journal of Fisheries Management 26:652-664.

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Appendix 10 – Protocol: Fall Trap Netting (TN) Targeting Bluegill

Method: Fall trap netting to estimate relative abundance and size structure of bluegill

Objective: estimate relative abundance and size structure of bluegill

To meet this objective, standard trap netting must be done in fall (water temperature range = 55 to 70 ^{o}F (13 to 21 ^{o}C). It is not known if trap net catch per unit effort (CPUE) of bluegill in fall reflects population density. However, trap netting in fall could provide more consistent data on relative abundance and size structure than standard trap netting because spawning is not occurring and submerged aquatic plant densities appear minimal. During standard trap netting (June through August), the highest CPUE of bluegill $\geq$ 150 mm TL occurred when gonadosomatic indices were highest, and day of year explained 66% of biomass, 63% of CPUE of bluegill $\geq$ 150 mm TL, and 40% of CPUE of bluegill of all lengths (Cross et al. 1993).

Selecting sampling stations:

Sampling stations should be the same as those used during summer assessments. If this is the first time trap netting of any type has been done on a given lake, consult the standard trap netting procedure for selecting sampling stations.

Sampling procedures:

Standard double-frame trap nets will be set one day and lifted the next. Trap netting should occur in September through early October when water temperatures range between 55 and 70 ^{o}F (13 to 21 ^{o}C).

All bluegill should be counted and at least 25 randomly selected bluegill be measured (TL in mm) per net. About 50 bluegills need to be measured for precise estimates of mean length (MNDNR sentinel lakes data set).

References:

Cross, T.K., M.C. McInerny, and D.H. Schupp. 1995. Seasonal variation in trap-net catches of bluegill in Minnesota lakes. North American Journal of Fisheries Management 15:382-389.

Appendix 11 – Vertical Gill Netting Description and Protocol

Vertical Gill Netting Description and Protocol

Holbrook July 2015

Gear description:

Vertical gill nets consist of seven 60m deep panels of monofilament webbing (bar-measure mesh size x panel width): ⅜” x 0.9m, ½” x 0.9m, ¾”mm x 1.5m, 1” x 1.5m, 1¼” x 3.0m, 1½” x 3.0m, 1¾” x 3.0m). The ⅜” and ½” panels are sewn together vertically into one net, as are the ¾”and 1” panels. The 1¼”, 1½”, and 1¾”panels are used individually for a total of five separate vertical nets. Each net is ganged together by a 12’ connecting rope for a total of five vertical gill nets with 7 different mesh panels. Mesh sizes are ordered smallest to largest. The webbing is hung on a ½ basis and the monofilament is clear and not treated. Twine diameters are relatively fine and consist of 0.12mm for ⅜”, 0.15mm for ½”, 0.20mm for ¾”, 0.23mm for 1” and 1¼”, and 0.28mm for 1½” and 1¾” meshes. Vertical gill nets are marked at 1 meter intervals. Species, mesh size, depth of capture (to the nearest 1m marker), length, and weight (optional) are recorded for each fish. Nets are rolled up on custom made axles.

Standard set:

VGN sets are typically used when a lake is thermally stratified (mid-June through mid-September). The net is set from the bottom to the surface, covering the entire water column in the deepest portion of a basin. A standard set is overnight, about 24 hours in duration. Where set locations have been established, they should be repeated in subsequent surveys whenever possible. A DO/Temp profile is taken **at each set** (and is critical information because the vertical distribution of fish is largely dependent on stratification of temperature and oxygen). One gang is usually set in simple lake basins with only one deep area. Two gangs are set in lakes with two distinct deep basins. A maximum of three gangs are set in complex lake basins with multiple deep areas.

Setting technique notes:

Boats are required to have custom-made brackets to hold the vertical gill net axles. The Detroit Lakes Fisheries Construction Crew has experience with fabricating and mounting the brackets and should be consulted before setting up a boat for vertical gill netting. Vertical gill nets are set as a gang, connected to each other, and anchored at the gang ends. Set and lift from downwind to prevent boat from floating over the gang. Order the gang from smallest to largest mesh (this will be consistent with standard gill nets and allow waypoints for each end). The procedure to set vertical gill nets is as follows:

1. With the boat stopped upwind of the desired gang location, deploy first anchor and rope. After bottom is reached, clip anchor rope end onto the boat’s bow eye and allow the wind to move the boat downwind to take slack out of anchor line. A 45 degree angle of the anchor rope is desirable. Too sharp of an angle will not allow the anchor to hold in windy conditions and too shallow of an angle allows part of the rope to float on the surface (a navigation hazard).

2. Record GPS waypoint for small mesh end.
3. Attach and deploy marker buoy from surface end of anchor rope.
4. Set first gill net (small mesh) into axle holders and deploy net to within 1 meter of the bottom using depth measured from a depth finder. It is better to have the net slightly short of the bottom, so there is not a fold in the net from being on bottom (bottom is hard to detect). Keep surface at a meter mark. For example, if the depth is 15.5 meters, set 15 meters of net.
5. Secure gill net on axle to prevent from unrolling (short, rounded-end bungee cords work well).
6. Record lake bottom depth from depth finder and meters of net deployed.
7. Remove gill net from holders, attach connector rope, and place alongside boat.
8. Unclip line from bow eye and clip to gill net axle.
9. Allow boat to drift downwind then clip end of connector rope to bow eye.
10. Repeat steps 4-9 for each net deploying smallest to largest mesh.
11. After last net is deployed, take a second waypoint for large mesh end.
12. Conduct a DO/Temp profile at one-meter intervals. Note the bottom depth. Take a secchi depth reading.
13. Clip anchor rope to large mesh end of gill net axle. Attach and deploy marker buoy from surface end of anchor rope. Drift (or slowly motor backwards) downwind to extend anchor line.
14. Deploy second anchor once all slack is taken from the line.

Lifting a gang of vertical gill nets is done in reverse order (and again working from downwind):

1. Retrieve marker buoy and unclip from the gang.
2. Unclip downwind anchor rope from gill net gang and retrieve anchor.
3. With downwind gill net alongside of boat, unclip connector rope and clip onto bow eye.
4. Raise gill net axle into holders and roll up net.
5. Repeat retrieval of each net, clipping connecting rope to bow eye each time.
6. Retrieve upwind anchor after last net is retrieved.

Gear uses:

VGNs sample the pelagic fish community that exists beyond and above traditional bottom-set gill nets. Warmwater fish are usually captured above the thermocline, coolwater fish near the thermocline, and coldwater fish below the thermocline. These vertical distributions of fish can be distinct in sharply stratified lakes. VGNs can also provide a suitable gear for targeting coldwater fish such as cisco in mesotrophic lakes that have anoxic hypolimnia. Since GDEs (deep set gill nets) need oxygenated bottom waters to be effective, they are generally not suitable for lakes with only a small layer of oxygen below the thermocline. Since VGNs have smaller mesh sizes than standard gill nets, they also provide information on smaller fish. Small yellow perch appear to make extensive use of the pelagic zone of lakes (usually just above the thermocline) and VGNs might be a useful gear for assessing that important species at ages and sizes not typically seen in standard gill nets. VGNs have typically been used in mesotrophic and oligotrophic lakes in the northern half of the state. However, sampling in deeper lakes in the central and southern portions of the state should provide information on pelagic fish communities important in those lakes as well.

VGNs are also useful as auxiliary gear for hydroacoustic assessments. Hydroacoustics use sound to sample the water column and can provide information on depth, size, location, and abundance of pelagic fish. However, hydroacoustics does not provide species information and similar-sized species have similar return signals. Therefore, vertical distribution, length, and weight data from VGNs are necessary to interpret hydroacoustic data so that species-specific estimates of pelagic density, biomass, and whole-lake populations can be generated.

Appendix 12 – Winterkill Sampling Protocol

WINTERKILL SAMPLING

INTRODUCTION

Winterkills often occur in lakes where high biological oxygen (BOD) demand during winter months results in decreasing dissolved oxygen (DO) available to aquatic life as a result of prolonged ice and snow cover that reduces or eliminates photosynthesis within the lake. Winterkill is highly variable (basin, year, season) and likely a result of many factors. Typically, fisheries biologists consider the magnitude (lowest DO) and duration (how long DO has been low) but also the manner in which DO drops. Some have theorized a rapid change in DO may be the driver in winterkill compared to the magnitude or duration (Meyer and Barclay 1990, Shroyer 2007, Jim Cotner pers. Comm.). These stressful conditions (less than 2.0 ppm is stressful for most fish species), if coupled with additional stressful water quality conditions such as decreasing pH and increasing CO_2, can result in mortality of intolerant species (Trout, Bass, Catfish, Crappie, and some non-game shiner and minnow species) (Meyer and Barclay 1990, Brian Herwig pers. comm.). Continued decreases in DO (below 1.0 ppm) can lead to mortality of tolerant species (Walleye, Yellow Perch, Northern Pike, Common Carp, Buffalo, Bullheads, and Fathead Minnow). The severity of the winterkill can be unpredictable with variability in which species and abundances are affected. Occasionally, winterkills can be partial (individuals or size groups of some species eliminated), moderate (some species entirely eliminated), or complete (all species eliminated) depending on conditions found in the lake at the time of the kill. Observations in the Windom Area suggest that complete winterkills are very rare, as most winterkill events in recent decades have been partial (0 out of 20 were complete in last 10 years and 5 out of 20 were moderate in the Windom Fisheries Management Area). Due to the highly variable nature of winterkill and the lack of understanding of how many factors act in concert to create stressful conditions favorable to winterkill, this protocol was developed to not only standardize but also encourage further data collection to build upon what is known and how to make fish management decisions following the events.

METHODS

Winterkill sampling is a targeted survey (TS) which should be conducted when a winterkill is suspected. Prior to that, areas should have protocol for inspecting susceptible winterkill lakes through the winter months with periodic dissolved oxygen readings done during ice cover. At a minimum, DO should be sampled at two or more locations on the lake (depending on size, <600 acres or >600 acres) every 3 to 4 weeks to document changes in DO during ice cover. It is not uncommon in lakes in southern MN to have aeration systems that can at times reduce the occurrence of winterkill by creating openings in areas of the ice to have wave action oxygenate surface water. However, in most harsh winters aeration systems can be insufficient to eliminate all winterkill events, causing erratic gamefish populations competing with undesirable fish species that begin to dominate the lake or system. Additional observations should be noted if a winterkill is suspected based on winter DO including collecting additional water quality parameters (such as pH, CO_2, alkalinity, etc.) and noting physical observations (smell of sulfur, dead organisms) during ice cover or during ice off. When a winterkill is suspected to be occurring, the management plan for the lake should be consulted to determine if contingency management is triggered by a winterkill and that all proposals for stocking are completed to be reviewed by regional staff if needed (need determined from targeted survey for winterkill, see below). For example and for planning purposes, it may be prudent to propose contingent species stocking and stage for lakes that winterkill frequently in case of a winterkill.

After ice-out, the lake should be observed to determine the extent of the kill by estimating the number of dead fish per 100 feet of shoreline and species composition by percentage along shorelines and observed floating (optional map of lake showing accumulation of dead fish). Digital pictures should be taken. Transects based on prevailing conditions (wind, decomposition state of fish, etc.) can be conducted to count the number of floating fish and the species composition if needed. Number of transects should be enough to visually inspect the lake surface acreage if needed. Based on initial observations, a TS with the appropriate gear selectivity can be proposed to effectively sample all species. For example, trap nets are great for targeting species near shore in the early spring such as Northern Pike and White Sucker however they may be ineffective to sample Walleye and Yellow Perch that may still be offshore. In the case where you are interested in observing species that may be offshore, then gill nets could be utilized. Additionally, electrofishing (day or night) may be a good method to determine presence of fish within a short period of time. For example, in a winterkill check on a SW MN lake trap nets collected Black Bullhead and Walleye while day time electrofishing captured Black Bullhead, Black Crappie, Common Carp, and Fathead Minnow. Therefore, selection of gear is critical to the documentation of species remaining after winterkill. Minimum requirements (optional recommendation in parenthesis) for winterkill netting are as follows:

Lake Acreage	**# Trap Nets**	**# Gill Nets**	**EF**
<600	5	optional (1)	optional (30 minutes)
600-1500	7	optional (2)	optional (60 minutes)
>1500	consider SD survey	consider SD survey	consider SD survey

Trap nets should be at a minimum standard ¾ inch mesh with single frames. Additionally, at least 2 smaller mesh (3/8" or 1/4" mesh) nets should be included to assess survival of smaller non-game species or for greater catchability of the specie(s) of interest. Net locations should be in areas known to concentrate fish during ice-out, however, focusing on a range of different habitats could be beneficial to maximize the number of species observed.

In addition to the number of species and number within each species remaining in a lake, it is imperative that lengths to the nearest mm of a representative sample of each species be done (Meyer and Barclay 1990, AFS special publication 24, 1992). Measuring of each species should follow Standard Survey protocol. Lengths of fish caught in sampling can be used to determine whether or not brood stock sized fish remain. If brood stock remain, then stocking may not be necessary due to presence of brood stock for natural reproduction. However, health of the brood stock should also be determined based on a qualitative assessment of whether they appear fit to spawn or not (optional: gonadosmatic index could be used). Documentation of individual fish sizes instead of just numbers or ranges of size is also beneficial for determination of impacts to the size structure of the managed fish in the lake (Hurst 2007). This could be useful to help determine whether management objectives can be met given frequency and extent of winterkills observed (i.e. – remove Walleye from management due to concerns over survival of stocked fish) and whether or not winterkill events target the largest, smallest, or all sizes within a species given severity of the kill determined from initial assessment of shoreline counts and floating counts of dead fish.

Overall, a methodical approach taking into account the number of suspected and reported winterkills from local observation and from public reporting will help in determining the proper management response on each lake. Overreaction and suppressed reaction can have detrimental effects upon area budgets, staff time, and the lake itself. Determination of a priority schedule of winterkill assessments should be done if many winterkills are suspected or reported and limited time can be dedicated to each lake. Ultimately, winterkill susceptible lakes will be colonized by opportunistic species left after each winterkill and usually those are non-desirable nuisance species such as Common Carp, Black Bullhead, and Fathead Minnows. If and when game species can be reintroduced to fill the biomass void left as a result of a winterkill, the lake resource will benefit as well as anglers that will enjoy the rapid response of the fish community to catchable sized fish within a few years. These consistent monitoring methods will also benefit the local knowledge of lake management planning efforts to which survey frequencies are adjusted to account for winterkill events.

References

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Appendix 13 – Introduction to Common Fish Diseases

Sources: Unless otherwise referenced, descriptions have been taken from the Manual of Instructions for Lake Survey (Special Publication No. 147, 1993; Appendix 8) and the Fisheries Stream Survey Manual (Special Publication No. 165, 2007; Appendix 7), with minor edits for clarity. Descriptions have been listed in the order, and in the naming format, in which they appear on Fisheries Survey Module (FSM) data entry screens, for ease of use with those screens. Conditions not currently supported by the FSM are so noted.

Fishing is a very popular outdoor activity in Minnesota and many anglers are interested in the welfare of the fish. Consequently, the fish they catch are often scrutinized for anything unusual, and fishery biologists and fish pathologists are questioned for identification of these conditions. Because fish, like humans are attacked by a wide variety of parasites, bacteria, viruses and anomalies, many inquiries are received every year. The specific identity of many parasites, bacterial and viral diseases, and tumors can only be accomplished through complex laboratory techniques. Any unusual specimens not described should be forwarded to the pathology laboratory. Live specimens are most desirable, but fresh refrigerated, or iced material is good, although material preserved in 10% neutral buffered formalin is also suitable. If there is any question about the method of preservation, the pathology lab should be contacted.

Fish are no different than other animals where disease is concerned. A healthy animal is more resistant to disease than a weak animal, or an animal under stress. Fish respond physiologically to environmental change. A fish's body temperature changes with water temperature. Metabolism also changes with water temperature. If the temperature changes very rapidly, physiological processes are drastically altered, sometimes causing death. Such things as low oxygen, excess silting, lightning, excessive current, supersaturation of water by gases and all kinds of pollutants exert stresses on fish. If fish are not damaged directly by these things, they may be weakened, their resistance lowered, and their vulnerability to disease caused by parasites, bacteria and viruses increase.

Common terms used to describe various stages in the life cycles of parasites and pathological conditions are defined below:

Parasite: An organism which lives in or on another organism (host) and which depends on the host for its food, has a higher reproductive potential than the host, and is suspected of harming the host when present in large numbers.

Host: An animal or plant which harbors or nourishes another organism.

Accidental host: The host in which a parasite of another animal will live for a variable length of time.

Definitive host: The host in which a parasite passes its adult or sexual existence.

Intermediate host: A host in which a parasite passes a larval or non-sexual existence.

Cercaria: Larval trematode form which produces rediae or sporocysts in infected snails.

Metacercaria: Larval stage of trematodes between cercarial and adult stage, a more or less quiescent stage. The larval stage of flukes which follows the cercarial stage.

Pleurocercoid: Larval stage of cestodes.

Cestode: Girdle-form. Tapeworms.

Trematode: The flukes. Monogenea are ectoparasitic in general, with one host. Digenea are endoparasitic in general, with two or more hosts.

Nematode: A diverse phylum of round worms, many of which are plant or animal parasites.

Lesion: Any visible alteration in the normal structure of organs, tissues or cells.

Stress: A state manifested by a syndrome or bodily change caused by some force, condition, or circumstance in or on an organism or on one of its physiological or anatomical systems. Any condition which forces an organism to expend more energy to maintain homeostasis.

Infection: The introduction or reentry of a pathogen or parasite into a host, resulting in the presence of the pathogen or parasite within the body, tissues, or cells of the host, whether or not this results in overt disease .

Disease: A morbid process or condition of the body or its parts, having a characteristic train of signs that distinguishes it from other morbid processor conditions and from the normal state. Any state which results in a gradual degeneration of homeostasis.

Common Diseases and Parasites

Anchor Worm

The genus Lernea contains species of copepods parasitic on fish. Identification of Lernea is based on the morphology of the adult female which is seen protruding from the skin of the host. Lernea is a long slender copepod which, when attached, gives the appearance of a soft stock with two egg sacs attached. Actually, the head-end is buried in the flesh. This end has large, leathery horns which aid in the identification of the parasite.

Lernea eggs hatch in 1 to 3 days, releasing larvae which are free swimming. The larvae pass through five successive stages before the female attaches to a fish, where they penetrate the skin and attain a permanently fixed position. Then they increase in length up to 3/4 of an inch, and develop the embedding anchors. After reaching adulthood, egg sacs and eggs are formed completing the life cycle.

Bacterial Gill Disease

Bacterial gill disease (BGD) is a common external infection of hatchery reared salmonids and occasionally warmwater species reared under intensive conditions. Flavobacteria sp. and Cytophaga sp. have been isolated from bacterial gill disease cases. BGD is a superficial infection of gill epithelium by large numbers of filamentous bacteria resulting in fusion and clubbing of gill lamellae. BGD usually occurs as a result of overcrowding and poor environmental conditions. Fish infected with BGD are usually lethargic, refuse food ride high in the current, orient themselves into the current, and space themselves equidistant from each other. The tips of the gills may appear slimy with whitened tips. The most important fact is that bacteria causing bacterial gill disease do not cause necrosis.

Bacterial Kidney Disease (Renibacterium salmominarum)

Bacterial Kidney disease is an internal infection that commonly causes high mortality in cultured salmon and trout. The disease course is typically chronic but acute outbreaks sometimes occur, especially at moderate temperatures of 13-18C. Kidney disease progresses slowly. Signs of the disease may not be evident until the disease is well established. External signs typically include exopthalmia and small closed blisters or open sores. The unruptured blisters contain fluid composed of blood cells, tissue and large numbers of bacteria.

Internally, the kidneys are the organs most often affected; they become swollen and develop discrete white areas that contain bacteria and host cell debris. Hemorrhages occur in the body wall and testes. The hindgut is sometimes bloody and filled with white or yellow viscous fluid.

Although BKD is seen mainly in fresh water, mortality is also significant in salt water. BKD develops slowly but its progress is affected by water temperature. At 15-20C infected fish begin to die 21-34 days after infection, but at 7C no fish died until 60-71 days post infection.

Bladderworm

This roundworm is a common parasite of trout, salmon, smelt, and whitefish. As an adult the worm is found in the swim bladder of the above fishes. These worms belong to the genus cystidicola. The adult worms found in the swim bladder of fish are from 1 to 2 inches in length, and usually a translucent white in color. They produce eggs which eventually reach water and are ingested by crustacea. Here the juvenile worms develop to a stage infective to fish. When infested crustacea are eaten by a suitable fish, the larval nematodes are freed and migrate to the swim bladder. There they grow, mature, and produce eggs thus completing the life cycle. It seems probable that larger fish, such as lake trout which do not feed on crustacea, develop heavy infestations by consuming smaller fish which have eaten infested crustacea and still have invasive juvenile worms in their guts. The worms cause little harm to the fish hosts even when large numbers are present in the swim bladder. Infested fish appear healthy, but no studies have yet been reported dealing with the effects of this parasite upon its host. This parasite is not harmful to man. Since the swim bladder is discarded in dressing the fish, the parasites are not objectionable in fish prepared for human consumption.

Channel Catfish Virus

Channel catfish virus is an acute communicable infection of cultured fry and fingerling channel catfish. The virus is a Herpes Virus, named *Herpesvirus ictaluri*. Infected fish swim erratically or convulsively, sometimes rotating along their lateral axis. Moribund fish hang with their head up at the surface or sink to the bottom become quiescent, respire weakly but rapidly prior to death. Clinical signs include abdominal distention due to fluid in the body cavity, exopthalmia, pale gills, and hemorrhages at the bases of the fins.

Channel catfish virus occurs in all southern, and most other states where channel catfish are cultured. As of this date it has not been found in wild or feral populations. Juvenile channel catfish are most susceptible to CCV but fingerling blue catfish and channel catfish X blue catfish hybrids are also susceptible by injection. Most clinical CCV outbreaks occur during June through October when water temperatures are above 25C.

Ceratomyxosis (not supported in FSM)

Ceratomyxosis is a disease of salmonid fishes caused by the myxosporidean *Ceratomyxa shasta*. The parasite has a tropism for the intestinal tissue of the fish and causes high mortalities in susceptible strains of salmonids.

Ceratomyxosis is an important parasite in the Pacific Northwest because it not only causes losses in hatchery reared and wild juvenile salmonids but also contributes significantly to prespawning mortality in adult salmon.

Clinical signs vary among salmonid species. Infected juvenile rainbow trout and steelhead become anorexic, lethargic, and darken. Ascites may distend the abdomen, the vent may be swollen and hemorrhaged and exopthalmia is common. Internally, the intestinal tract becomes swollen and hemorrhaged with the intestinal contents mucoid and caseous material lines the intestine and cecca. The entire digestive tract may become hemorrhaged and necrotic.

Coldwater Disease (Cytophaga psychropila)

Coldwater disease, caused by the bacteria Flexibacter psychrophilus, is a common problem in salmonid fish culture. The bacteria is usually pathogenic at less than 10C. When temperatures in Spring are 4-10C the bacteria begins to show itself and mortality begins to rise. Mortality is most acute at 15C.

Coldwater disease causes epithelial erosions and necrotic skin lesions and often becomes systemic. Young fish show damage to the skin covering the yolk. In older fish, typical signs of peduncle disease appear. External signs include: tail darkening, white or bluish areas behind dorsal or adipose fins; loss of epidermis on dorsal or posterior surface; erosion of the dermis on the peduncle; erosion of lower jaw or snout; gill hemorrhages and edema.

Internal signs: generally not remarkable but sometimes has enlarged spleen with myriad number of filamentous rods; and petechial hemorrhages of adipose tissues.

Columnaris

Columnaris disease is an acute to chronic bacterial infection that infects anadromous salmonids and virtually all species of warmwater fish. It occurs both as external or systemic infections and under certain conditions, can result in significant losses of hatchery reared fish. Epizootics of columnaris disease frequently cause substantial mortalities in natural fish populations primarily in the spring as water temperatures in the shallows warm and primarily in crappies, other sunfish and catfish. The disease was named columnaris because of the haystack pattern which the bacteria tend to form on the gill lamellae.

Columnaris disease is caused by the bacteria Flexibacter columnaris. The disease begins externally on the body surfaces and gills but lesions vary. Lesions of scaleless fish begin on the body as small circular erosions of the skin which have grey-blue necrotic centers and red margins surrounded by a ring of inflamed skin. As the disease progresses, these lesions spread over the rest of the body. In scaled fish, necrotic lesions begin at the outer margins of the fins and spread inward towards the body. Columnaris also causes extensive gill necrosis. In well advanced cases the bacteria may also be isolated using special growth media.

Diplostomum spathaceum (not supported in FSM)

Diplostomum spathaceum is a trematode that utilizes many species of fishes as a second intermediate host, the metacercariae localizing in eye tissue. Several fish-eating aquatic bird species, especially gulls, are the primary hosts of this fluke. The life cycle of D. spathaceum begins as an adult trematode in the intestine of gulls or other pisciverous birds. The body is 0.3 to 0.5 mm in length and distinctly divided into a flattened anterior forebody and a more cylindrical and narrower hindbody. Eggs are shed and passed in feces to the water. They hatch in about 21 days at summer water temperatures into free-swimming ciliated miracidia.

Miracidia seek aquatic snails for a first intermediate host; only lymnaeid snails are acceptable. The Miracidia penetrate the hepatopancreas of the snail and metamorphose to a mother sporocyst, then to one or more daughter sporocysts. Each produces many cercariae which are released into the water. The free-swimming cercariae seek second intermediate hosts. The usual route of transmission from the snail to the second intermediate host is through water and active penetration of the cercariae. However, much evidence points to the fact that transmission is possible by fishes feeding on snails containing cercariae. Some cercariae which enter the skin, fins, and gills enter the blood stream and are carried to the eyes within 30 minutes of the time of penetration. The cercariae cause a parasitic blindness diagnosed by cataract and isolation of the parasite.

Enteric Redmouth (Yersinia ruckeri)

Enteric Redmouth disease, an internal bacterial infection of fishes, is principally known for its occurrence in rainbow trout, in which it was first seen in Idaho in the 1950's. The causal organism was named Yersinia ruckeri. In early acute disease outbreaks, the affected trout are typically lethargic, off feed, and have hemorrhages at the bases of the fins, in and around the mouth, and oral cavity. Gill filaments also may have hemorrhages along with the surfaces of internal organs and in the lateral muscles. The lower intestine is often inflamed and filled with a thick yellow fluid. One or both eyes may protrude, have hemorrhages around the ocular cavity and iris, and commonly rupture. Fish that survive darken in color and seek shelter or withdraw from other fish. Experimental evidence suggests that incubation time is 5-10 days at 13-15C.

Enteric Septicemia of Catfish (Edwardsiella ictaluri; ESC)

Enteric septicemia is a chronic, to sub-acute disease in channel catfish with nearly definitive clinical signs. Diseases fish hang listlessly with a "head up- tail-down" posture at the surface, spin in circles followed by morbidity, and death. Affected fish have pale gills, bulging eyes and occasionally enlarged abdomens. Small, circular, pale lesions of 1 to 3 mm in diameter appear on the flanks and backs of infected fish and progress into inflamed cutaneous ulcers.

Although ESC has been diagnosed during every month of the year and in a wide range of water temperatures, it is considered a seasonal disease occurring primarily when temperatures range from 18-28C in late spring to early summer and again in autumn; the optimal temperature is 20-25C.

Erqasilus

Ergasilus is a small, cyclops-like gill parasite which is found attached to the gills of a wide variety of fish species by means of clasper-like claws. These copepods appear as small, elongated white spots on the gills of fish. Impregnated females are the only Ergasilids found on fish and they produce eggs at intervals of 3-12 days depending upon the temperature and species of parasite. Up to 1 million eggs may be produced during the 1 year life span of the female. Eggs hatch in 2-4 days and another 10-70 days is required for the copepod to reach sexual maturity.

Fish Lice (Argulus)

Argulus sp. have been given the common name fish lice as they have the ability to creep about over the surface of the fish. These are large copepods and consequently, they are conspicuous objects on the fish they inhabit. At first glance they look like a scale but on closer examination are seen to be saucer-shaped and flattened against the side of the fish. They have jointed legs and two large sucking discs for attachment which may give them the appearance of having large eyes. Argulids penetrate the skin of the host fish, inject a cytolytic substance, and feed on blood. Lice prefer those parts of the skin best supplied with blood vessels like the mouth region, the operculum and the base of fins.

Fungus

Fungal diseases are encountered by all freshwater fishes at one time or another. Under fish culture conditions certain fungi are especially troublesome. Fungi which infect fish or fish eggs are generally considered to be secondary invaders after tissue injuries or tissue death. However, once the fungus begins growing, lesions continue to enlarge and potentially cause death.

Good sanitation and cleanliness are absolutely essential to effectively control fungal infection under intensive culture conditions. There are two general methods for the control of fungal infections on eggs: mechanical and chemical. The mechanical method used for salmonid eggs involves the removal of dead and/or infected eggs at frequent intervals during incubation. This method is time consuming and there is a risk of injuring healthy eggs in the process. There are three prominent chemical controls for fungal infections: formalin, salt and malachite green. Malachite green has never been cleared for fishery use.

Saprolegnia: Saprolegnia fungus, or water mold, is frequently found on fish in the natural environment and in fish hatcheries nationwide. The appearance of grayish-white, furry or cottony like patches is an indication of a fungal infection, most likely caused by Saprolegnia parasitiea. Several other species can also be found but saprolegnia is the most common. Water with a high silt or dirt particle content will mask the white fungal color to a brownish color as the particles collect on the fungus.

The fungal growth consists of a mass (mycelium) of nonseptate filaments (hyphae) each of which is about 20 microns in diameter. This fungus reproduces sexually and asexually. The lesions are circular and grow by radial extension around the body until lesions merge. At this point, the lesions may appear dark gray or brown because the mycelium traps mud and silt.

Fungus attacks on fish are considered to be secondary invaders. Any physical injury, such as produced during spawning, or migrating activities or by infection by external parasites or bacteria may enable fungus to gain a foothold on the fish. Once the protective mucus covering of the fish is broken, an opportunity is offered for the zoospores to germinate and penetrate the epithelium at the point of injury. Fungal infections rarely develop on strong fish, even in injuries. It develops rapidly on fish which have been weakened by stresses such as spawning activity, disease, overcrowding and rapid environmental change.

Branchiomycosis: Branchiomycosis is a fungal disease affecting the gills of freshwater fish. The fungus grows within the blood vessels and reduces the blood supply to the gills causing loss of oxygenation of the blood. The gill tissue becomes necrotic and sloughs away, which is why the condition has been referred to as "gill rot."

Fish having acute to subacute infections may be weak and lethargic and have labored opercular movements. Gills may appear bright red from impaired circulation. Some areas of the gill may be white to brown depending on the stage of necrosis. Subacute cases develop more slowly and a definite marbling appears on different sections of the gills as necrosis advances. The gills may eventually develop a very ragged or corroded appearance.

Furunculosis (Aeromonas salmonicida)

Furunculosis is a generalized internal infection prevalent in trout and salmon. The disease was first described in Germany in 1894. Affected fish darken, stop feeding and develop hemorrhages at the bases of the fins. The furuncle occurs in long term chronic disease but not in rapidly developing epizootics. Internally, hemorrhages occur in the intestine, abdominal walls and heart. The stomach is devoid of food and the intestine may be filled with a yellowish mucoid material.

Goldfish ulcer disease and carp erythrodermatitis are also caused by Aeromonas salmonicida. Although A. salmonicida infections usually occur in salmonids and less often in common carp and goldfish, the causative bacterium also infects many other species of warmwater and coldwater fishes-both freshwater and marine.

Gill Erosion

Eroded gills may appear shortened or frayed, and may appear bleached or bleeding at their tips. A marked over-secretion of mucous may be evident. Gill erosion may be caused by chemical irritants in the water, or by parasites (Reichenbach-Klinke 1973).

Gill Parasites

Nearly all gill parasites are going to require the use of a microscope and some fish pathology training in order to be able to determine the actual organism responsible.

Chilodonella: These ciliated protozoans are most frequently found on warmwater fish such as pike and carp, although infestation of trout fry in hatcheries is not uncommon. The parasites are tiny, 50 to 70 microns long, and cannot be seen without magnification, although heavily parasitized fish may show blotchy gray areas on the surface of the skin. Under magnification the parasites may be seen as tiny, motile, oval bodies covered with fine cilia.

When Chilodonella occurs in very great numbers on a fish, particularly on the gills, it causes the fish to produce great quantities of mucus which impair respiration. Affected fish may become lazy, lie on their sides, rise to the surface, and eventually die. The parasite shows a preference for debilitated and undernourished fish. It is frequently observed on northern pike in the spring of the year as they enter a marsh for spawning. The parasites are not harmful to man.

Gyros: Fish culturists frequently observe the symptoms of "Gyro" infestation. "Gyros," Gyrodactylus elegans and Dactylogyrus sp. seldom become a serious menace to fish in nature. However, they may become a problem in hatcheries where fish are closely crowded and the worms may be easily spread from one fish to another. Infested fish can be seen 'flashing" as they rub themselves against the sides and bottom of the trough or stream in an effort to rid themselves of the parasites.

"Gyro" infestation can be identified only with the use of a microscope as the worms are quite small, 0.5 to 0.8 mm long. The posterior end of these worms is disc shaped and equipped with hooks which are used to hold the parasite to the host. These hooks penetrate the skin or gill tissues, creating open sores which frequently become infected with fungus, and may serve as portals of entry for pathogenic bacteria and viruses.

Gyrodactylus may be distinguished from worms belonging to the genus Dactylogyrus by its absence of eye spots in the anterior end. Gyrodactylus may live almost anywhere on the host but it is usually most abundant on the fins, especially the dorsal and caudal. "Gyros" give birth to live young which are already well developed and immediately become attached to a fish host.

Dactylogyrus is easily identified by the presence of two pairs of eyes which appear as small black dots near the anterior end. This genus differs from Gyrodactylus by laying eggs, which become attached to the gills of the host. After the young hatch they require some time to grow to maturity. The eggs of Dactylogyrus may resist treatment and hatch later, so treatment must therefore be repeated to kill the newly hatched young before they mature and lay eggs.

Heterosporis

A microsporidea found in the muscle tissue of several fish species. Infected tissue will show white or "opaque areas" in an uncooked fish fillet. White regions in the muscle tissue resemble cooked meat. It has been detected in several Minnesota lakes, including Big Sand, Winnibigoshish, Leech, Clitherall, Vermilion, Mille Lacs, Bear, Moose, Cass, Andrusia, and Gull. The disease is also found in Canada. This parasite has been found in yellow perch, walleye, northern pike, pumpkinseed sunfish, burbot, sculpins, trout-perch, rock bass, and tullibee. Experimentally fathead minnow, rainbow trout are susceptible and largemouth bass and sunfish are somewhat refractory. The parasite infects muscle cells which cause the cells to have a white appearance. The parasite’s life cycle is not completely known but research is underway to learn more.

Ich or White Spot Disease (Ichthyopthirias)

A common disease of hatchery and aquaria fish is white spot, a condition caused by large ciliated protozoans. The adults od this parasite are up to 1 mm in diameter, and may be seen with the unaided eye as tiny white spots on affected fish. The parasites live under the epithelial layers .of the skin, fins, and gills of many species of fish, especially young fish. They are found more frequently on warmwater fishes than on fish from coldwater because low temperatures inhibit their activity. When the parasite has grown to maturity it leaves the host and becomes enclosed in a cyst. Within this cyst multiplication occurs resulting in the production of from 400 to 2,000 young parasites. These are also ciliated, and when they leave the cyst, swim actively until contacting a fish. If a fish is not found within a few days, the parasites die. If they find a fish, they burrow into the skin, migrate for a time, then grow to maturity. The entire life cycle takes from 4 days to 3 weeks, depending on the water temperature. White spot can be very serious, causing high mortality, especially when fish are under crowded conditions and heavy infestation occurs.

Infectious Hematopoietic Necrosis (IHN)

Infectious Hematopoietic necrosis is a viral disease of fry and fingerling rainbow trout, Chinook and sockeye salmon, and occasionally of yearlings. The virus has only been isolated from fish showing signs of the disease and from sexually mature carrier adults. Coho salmon are also suspected of acting as carriers but coho fry are resistant to the disease. IHN is primarily a west coast disease being found in California, Oregon, Washington, Alaska, Idaho, British Columbia and Japan. In the mid 1970's it was found at a private fish hatchery near Brownsville, Minnesota.

Mortality can reach up to 90% of an infected population. Clinical signs include: distended abdomen, exopthalmia, petechial hemorrhage, no food in gut, pale liver, spleen cherry red, and transparent kidneys.

Infectious Pancreatic Necrosis (IPN; not supported in FSM)

Infectious Pancreatic Necrosis is a viral disease of fry and fingerlings and occasionally of yearling rainbow trout. The virus has also been isolated from nonsalmonid fish and marine invertebrates. Acute infection occurs in 1-4 month old salmonids and can result in cumulative mortality of 100%. Fish six months old or older can undergo subclinical infection and experience no mortality. Survivors can become lifelong carriers of the virus.

Affected fry and fingerlings are darkly pigmented, exhibit exopthalmia and abdominal distension, and trail mucoid pseudocasts from the vent. Infrequently, petechial hemorrhages can occur at the bases of the pectoral and pelvic fins. The behavior of infected fish varies from quiescence with weak respiration to periods of hyperactivity during which fish swim in a corkscrew manner, rotating about their long axis or whirling violently. Internally, the liver and spleen are pale, and the stomach and intestines are devoid of food but filled with a mucoid material. Petechial hemorrhages are evident throughout the pyloric ceca and pancreatic tissues.

Nonsalmonid species that can be infected with IPN include: shad, common carp, eel, goldfish, northern pike, walleye, white sucker, lamprey, minnows, and yellow perch.

Largemouth Bass Virus (LBV)

Largemouth Bass virus, the cause of largemouth bass virus disease, was the first systemic virus isolated from any centrarchid. The initial isolate came from Santee Cooper reservoir, South Carolina in 1995. The virus has been shown to be an iridovirus.

Adult largemouth bass with clinical LBV loose their equilibrium to different degrees, may float at the surface and have swollen abdomens, which are apparently due to enlarged swim bladders. Internally the swim bladder may be inflamed and contain a yellow to yellow-brown mucoid substance. The virus has been found in most southern states from Florida to Texas and north to Oklahoma, Missouri, Indiana and Michigan. Last year it was detected in the Mississippi River between Minnesota and Wisconsin.

Largemouth Bass are the most susceptible but smallmouth, spotted and suwanee are also affected. Black and white crappie, redear sunfish and bluegill have also been found to harbor the virus. Epizootics usually occur between July and September.

Leeches

Certain leeches attack fishes, but do little damage unless present in large numbers. The damage done to the fish is proportional to the number of leeches present and the amount of blood they remove. Leeches attach periodically to fish, take a large blood meal, and leave for varying periods of time.

The true fish leeches belong to the family Piscicolidae and are related to the common earthworm. Leeches usually have a greenish brown color, are from 1/4 to 1 inch long, and may be found in the mouth, on the gills, fins, or body of bluegills, perch, and many other fishes. All leeches are composed of only 34 true segments with each segment subdivided into a definite and constant number of superficial annuli. Leeches have two suckers, one at each end. The anterior one surrounds the mouth and may be large or small, and lip-like. The caudal sucker faces ventrally and is much larger, disc1ike, powerful and expanded over central attachment pedestal. Leeches are flattened dorsoventrally and are highly muscular and contractile.

Liver Flukes

Liver fluke is a misleading term for the parasitic flatworm *Metorchis conjunctus* that lives as an adult in the bile ducts or gall bladder of fish-eating mammals (Kennedy 2004).

The adult fluke produces eggs that pass down the common bile duct to the intestine and are excreted in the feces. Eggs entering fresh water and eaten by an aquatic snail, *Amnicola limosa*, hatch and release a larva that burrows through the snail's intestine to the liver to continue its development. New larvae, called cercariae, are produced. These larvae leave the snail and swim freely in the water. When cercariae contact a suitable fish host, they penetrate its skin and encyst in the muscle. The encysted larva is now called a metacercaria. When infected fish are eaten, the metacercaria excysts, and the young worms migrate up the bile duct to the liver where they develop and begin passing eggs in approximately 28 days.

Metorchis occurs most often in the white sucker, but it has been reported occasionally in other fresh-water fish including yellow perch, northern pike and brook char. The encysted stage of the flatworm can survive freezing in the muscle of fish. Fish should be cooked thoroughly before it is fed to dogs or used as food for people. Consumption of uncooked fish infested with this parasite has deaths of sled dogs in Canada.

Lymphocystis

Lymphocystis is a viral caused disease of the higher order of fish (Percidae and Centrarchidae). The incidence of the disease in walleye may be high in some locations and affected fish are discarded by fishermen.

The lesions of lymphocystis disease are raised nodular masses of the generally light-colored tissue which resemble warts. The wart like growths are usually located on the skin or on fins but often may be restricted to a small area of a single fin. The growths are due to viral infected cells enlarging. Color of the lesion is usually light and may be white, gray or cream colored. There is a tendency toward opalescence, and larger lesions may show pink due to the vascular network. Lymphocystis cells may occur internally, but the infection is characteristically a disease which involves the skin.

Transmission of the virus is by the bursting and/or sloughing of host cells and release of the viral particles. This can occur intermittently through the duration of the infection, or it can be massive as upon death and decomposition of the host fish. In temperate freshwater fishes, lymphocystis disease usually appears in the spring, peaks in summer and disappears through fall and winter.

Lymphosarcoma

A red sore disease of the pike, Esox lucius, has frequently been observed by Minnesota anglers. The disease is specific to northern pike and muskellunge. The disease is circumpolar in distribution in the northern hemisphere and widely distributed in the United States and Canada. This condition is known to be fatal to muskellunge, but its effect on pike is not totally understood.

Lymphosarcoma is a tumorous condition which appears as weltlike sores on the flank, fins, or head. The tumor may appear as a cluster of pink blisters which may rupture, resulting in a sore resembling a lamprey scar. The tumor may also appear as a series of bluish blisters surrounding a "cream-like core." Or the tumor may most typically appear as what we have traditionally called "red sore."

Studies to date indicate that the disease is a contact-transmitted virus spread from fish to fish during the spawning act. The disease begins as a skin lesion which invades the underlying tissues and muscle. Two sequels are then possible: the tumor may progress to involve internal organs and subsequent death of the animal or the tumor may regress and heal. The highest incidence of the disease is seen in spring, suggesting that the syndrome may cause death of most tumor bearing fish during the summer months.

There is no evidence at this time that this disease affects humans or other animals. However, heavily infected fish are not considered very palatable and are discarded by most fishermen.

In general, warmwater fish are most susceptible in the spring although cases have been reported during the winter months. The infection frequently occurs during the winter months, and the disease not showing itself until spring. The best method of control is to avoid the transfer of fish from infected waters to those where the disease has not been known to occur.

Myofibroqranuloma

Myofibrogranuloma (MFG) is a muscular dystrophy-like anomaly of walleye in which the skeletal muscle has undergone profound structural changes. The myopathy is recognized by its swollen, coarsely fibrous, granular, and fatty characteristics. The lesion has an opaque yellow-brown color. Included in this pattern of striated muscle deformation is a consolidation and fusion of contiguous muscle fibers to form prominent aggregates of rough, cordlike strands which eventually undergo a coagulation necrosis and calcification. A simple description is that it looks like the flesh has been freezer burned. The lesions are typically found along the vertebral column while filleting.

Myofibrogranuloma has been found exclusively in adult walleyes whose ages range from 3 to 10 years. The sex frequency ratio of the disease is about equal. A higher frequency of this anomaly has been observed to occur in walleyes from comparatively small, fertile lakes and ponds in which the species is maintained exclusively by periodic stocking of hatchery-reared walleyes.

Neascus (Black Spot)

These parasites are easily discerned as obvious pigmented cysts (the size of a pinhead) slightly raised from the skin or fins, or sometimes in the mouth or flesh. The parasites commonly infest rock bass and other sunfish, bass, pike, minnows, and other fish species. Various species of black spot are found in practically all parts of the world. The black spots are actually pigmented cysts of larval trematodes which mature in fish-eating birds. The life cycle is snail to fish to bird.

Fish may be heavily infested, yet the parasites do relatively little damage in most cases and do not obviously affect growth or longevity of the fish. There is some evidence, however, that a massive infestation on a young fish may cause excessive blood loss, physiological stress, and sometimes though not frequently death.

These trematodes are incapable of infesting man, and even a heavily infested fish is safe to eat. It may be more aesthetically pleasing to skin a very heavily infested fish before eating. Cooking kills the parasite.

Nematodes

Nematodes are round, thread-like parasitic worms. As larvae or mature worms they may infest the body cavity, the swim bladder (see bladderworm), intestines, the liver, muscles, blood vessels, and the gill cavity of a wide range of fish species (Reichenbach-Klinke 1973). Some are blood parasites and can be identified by their blood red color.

None Observed

Use of this entry should be reserved for those cases where fish are examined externally, internally, or in the lab for a short list of specific conditions. In that case, “none observed” can safely be assumed to mean the fish was examined, and the targeted organism was not found.

Northern Pike Herpesvirus

Pike Herpesvirus is an agent associated with and most likely the cause of unusual hypertrophy of some epithelial cells that are embedded in plaques of hyperplastic skin epithelium. Usually seen in the spring of the year, northern pike have faint blue spots across the skin. They can be small patches or over the entire surface. Believed to be non-pathogenic, it disappears after water temperatures warm.

Open sores/ Hemorrhage

Any time one sees open sores, furuncles, fluid filled cysts the first and most likely cause is bacteria. Primary damage to the epithelial layers may have been due to parasites but now the intrusion is due to bacteria. Bacterial species responsible for such damage may be Aeromonas, Pseudomonas, Citrobacter, or other opportunistic species. Diagnosis cannot be accomplished by the naked eye. Tissues need to be cultured and tissue sections need to be studied to determine the actual identity.

Physical Injury

Fish are subject to physical injury from a number of causes. Encounters with fishing tackle, predators, and even propellors can cause injury, as can actions like creating spawning nests or driving off rivals. Physical injuries can serves as infection points for fungus and other agents, and those secondary effects may be more noticeable than the original injury.

Proliferative Kidney Disease

Proliferative Kidney Disease is a condition of salmonids first recognized in the Hagerman Valley of Idaho. The disease has been a major problem in Europe and the British Isles for many years, where it is recognized as a major problem affecting rainbow trout production, especially in Italy and France.

Affected fish typically have a distended abdomen with longitudinal swelling of the body wall at the level of the lateral line. Some fish may show dark body coloration with varying degrees of mono or bilateral exopthalmia. Prior to death, respiratory distress is obvious, probably due to a pronounced anemia. Internally, there is gross enlargement of the kidney into swollen, grayish, bulbous ridges. The swim bladder may be displaced and distorted and the abdominal swelling may be compounded by excess peritoneal fluid. The spleen may be smaller than normal or massively enlarged with patches of grayish mottling beneath the capsule.

Skeletal Deformities

Spinal and other skeletal deformities are not unusual among fish of various species. Drastic temperature changes during early developmental stages are thought to be responsible in some cases. Diet and contaminants may also be responsible in some instances.

Slime Discoloration

Most slime discoloration is due to either chemicals in the water environment or parasites present on the fish. Trichodina and Ichthyoboda are two ciliated protozoans which cause excess mucus to build causing the skin coloration to change. Skin discoloration is a clinical sign of a problem which can be very valuable to a diagnostician in determining the cause of a problem.

Spring Viremia of Carp (SVC)

Spring Viremia of carp is a subacute to chronic disease of cultured yearling, sub adult and adult common carp. The virus was first isolated in the former Yugoslavia from carp with clinical signs of erythrodermatitis and infectious dropsy, both of which are bacterial infections. Early in a SVC epizootic, fish are attracted to the water inlet and as the infection advances they become moribund, respire slowly and lie on their side. External signs include darker pigmentation, enlarged abdomen, protruding eyes, inflamed prolapsed anus, and gills are pale with distinct petechiae. Internally, there is severe hemorrhage in the visceral organs.

SVC is caused by the virus Rhabdovirus carpio. SVC only occurred in Europe until it was found in North Carolina at a koi aquaculture operation and then in Cedar Lake in Wisconsin. Species of fish commonly affected are common, crucian, bighead, silver, and grass carp. Northern pike also can be infected although not with the same clinical signs. Epizootics due to SVC occur at water temperatures of 12 to 22C with an optimum of 16-17C.

Tapeworm

Bass Tapeworm (Proteocephalus): Several species of Proteocephalus may be found in a wide variety of fresh water fish species. This tapeworm has been given the common name of the bass tapeworm as Proteocephalus ambloplitis is commonly found in the adult stage in the intestine of both largemouth and smallmouth black bass. The pleurocercoid larvae, however, are found in the body cavity and internal organs of many species of fish, especially rock, largemouth and smallmouth bass in many lakes and streams. It is the larval plerocercoid stage which is most often seen, and which causes damage to fish. The pleurocercoids develop in the body cavity and internal organs, especially the liver and ovaries. Because they do not encyst, but continue to move around, they destroy tissue and cause multiple tiny hemorrhages. This may produce adhesions and a brown color in the body cavity. Heavy ovarian infestation may cause sterility.

The life cycle of this tapeworm involves a larger bass eating a smaller fish (intermediate host) infested with pleurocercoids. Research has shown that the pleurocercoid may also migrate from the body cavity directly into the gut, thus omitting the intermediate host stage. These larval tapeworms attach to the intestinal wall of the larger fish and grow to maturity. Eggs produced by the adult worm pass into the water where they are fed upon by copepods and amphipods. Inside these invertebrate hosts a larval form emerges from the egg, penetrates into the crustacean's body cavity, and develops into a pleurocercoid. When an infested crustacean is ingested by a small fish, the pleurocercoid emerges, burrows through the intestinal wall of the fish, and migrates into visceral organs where it may cause extensive damage as a pleurocercoid. The pleurocercoid may live several months in the internal organs of a fish. The bass tapeworm will not infest humans.

Ligula: This is a large, long, thick-bodied, tapeworm found in the body cavity of cyprinids, suckers, and more rarely perch (Reichenbach-Klinke 1973). The tapeworm can fill the body cavity, crowding organs into a corner, and can cause parasitic sterilization.

Asian Tapeworm (Bothriocephalus acheilognathi): Bothriocephalosis is an intestinal infection of certain fish by the cestode Bothriocephalus acheilognathi, a Pseudophyllidian tapeworm. This tapeworm has been reported in Asia, Europe, Australia, South Africa and North America. In

North America it has been reported in Mexico, British Columbia throughout the southern US and in New Hampshire, New York and Hawaii. Fish become infected after ingesting infected copepods and development of the worm occurs in the anterior intestinal tract. Bothriocephalus is a thermophile that has an optimal temperature for growth and maturation above 25C.

Most members of the Family Cyprinidae are considered potential hosts, with the exception of goldfish. Infections have also been reported in species in the following families: Siluridae, Poeciliidae, Percidae, Centrachidae, Gobiidae, and Cyprinodontidae.

Triaenophorus

Main hosts for tapeworms of the genus Triaenophorus are northern pike and salmonids, although one species (T. stizostedionis) inhabits the digestive tract of walleye (Reichenbach-Klinke 1973). Eggs produced in the main host hatch into ciliated larvae, which are taken up by the first intermediate host, a copepod. From there the organism moves to its next intermediate host, where it becomes established in the muscle tissue, or in cysts in the liver. Intermediate hosts for this stage include lake whitefish and cisco, where its obvious presence in the muscle tissue (large elongated whitish masses spreading through the tissue) make the fish unpalatable for human consumption.

Tumors (and Anomalies)

Tumors and malformations of many kinds, some due to injuries, are found among fishes and the cause of many of them is seldom diagnosed. Certain tumors of the liver of hatchery rainbow trout, called hepatomas, are caused by various ingredients in the diet and can be avoided by altering the diet. Viruses are implicated in some tumors. Tumors occur on nearly all organs or tissues. Those on the skin are very obvious and some are spectacular. Most tumors do not appear to be fatal to the fish, and the fishermen can remove them along with the entrails before the fish is cooked.

The cause of tumors is for the most part poorly known. Of course, certain chemicals are known to be carcinogenic and may cause tumors. There is also suspicion that viruses may cause certain tumors, and that is the case with lymphocystis and lymphosarcoma. But more and more data are accumulating to implicate environmental agents as important for carcinogenesis in humans and other animals including fish. Many of these agents enter the natural waters and come in contact with fish and invertebrates. These agents, of natural, industrial and agricultural origin, are numerous and include such natural agents as ultraviolet light. Other agents include crude oil, various soluble metals and their salts, petroleum wastes, pesticides, benzyl, arsenic, domestic wastes, herbicides, aromatic amines, and various components of effluent from mines, industry, and dyestuffs.

The mechanisms by which these environmental agents act to generate neoplasia are presently unknown. That these probably do act additively and even synergistically in conjunction with multiple host factors is well known in mammalian systems and certainly should be similar in fish.

Unidentified Disease

Common symptoms of disease include (but are not limited to) abnormal swimming (changes in locomotion), color changes, growth abnormalities, changes in external characteristics (swelling, bleeding, malformations), and changes in internal characteristics. Many diseases and parasitic infestations cannot be identified without a detailed microscopic examination.

Viral Hemorrhagic Septicemia (VHS)

Viral Hemorrhagic Septicemia is a viral disease of trout, salmon and several nonsalmonid fishes. The disease occurs in susceptible fish of any age and is known to cause significant losses to fish populations. The VHS virus was once confined to European and Scandinavian countries, but has now become established in North American waters. As of 2017, the only Minnesota water known to be infested was Lake Superior.

Clinical signs of VHS vary with the severity of the infection. In acute infections, death is rapid and numerous. Fish are sluggish, appear dark in color, have exopthalmia, and are anemic. Externally, hemorrhaging occurs in the eyes, skin and gills and at the bases of the fins. Pinpoint hemorrhages appear internally in tissues around the eyes, in skeletal muscle and in the organs. The liver is enlarged and discolored and the kidneys are red and thin. In chronic infections, deaths are numerous but they occur over a greater period. External signs of the chronic form are similar to the acute form, but hemorrhaging is not as extensive. The abdomen is swollen from accumulation of fluid in the liver, kidneys and spleen. Internally the liver is pale and the kidneys gray.

The virus is a member of the Rhabdovirus group. The incubation period can be 7-15 days depending on water temperature. Outbreaks usually occur in water temperatures below 15C and cease when water temperatures rise. The greatest loss of infected fishes is between 3-5C.

The State of Minnesota is actively monitoring lakes and streams for incidences of VHS infection. Any fish suspected of being infected with VHS should be preserved unfrozen and be transported to the pathology lab immediately.

Whirling Disease (<u>Myxobolus cerebralis)</u>

Whirling disease (Myxobolus cerebralis) may be difficult to detect because the life cycle of the parasite includes two alternate hosts (salmonids and the aquatic oligochaete worm Tubifex tubifex) and the extended time required for sporogenesis in the salmonid host. The species most susceptible are rainbow trout, sockeye salmon, and steelhead. Brook trout, cutthroat trout, atlantic salmon and Chinook salmon are moderately susceptible; brown trout and bull trout, coho salmon and splake are partially resistant. Conflicting data are present for grayling and lake trout but in general these species may be considered partially resistant. Physical symptoms of whirling disease include blackened tail, whirling behavior, and deformities of the head and spine. Severe infections can lead to death. Fish are most susceptible if exposed when young, however older fish may become infected and act as carriers of spores. Development of myxospores is temperature dependent, requiring a minimum of 90 days at 16-17C and 120 days at 12-13C.

Yellow Grub

This is the common "grub" found in our freshwater fish as a yellow worm up to 1/4 inch long just under the skin, or in the flesh. Yellow grub has been reported from so many kinds of freshwater fish in North America that apparently no fish is immune to it. The grub is the larval stage which must be eaten by fish-eating birds, such as herons and bitterns, to develop. The grub matures in the throat of the bird, and eggs wash into the water from the bird's mouth when feeding. The eggs hatch and the first larval stage (miricidia } swim by means of fine hair like cilia until they find a snail of the genus Helisoma. Unless they find this snail they die within several hours. In the snail they go through several developmental stages during which they multiply a thousand fold, finally leaving the snail as a free-swimming cercariae. Unless the cercariae find a fish within a few hours, they die. When they find a fish, they burrow through the skin and encyst, where they develop into metacercariae, which are the yellow grubs. There they remain until eaten by the bird host, thus completing the life cycle.

The grubs may live for several years in the fish, thus in many lakes rather heavy infestations accumulate and the fish are classed by fishermen as unfit for food. Normal cooking of the fish destroys the grub.

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Appendix 14 – Fisheries Survey Attachment Guidelines

Fisheries Survey Attachment Guidelines

4/24/2015

Purpose of this document:

- Provide guidance on what files are and are not stored in the Fisheries Survey Database.
- Prevent storage of unnecessary files that will only take up useable space in the database.
- Provide consistency in where different attachments are kept across surveys and users.

Background:

There are numerous potential files that might be saved as attachments to surveys. Examples include maps, graphs, and tables that are currently added to a survey outside of the database, as well as raw data such as photographs, spreadsheets, or Rivermorph files relating to the survey that are not intended for reports, but may be useful for others to access in the future. We now have the capability to store these files in the database with the survey, so that they can be accessed by others besides the survey author. At present the survey reports will not automatically bring in stored attachments. We will be working with MNIT staff to create this functionality, hopefully by early 2016 in time to produce reports from the 2015 field season.

How does saving attachments work?

Within a stream or lake survey, you'll have the option to add attachments to the survey as a whole from the Survey Detail screen, or from the Component Detail screen. There is guidance later in this document on what types of files should be attached where. At either screen, clicking the "Add Attachment" button will open a window that allows the user to select a file by browsing their computer, enter a title, notes, and UTM location (if applicable) about the file, and indicate whether the file is intended to be attached to the survey report including the order of attachments. It is important to use an informative title and notes about the file, because these are the only searchable parts of the attachments. The database can't search the contents of the attachment itself to extract relevant information.

What's in?

- Maps, graphs, tables, and figures that are intended as attachments that will be printed with the survey report. These will typically be saved as pdfs or jpgs.

- Data files such as spreadsheets and Rivermorph projects that include raw and calculated data from the survey that isn't intended to be printed with the survey report, but may be useful to others now or in the future. Do not check the "Include in reports" box for these files, and leave the "Sort Order" box empty for these files.
- Photographs that are useful and relevant to the survey, but aren't intended to be printed in the report. These may include photos of sampling site locations that will aid it future staff finding the site (e.g. seine hauls, benchmarks, stream cross sections), or visual records of site conditions (e.g. emergent aquatic vegetation stands, water level benchmark locations, bankfull calls, BEHI stream banks). Do not check the "Include in reports" box for these files, and leave the "Sort Order" box empty for these files.
- Shapefiles or geodatabases that include data collected during the survey, such as GPS tracks of electrofishing runs or delineating aquatic vegetation stands. See "Saving GIS Data" section below for instructions on best practices.

What's out?

- Due to constraints on the storage space that we have available, do not use this feature as a repository for photos and other files that don't have a direct purpose for other users of the survey data. Examples might include photos of fish caught or of general survey sampling activities.
- Do not store data that are already archived somewhere else, such as GIS data that is already stored on the Geospatial Data Resource Site (GDRS).
- Do not store file types such as videos that require large volumes of storage.

Survey Detail vs. Component Detail attachment locations

- Attach files to the level that makes the most sense to the content. If the attachment relates to a specific component such as a water level benchmark location photo, attach the file at the Survey Component level. If the attachment applies to the survey as a whole (e.g. watershed maps), attach it to at the Survey Detail level.

UTM locations and dates of attachments

- If the attachment is a .jpg that comes from a GPS-enabled device or has an embedded time/date stamp, the Survey program will detect the embedded information and auto-populate those fields. However, the user will have the ability to overwrite that information if necessary (e.g. the time/date setting on the camera wasn't correct).

Saving GIS data

- Ideally, GIS data files should be <u>zipped</u> before adding as attachments to Lake Survey DB

- If data is in **shapefile** format, make sure that all files ending with the following extensions are added to the same .zip file: ***filename.shp, .shx, .dbf, .prj***
- If additional files exist, you may add them also: e.g., *.sbn, .sbx, ain, .aih, .cpg, .shp.xml*
- **To zip files:** *Select files; Right-click→Send to→Compressed (zipped) folder*
- If data is within a **geodatabase** (.gdb) format:
  - First make a new folder using Windows Explorer
  - Copy the ***filename.gdb*** file into the new folder
- **To zip folder:** *Select folder; Right-click→Send to→Compressed (zipped) folder*

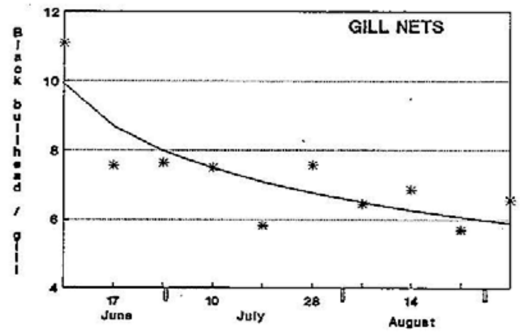
- To conserve storage space and avoid duplication of data, do not store GIS data that is/will be/or could be available via DNR Quick Layers
  - *Examples include:* standard lake outlines, stream centerlines, lake bathymetric data, mapped aquatic vegetation, sampling stations, etc. for which we have statewide GIS layers
  - If you have improved delineations, submit them to Lyn Bergquist or Andy Williquett for incorporation into the statewide GIS layers.
- To store GIS maps as attachments, export from Data Frame or Layout as PDF or an image type
  - In ArcMap, use *File: Export Map: Save as type (choose .pdf, .jpg, .bmp, .gif, .tiff, etc.)*
  - These files do not need to be zipped unless there are multiple files for the same thing

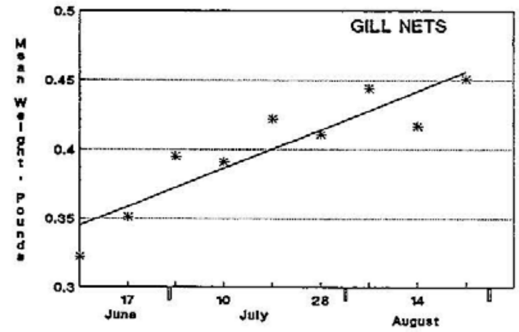
Appendix 15 – Seasonal Catch Rates for GN and TN

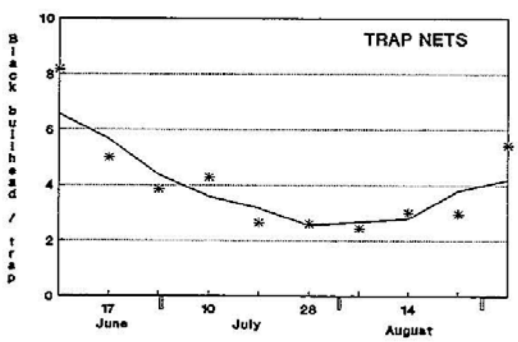
The following figures show catch rate (fish/net) and mean weight (pounds/fish) by season and species for gill nets (GN) and trap nets (TN). These figures were generated from lake survey data collected between the early 1980s and the early 1990s, and represent the average catch (statewide) for each species at specific times during the summer. This information can be used to determine the "best" sampling time for these survey methods, depending upon the target species, and to illustrate the degree to which catches may vary seasonally.

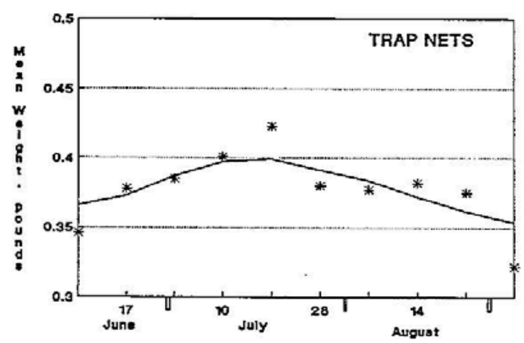
Source: Compiled by Dennis Schupp for the Manual Of Instructions for Lake Survey (Special Publication No. 147, 1993; Appendix 6).

BLACK BULLHEAD

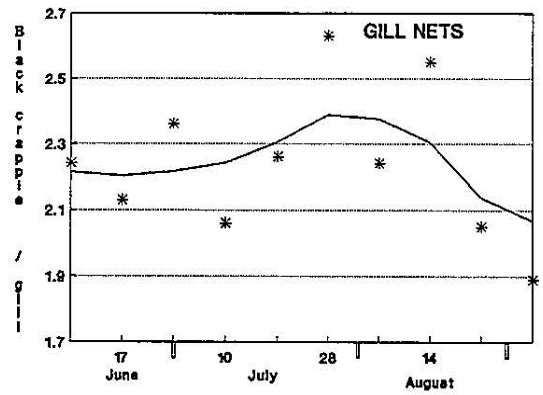


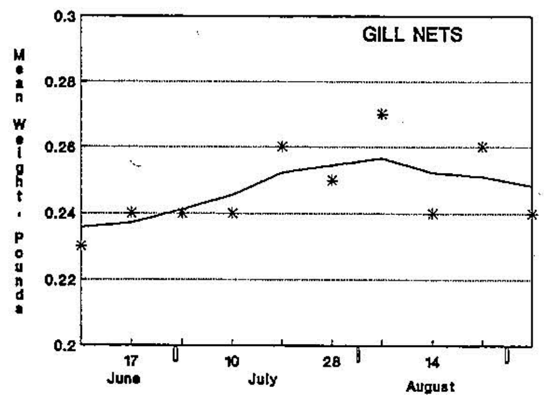


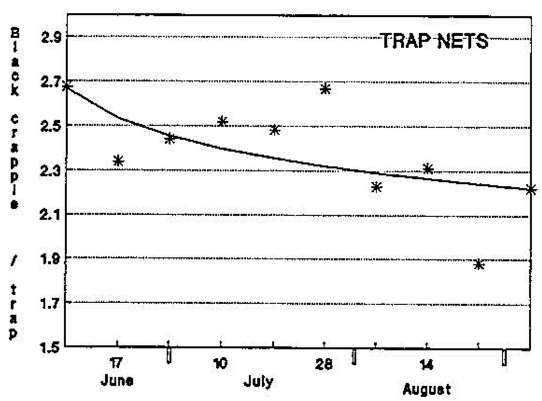


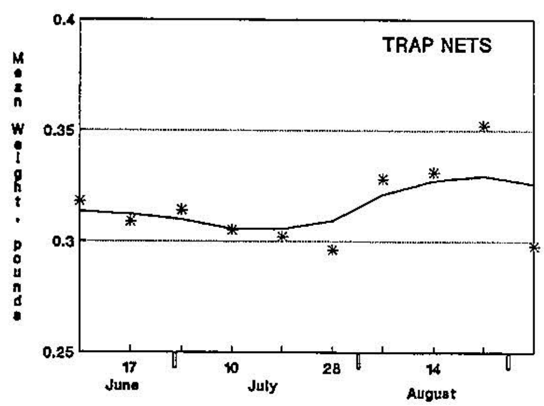


BLACK CRAPPIE

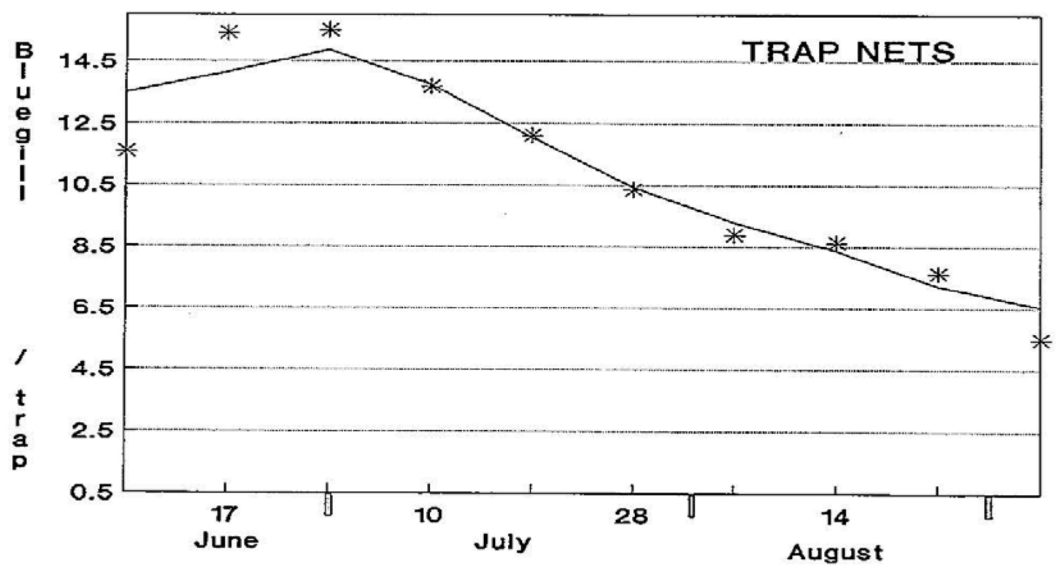


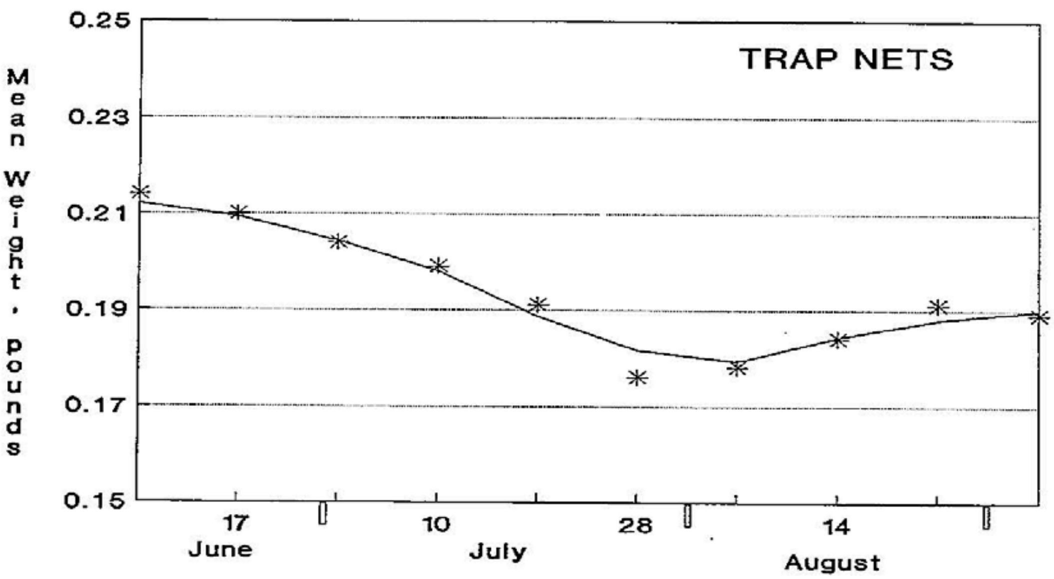




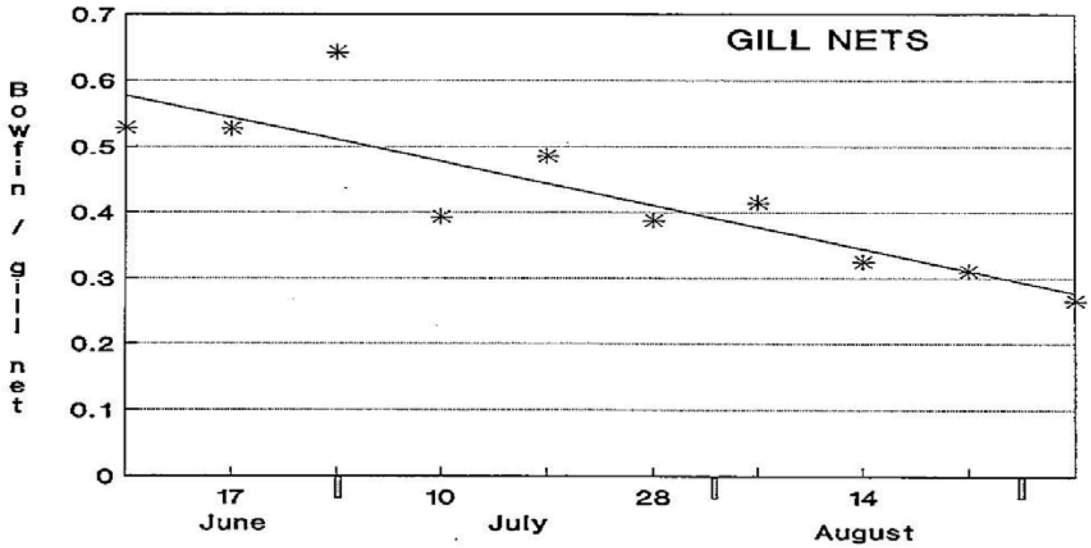


BLUEGILL

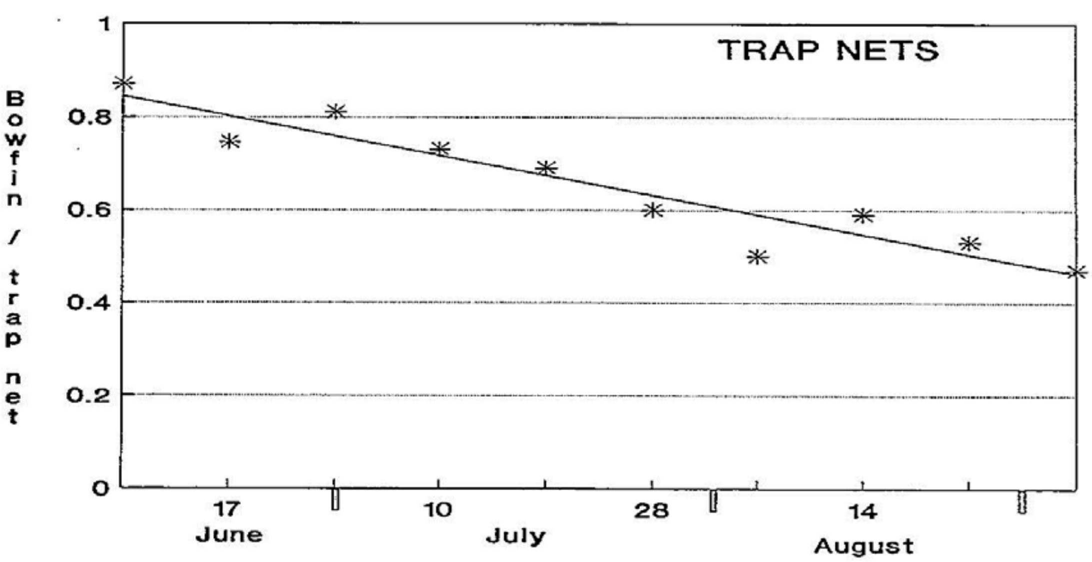

TRAP NETS
Bluegill / trap
14.5
12.5
10.5
8.5
6.5
4.5
2.5
0.5
17
June
10
July
28
14
August


TRAP NETS
Mean Weight, pounds
0.25
0.23
0.21
0.19
0.17
0.15
17
June
10
July
28
14
August

BOWFIN

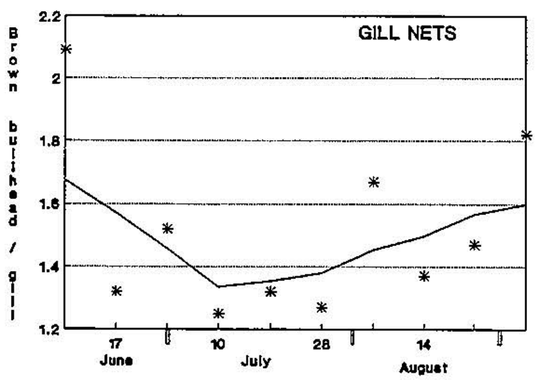


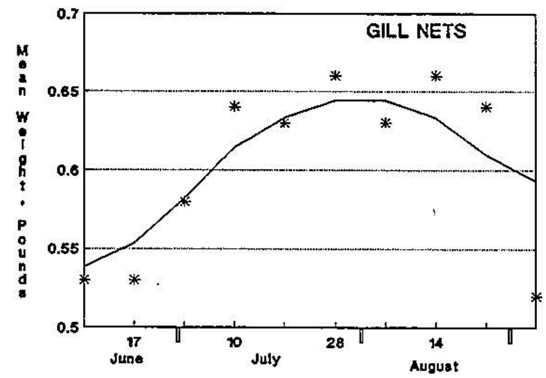
GILL NETS
Bowfin / gill net
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
17
June
10
July
28
14
August

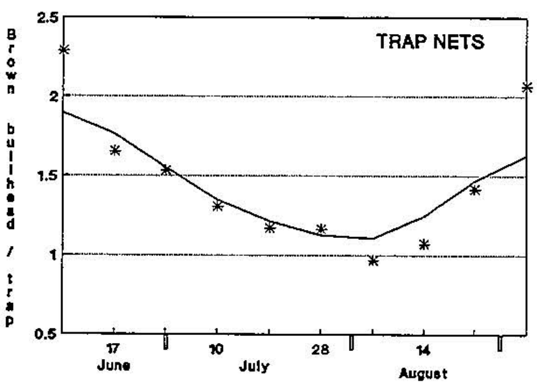


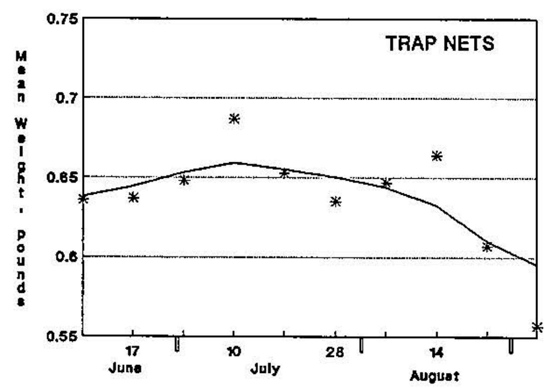
TRAP NETS
Bowfin / trap net
1
0.8
0.6
0.4
0.2
0
17
June
10
July
28
14
August

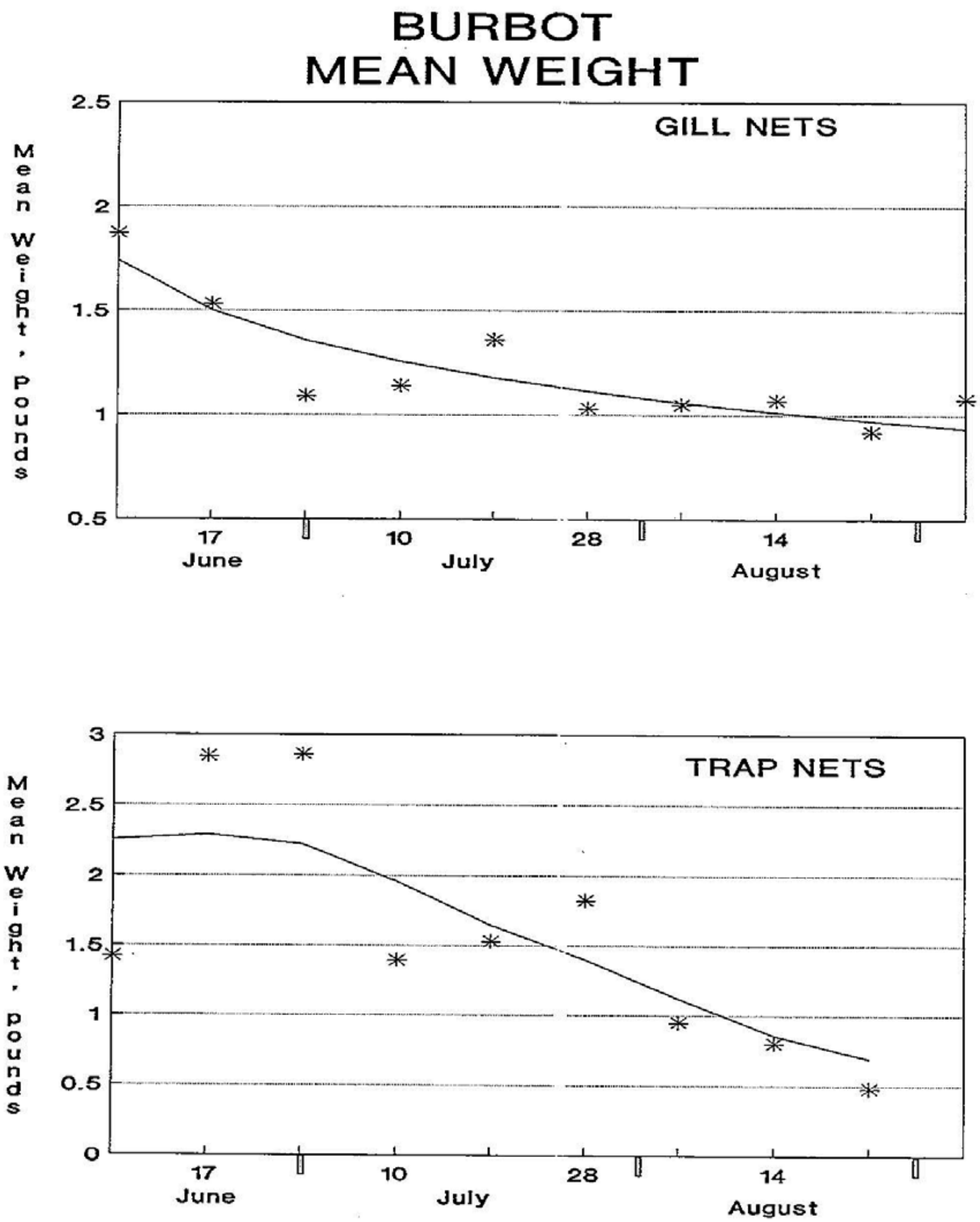
BROWN BULLHEAD



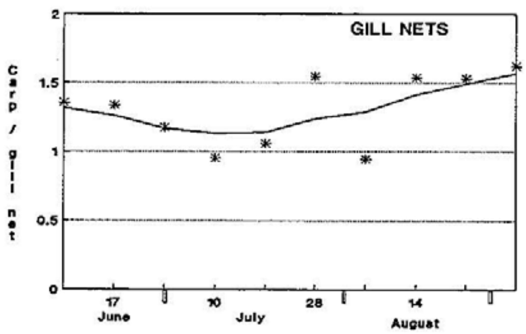


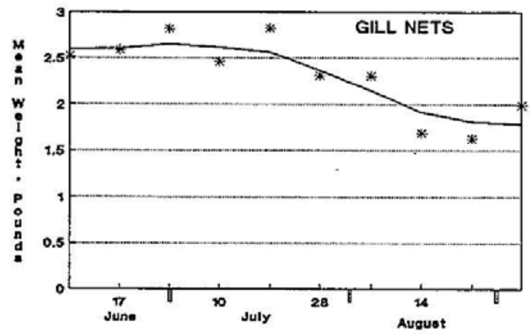


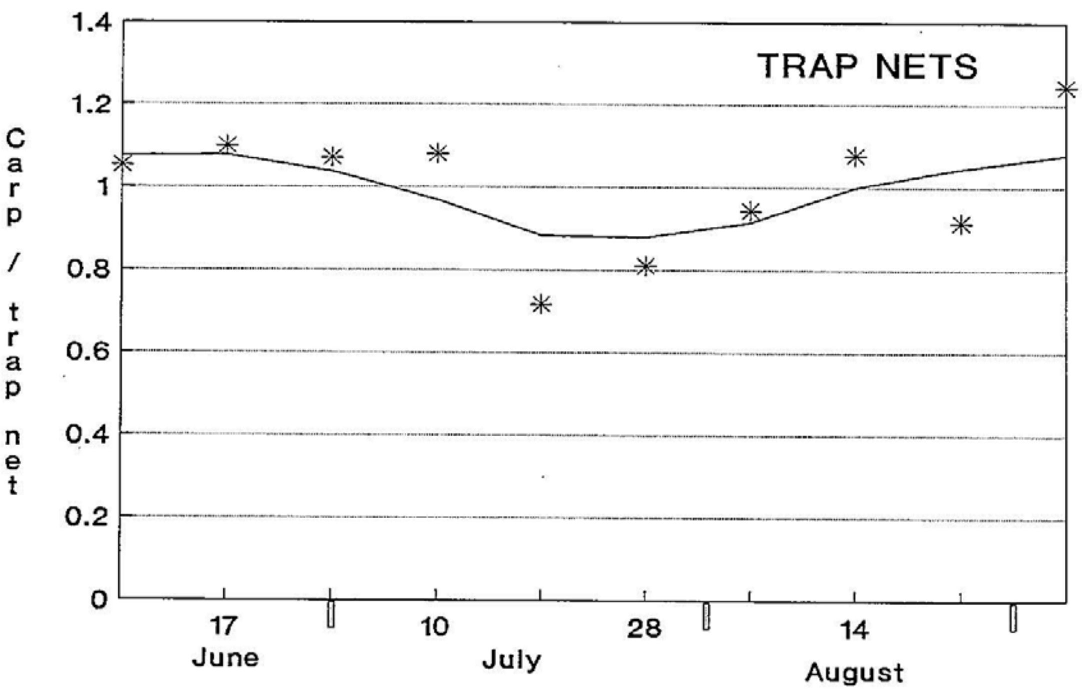



BURBOT
MEAN WEIGHT
GILL NETS
Mean Weight, Pounds
2.5
2
1.5
1
0.5
17
June
10
July
28
14
August
TRAP NETS
Mean Weight, pounds
3
2.5
2
1.5
1
0.5
0
17
June
10
July
28
14
August

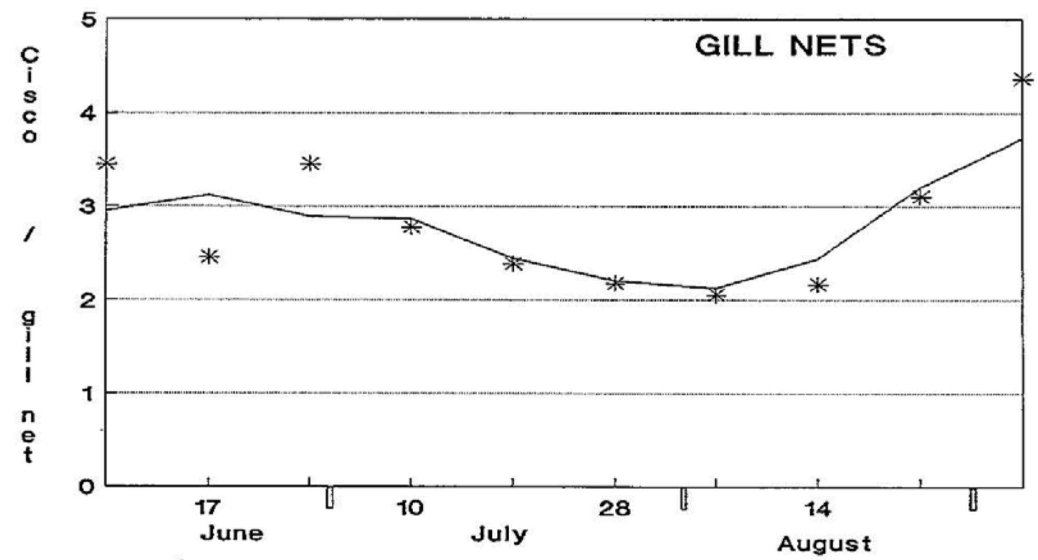
CARP

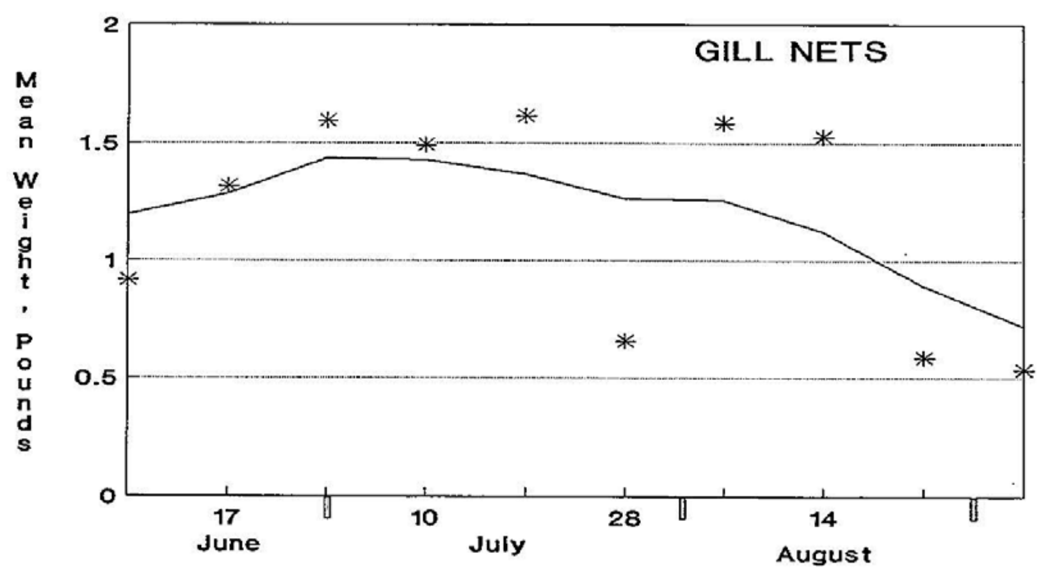

GILL NETS
Carp / gill net
2
1.5
1
0.5
0
17
June
10
July
28
14
August


GILL NETS
Mean Weight - Pounds
3
2.5
2
1.5
1
0.5
0
17
June
10
July
28
14
August

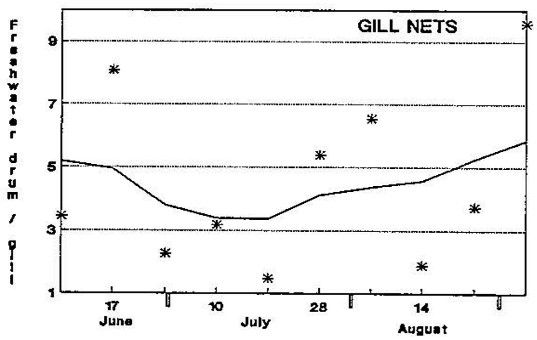

TRAP NETS
Carp / trap net
1.4
1.2
1
0.8
0.6
0.4
0.2
0
17
June
10
July
28
14
August

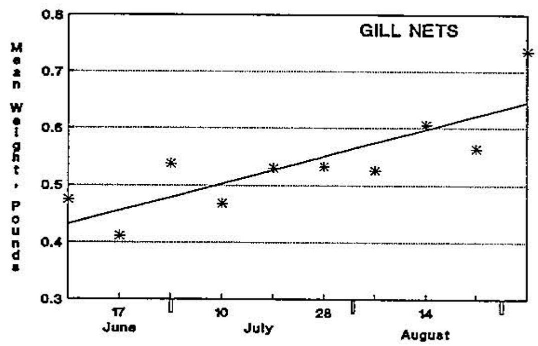
CISCO (TULLIBEE)

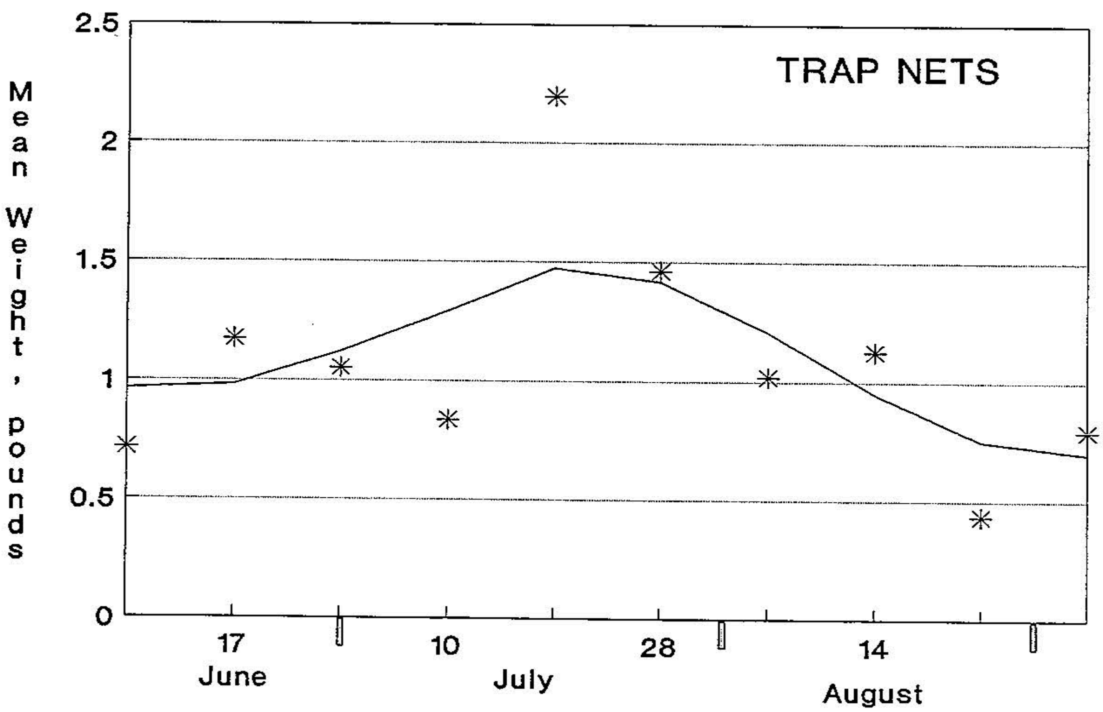


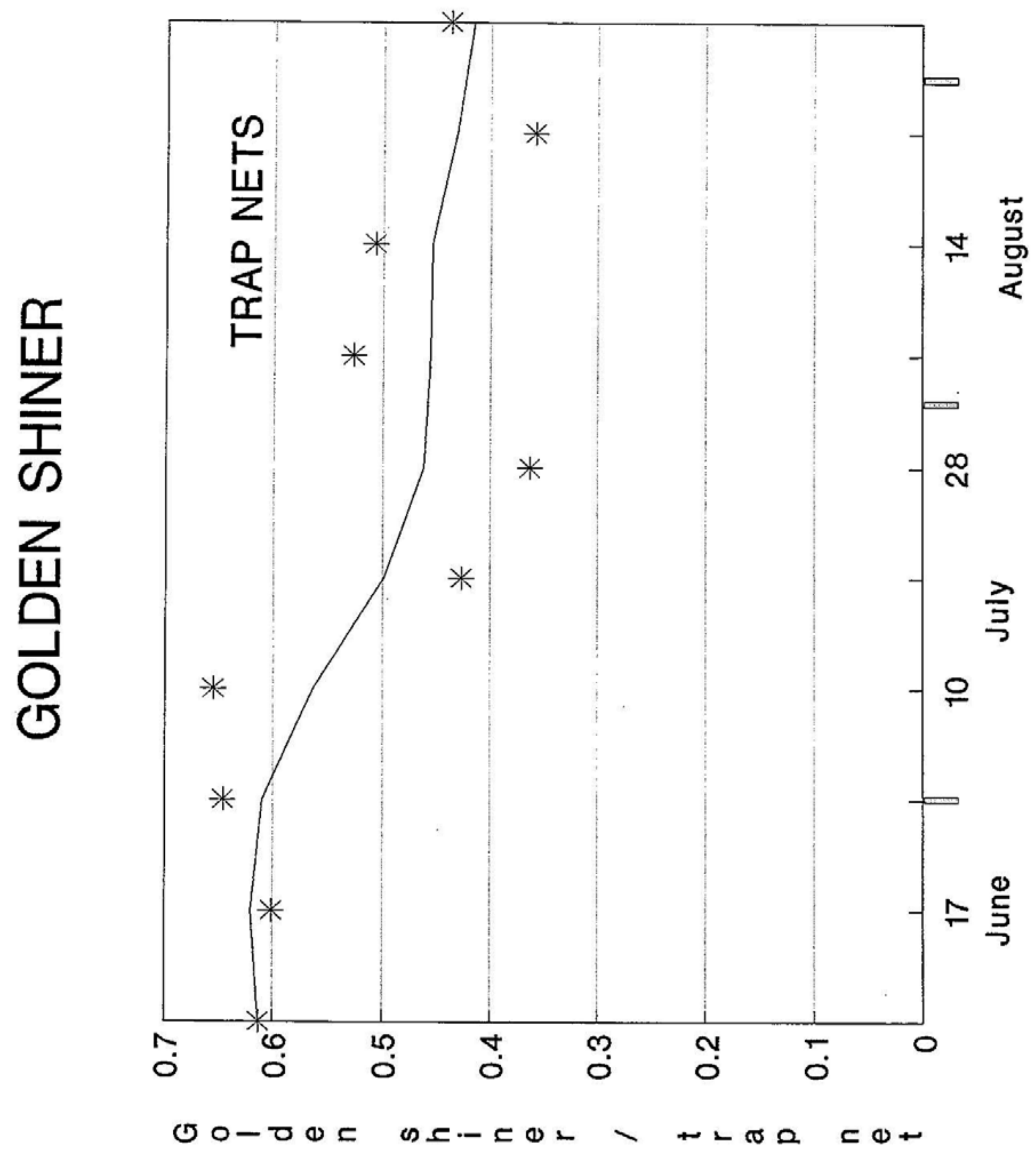


FRESHWATER DRUM

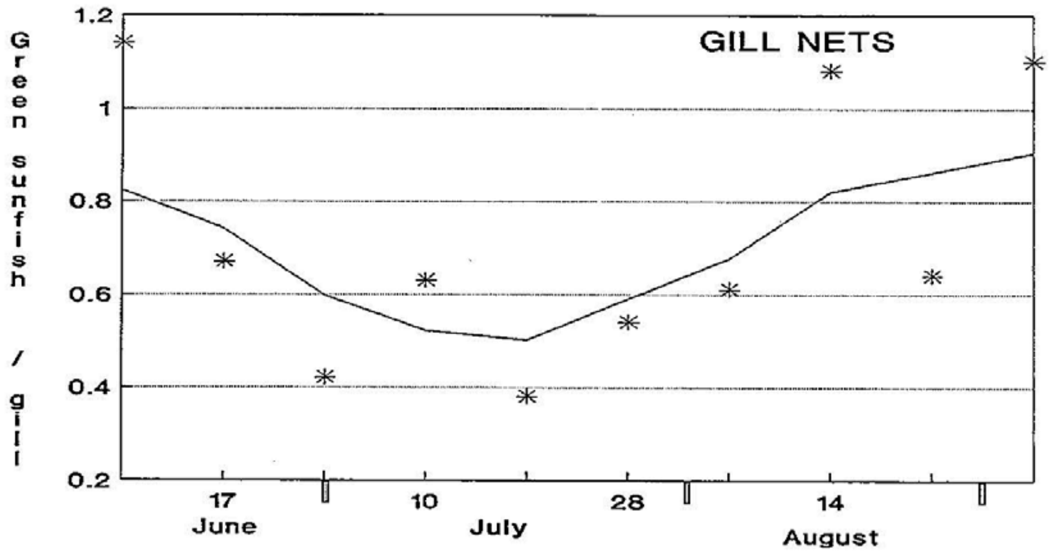


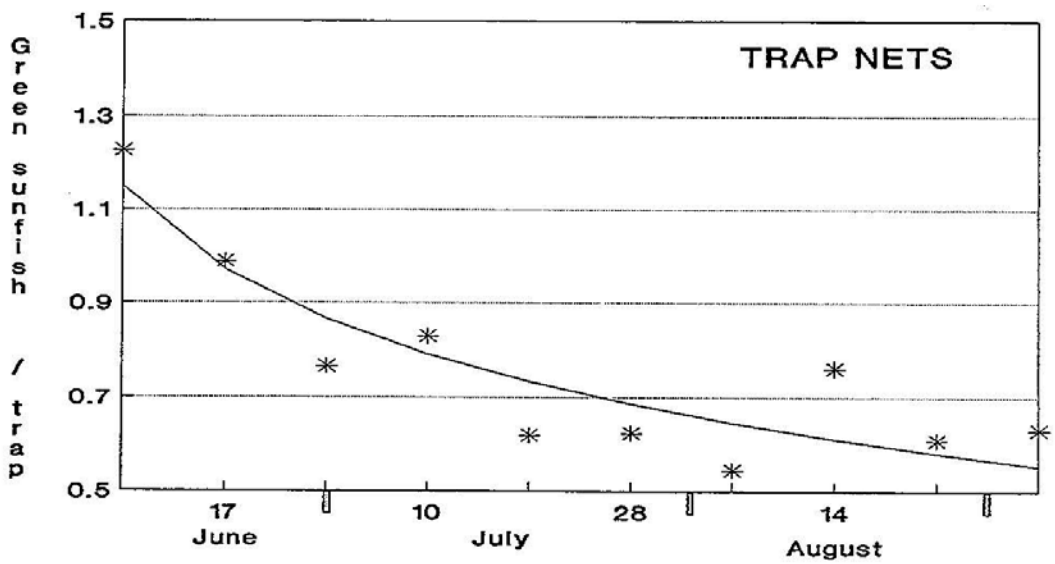




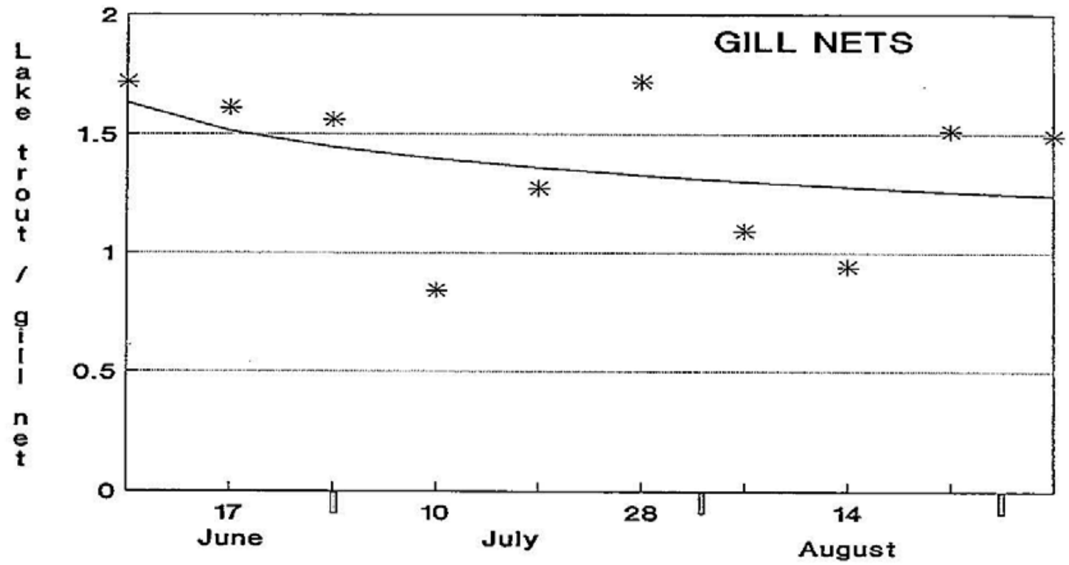

GOLDEN SHINER
TRAP NETS
Golden shiner / trap net
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
17
June
10
July
28
14
August

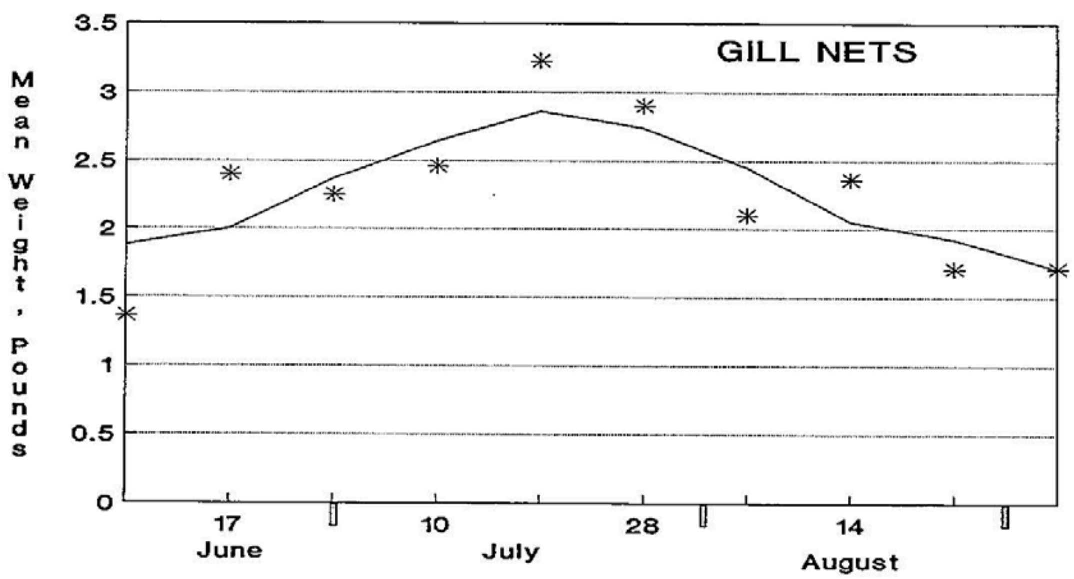
GREEN SUNFISH



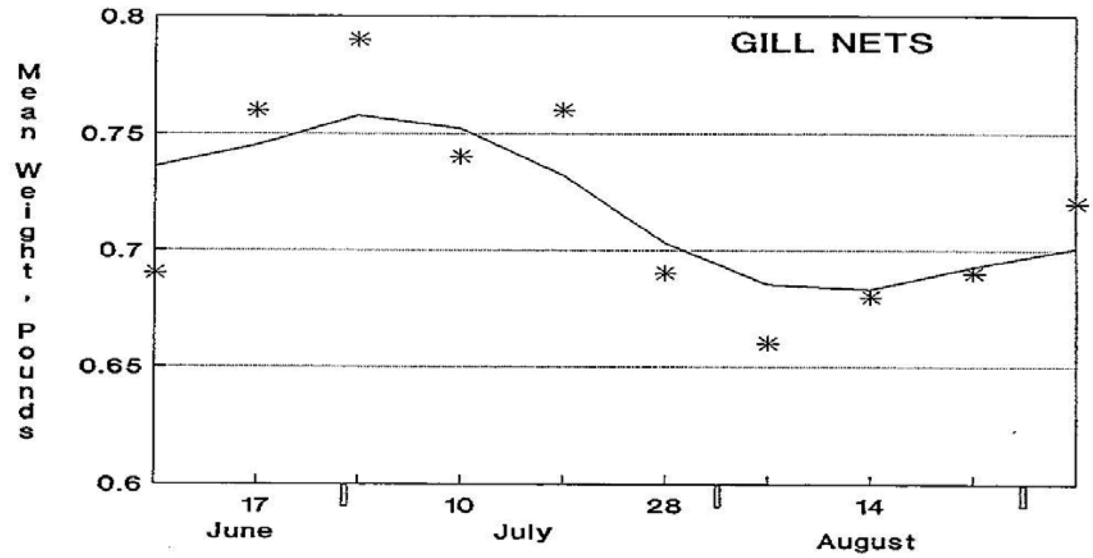


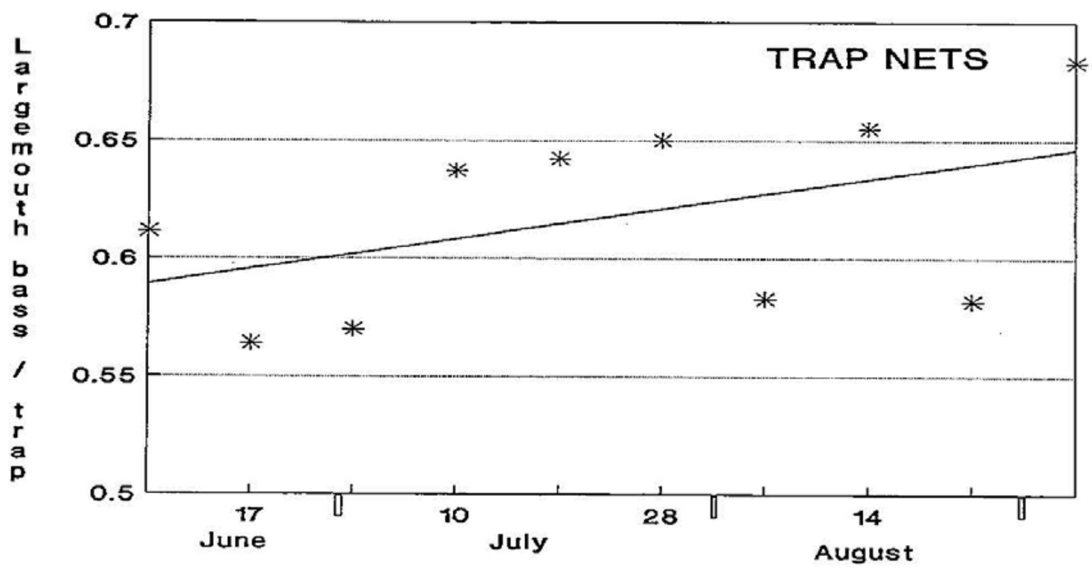
LAKE TROUT

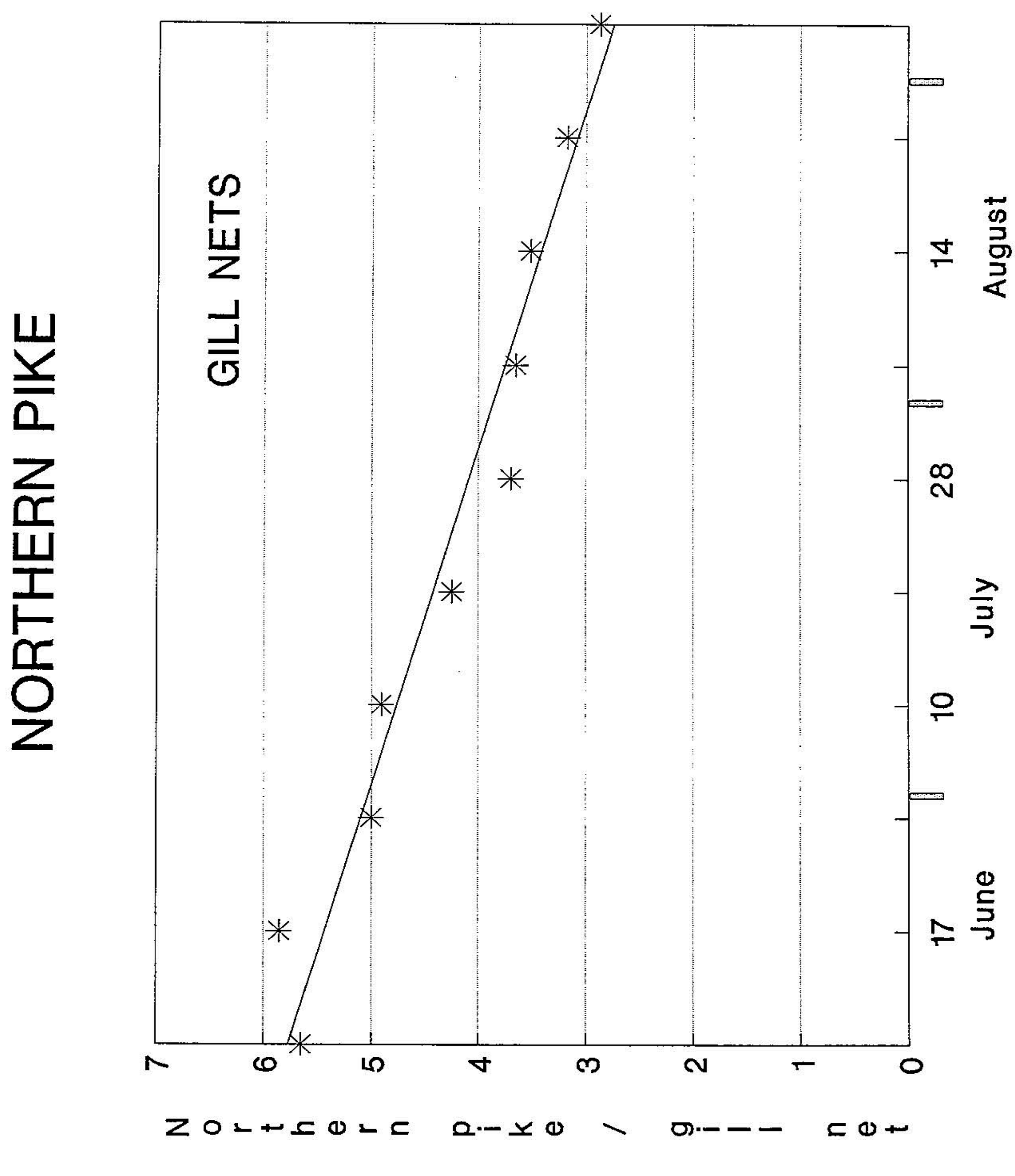

GILL NETS
Lake trout / gill net
2
1.5
1
0.5
0
17
June
10
July
28
14
August


GILL NETS
Mean Weight, Pounds
3.5
3
2.5
2
1.5
1
0.5
0
17
June
10
July
28
14
August

LARGEMOUTH BASS

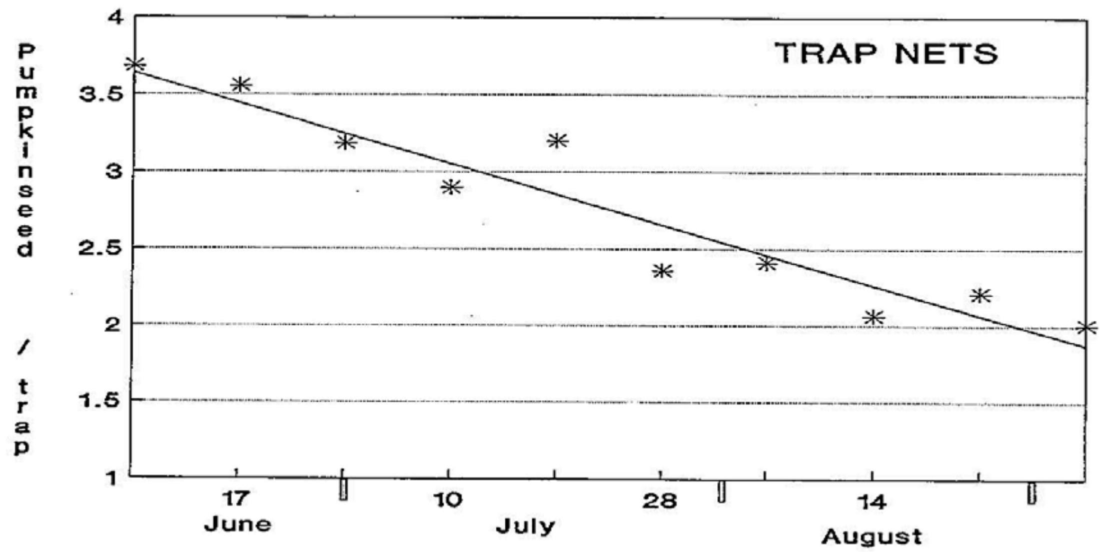


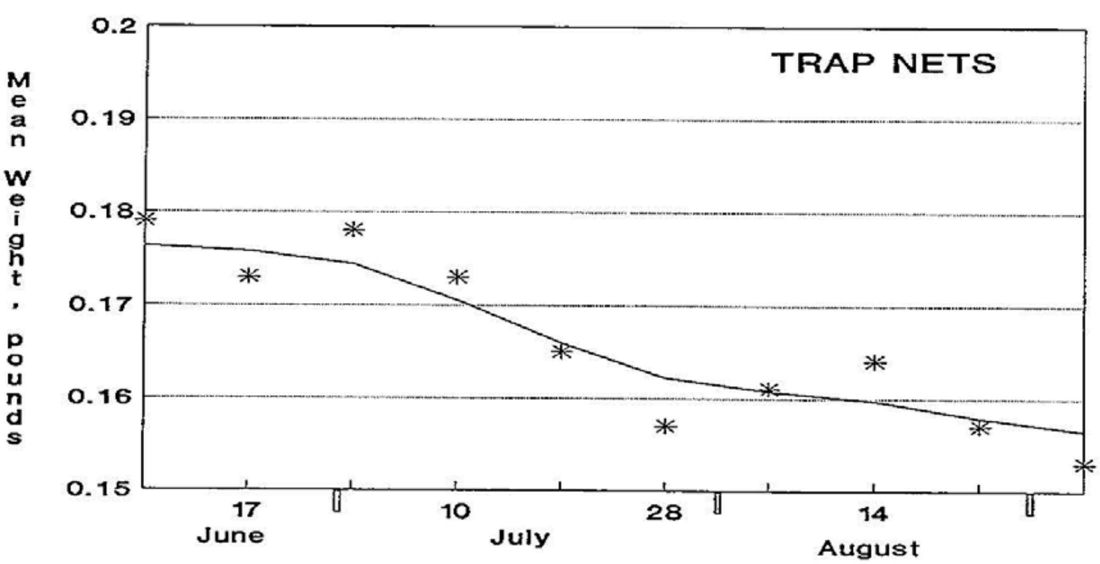




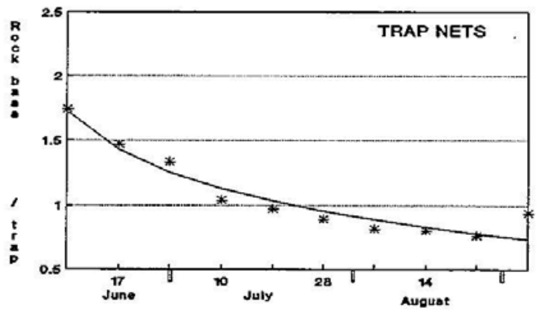
NORTHERN PIKE
GILL NETS
Northern pike / gill net
0
1
2
3
4
5
6
7
17
10
28
14
June
July
August

PUMPKINSEED

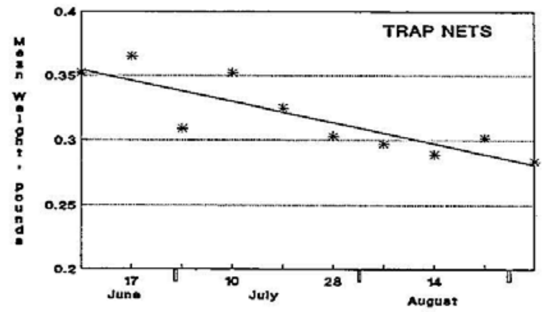




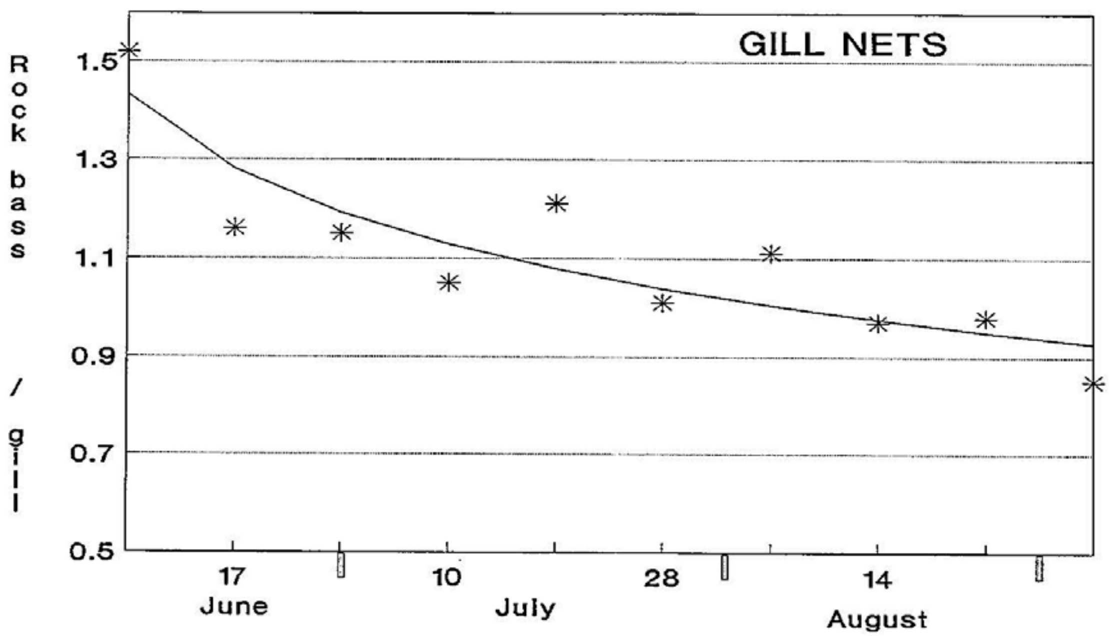
ROCK BASS



TRAP NETS
Rock bass / trap
2.5
2
1.5
1
0.5
17
June
10
July
28
14
August

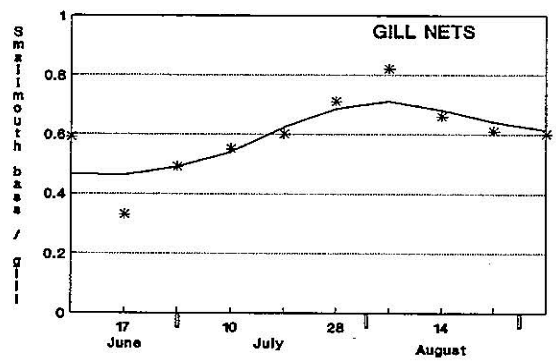


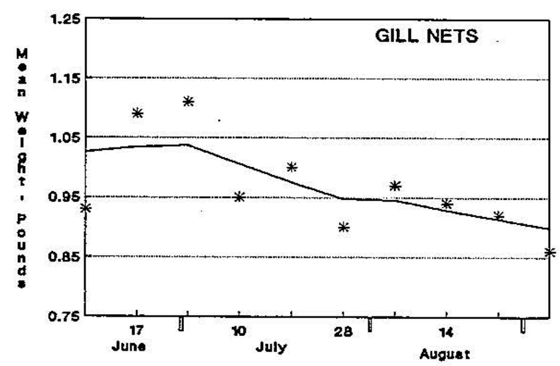
TRAP NETS
Mean Weight - pounds
0.4
0.35
0.3
0.25
0.2
17
June
10
July
28
14
August

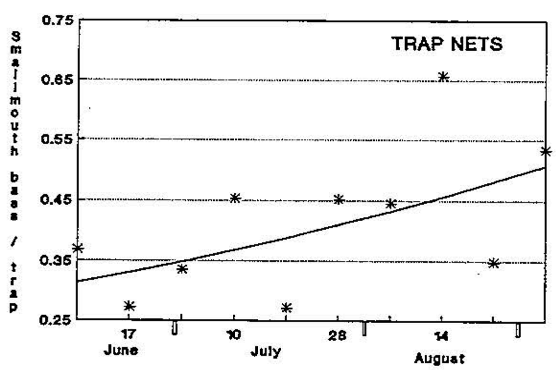


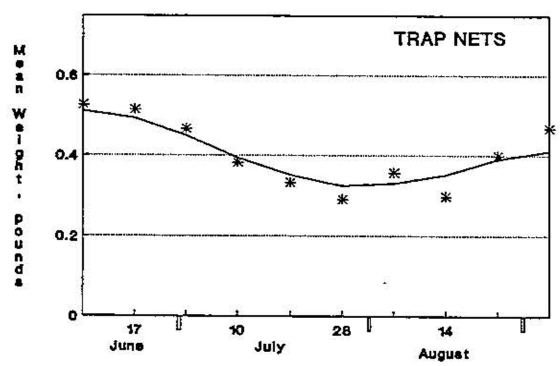
GILL NETS
Rock bass / gill
1.5
1.3
1.1
0.9
0.7
0.5
17
June
10
July
28
14
August

SMALLMOUTH BASS

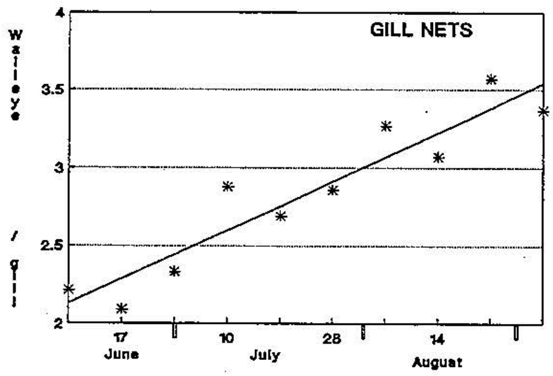


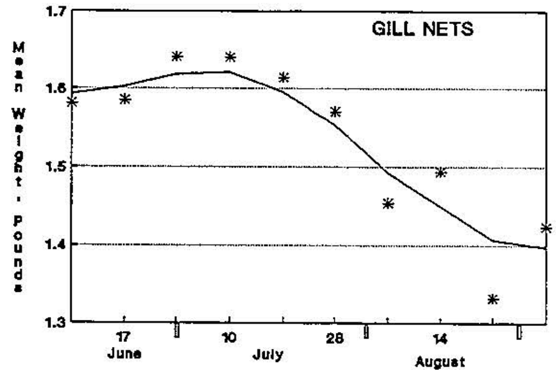


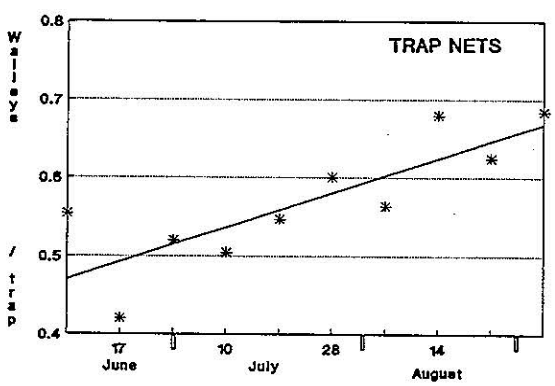


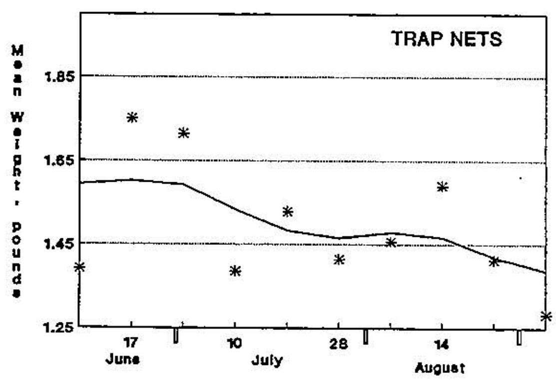


WALLEYE

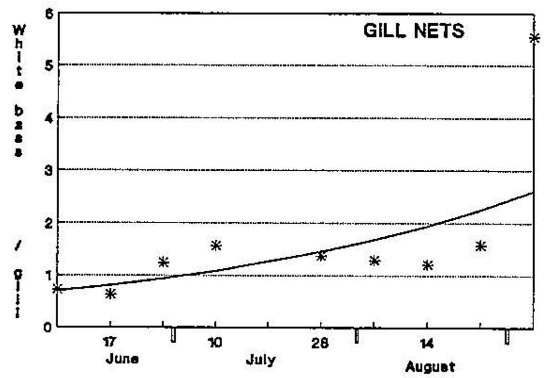

GILL NETS
Walleye / gill
4
3.5
3
2.5
2
17
June
10
July
28
14
August

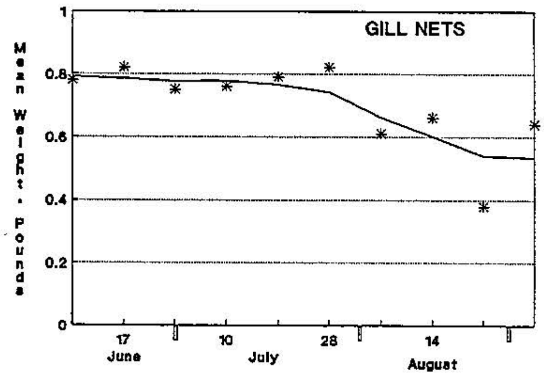

GILL NETS
Mean Weight - Pounds
1.7
1.6
1.5
1.4
1.3
17
June
10
July
28
14
August

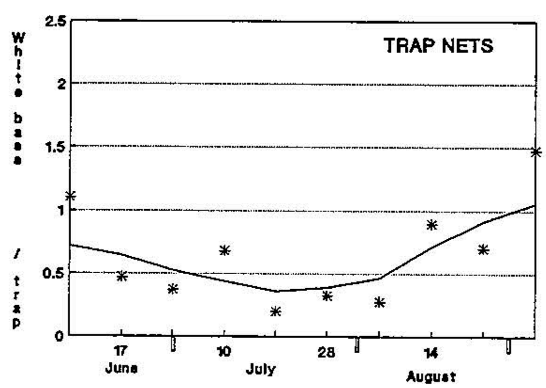

TRAP NETS
Walleyes / trap
0.8
0.7
0.6
0.5
0.4
17
June
10
July
28
14
August

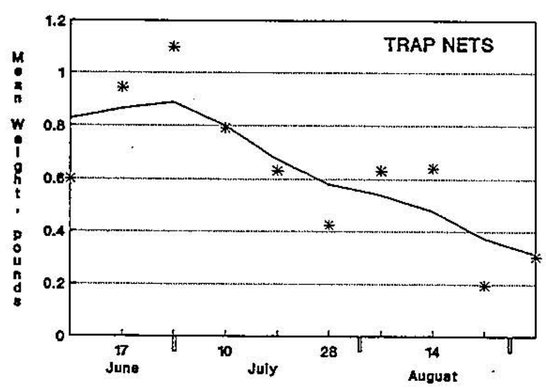

TRAP NETS
Mean Weight - pounds
1.85
1.65
1.45
1.25
17
June
10
July
28
14
August

WHITE BASS

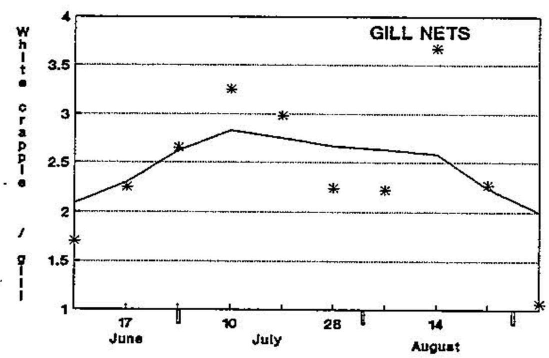

GILL NETS
White bass / gill
0
1
2
3
4
5
6
17
June
10
July
28
14
August

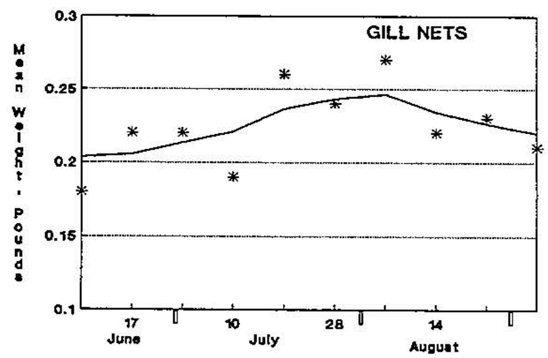

GILL NETS
Mean Weight - pounds
0
0.2
0.4
0.6
0.8
1
17
June
10
July
28
14
August

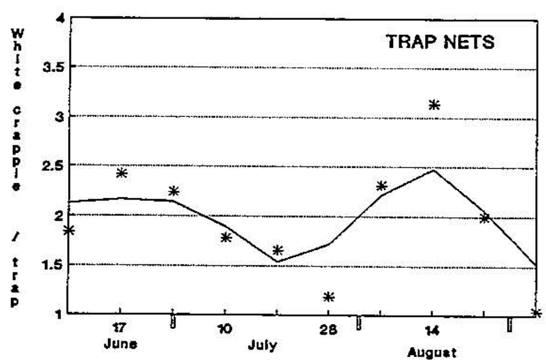

TRAP NETS
White bass / trap
0
0.5
1
1.5
2
2.5
17
June
10
July
28
14
August

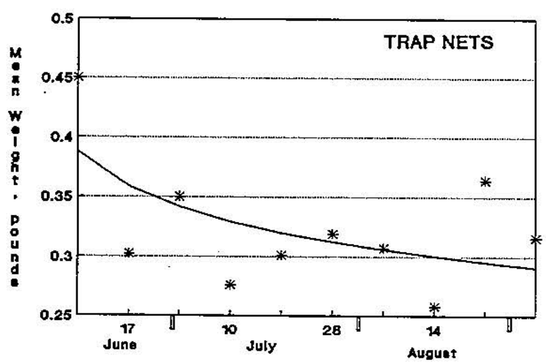

TRAP NETS
Mean Weight - pounds
0
0.2
0.4
0.6
0.8
1
1.2
17
June
10
July
28
14
August

WHITE CRAPPIE

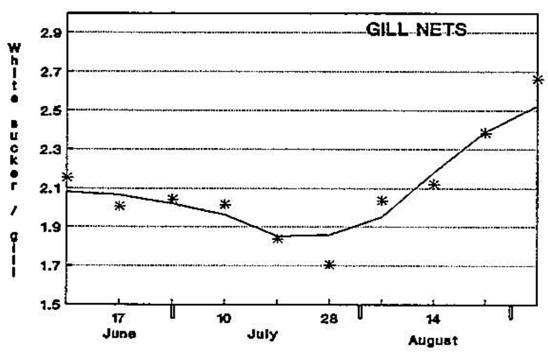


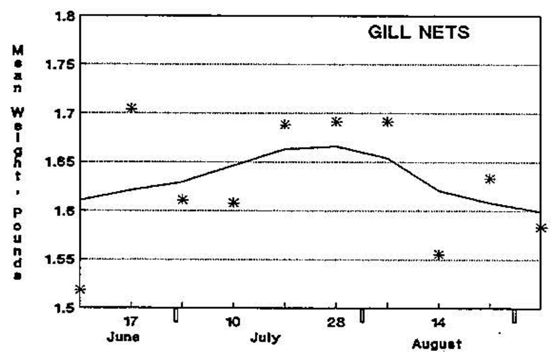


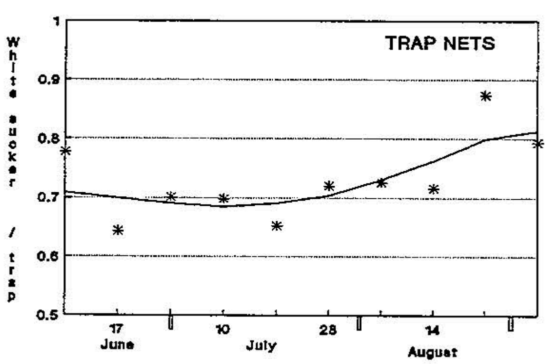


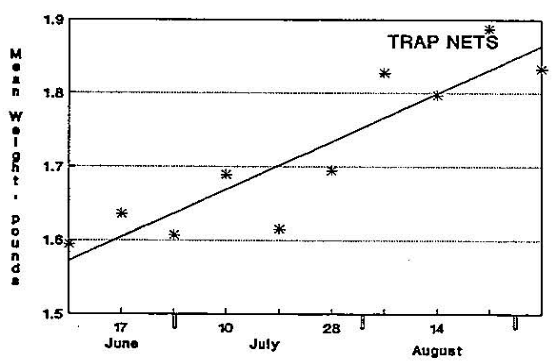


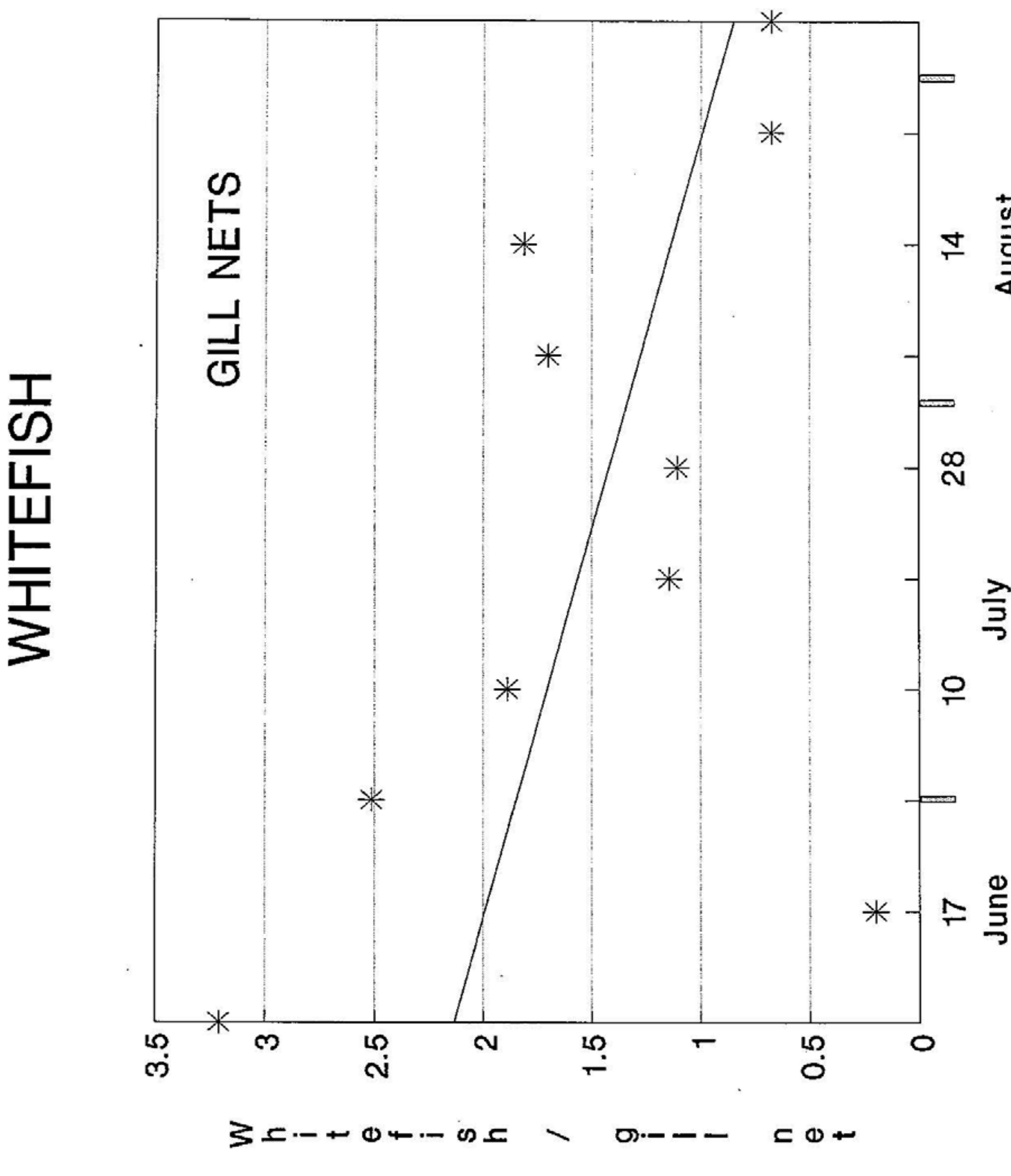
WHITE SUCKER



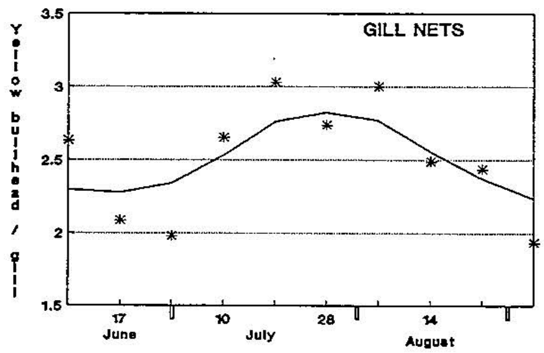


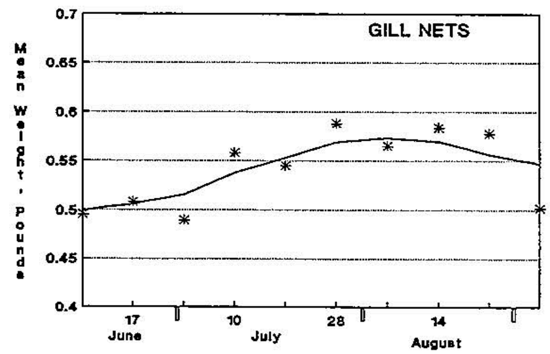


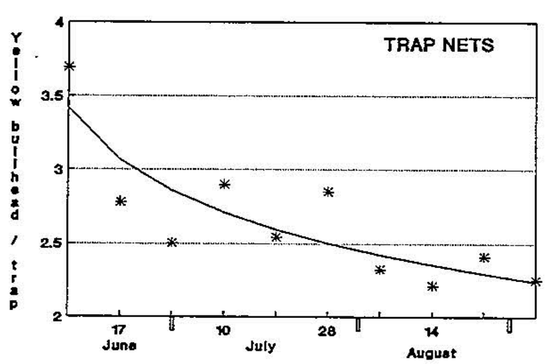


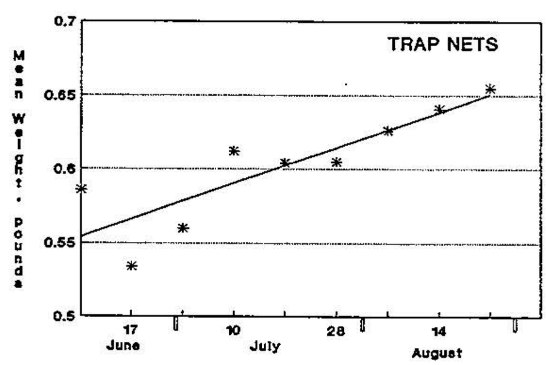

WHITEFISH
GILL NETS
Whitefish / gill net
3.5
3
2.5
2
1.5
1
0.5
0
17
June
10
July
28
14
August

YELLOW BULLHEAD









YELLOW PERCH