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Manual of Fisheries Survey Methods II: with Periodic Updates

James C. Schneider, Editor

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MANUAL OF FISHERIES SURVEY METHODS II: WITH PERIODIC UPDATES

James C. Schneider, Editor

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Foreword

The Manual of Fisheries Survey Methods was prepared in 1981 to provide a philosophical framework for sampling Michigan waters and reaffirm and standardize procedures that had drifted through the years. Forms were revised, as needed, to record the most important elements of information. The target audience was field biologists and technicians of the Fisheries Division. Generally, the emphasis was on why and how to sample, rather than exactly how to sample. That left considerable discretion in the hands of the surveyor about, for example, which species to target and how large a sample was needed to solve a specific management problem. It also left open the option to ignore fishes considered to be relatively unimportant to sport fishing.

This has been a "living" document. Sections of the original, especially appendices on growth and length-weight relationships, were updated on an irregular basis and distributed to the small list of manual holders. Some revisions did not reach their audience. By 1998, it was apparent that more sections needed updating, some ideas should to be added and others deleted, and the reasons for surveying should be broadened. Thus, this first major revision was born. It too, will never be completely finished. Some of the above problems will be reduced by maintaining an official version of the Manual of Fisheries Survey Methods II on our Intranet Web Site where it can be more easily updated and distributed. All sections of the document were updated and edited. The names of the original authors (some of which have retired) were retained on the new version unless changes were substantial.

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In 1981, as now, certain types of information were essential and could be meaningfully summarized on forms. Paper forms are gradually being replaced by computerized forms linked to databases. However, the concept of forms as packets of related information remains viable and is still the organizing theme of this revision. The new computerized "Fish Collection System" has eliminated some paperwork and guarantees accurate computation of many statistics used routinely. Forms that have been essentially replaced by the computerized system are FISH COLLECTION (R-8058), SURVEY PLANNING (R-8060), and FISH GROWTH (R-8070). Variations of these forms are in electronic format and can be downloaded. Computer software can also create tables used for Status of the Fisheries Reports. These reports summarize catch by species and size, and growth and age composition information.

"Users Guide for the Fish Collection System, April 8, 1997, DNR Fisheries Division" describes the current capabilities of the computer system and exactly how to use it. Consider it a companion document to this survey manual. It is available as a MS-Word document on file servers at most DNR offices under the file name: FISCOL.DOC.

Some forms have been little used since 1981. Examples are LAKE SURVEY SUMMARY (R8063), STREAM SURVEY SUMMARY (R8064), and LAKE PHYSICAL DESCRIPTION (R8057). They are still included in the revision because they contain important elements of information and should be used when appropriate. If nothing else, they can guide the assembly of databases that are in the process of development.

For additional practical discussion of fish survey methods, see "Fisheries Techniques" (2nd edition), edited by B. R. Murphy and D. W. Willis and published by the American Fisheries Society in 1996.

Special thanks go to Alan D. Sutton and Ken Muha for preparing the electronic version of Manual of Fisheries Survey Methods II and to James Breck for editorial assistance.

James C. Schneider, editor
January 2000

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Manual of Fisheries Survey Methods II: with periodic updates

Chapter 1: Introduction to Survey Manual

James C. Schneider and James W. Merna

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Chapter 1: Introduction to Survey Manual

James C. Schneider and James W. Merna

1.1 Perspective

Surveys are important. They:

- Document the characteristics of the state's aquatic resources at a point in history;
- Provide a factual basis for fisheries evaluation, planning, management, and re-evaluation;
- Supply data for other aquatic scientists and managers.

Good survey information becomes increasingly valuable as time passes and conditions change. Data collected by fisheries personnel over many years are essential for defining and understanding historical trends in fisheries and water quality. However, survey data become almost useless if their precision is in doubt, or if they are not recorded accurately or in sufficient detail. Quality control must be maintained for both present and future needs.

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1.2 Survey planning

Problems of modern fisheries management are complex and diverse, and so are the types of information and surveys needed to solve them. Consequently, it is essential that survey objectives be carefully defined before field work begins so that the right data can be collected efficiently. In formulating survey objectives, consider the types of information needed, how precise it must be, limitations of sampling gear, and financial and time constraints. The **Survey Planning Report** in the computerized **Fish Collection System** has been developed to aid the planning process.

1.3 Objectives and description of survey modules

The goal of lake and stream surveys is to develop a description of a body of water, its watershed, and its inhabiting biota that will be useful for fisheries management. This description will be developed by summing information from several survey modules. Each module describes one facet of the water body, watershed, or biota. Biota includes primarily fish populations, but also supporting organisms. Specific objectives and sampling techniques may vary between lotic and lentic environments, and according to the need to address specific management questions.

It is recognized that seldom will there be occasion to complete a comprehensive study of a water body in any one survey. However, it is advantageous to accumulate data in an orderly fashion by completing entire survey modules at every opportunity. In time, the summation of modules will furnish a complete description of all major waters of the state.

The following five types of survey modules will serve as a guide for the orderly accumulation of data.

1.3.1 Drainage and basin descriptions

The objective of this module is to provide appropriate uniform methods for describing relevant characteristics of the setting of a lake or stream. The description should include the immediate drainage area and the basin itself. Observations about drainage area should focus on characteristics that may directly or indirectly affect the subject body of water.

Lake basin descriptions should include shoreline features, bottom types, morphometry, and critical habitats vulnerable to human degradation. Critical habitats might involve marshes, spawning areas, or shoreline areas vulnerable to dredging, filling, or erosion.

Stream descriptions should include bottom types, stream profiles, flows, depths, and critical areas subject to abuse and damage.

1.3.2 Limnology

The objective of this module is to provide appropriate uniform methods for describing physical and chemical parameters that delineate fish habitat and reflect the biological productivity of the water body. Properties to be measured include pH, alkalinity, nutrient concentrations, clarity, and temperature-oxygen depth profiles.

1.3.3 Plants and Invertebrates

The objective of this module is to provide appropriate uniform methods for describing biota (other than fish) that are indicators of productivity and habitat. Organisms of interest include phytoplankton, macrophytes, zooplankton, and benthos. Seldom do we have the luxury of sufficient time to enumerate abundance of individual species, or even to make reliable estimates of community biomass. However, qualitative estimates of abundance often serve as indicators of productivity. Since phytoplankton is usually the most significant constituent of the primary producers, measures of chlorophyll and Secchi disk transparency serve as the most practical indicators of primary production and are predictably linked to fish production (see Chapter 21). Estimates of both density and coverage of macrophytes are important not only as indicators of productivity, but also because of their role in sheltering fish, providing spawning substrate, protecting shorelines from erosion, absorbing nutrients, and indicating general lake quality.

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Surveys of zooplankton and benthos are highly desirable when conducted with a specific goal in mind, such as evaluating survival and production of trout in lakes (see Chapter 18).

1.3.4 Fish Surveys

The objective of this module is to provide appropriate uniform methods for collecting key statistics needed to describe and analyze fish communities and populations. Fish surveys are usually conducted to:

- Describe the status of the fish community and its component populations, or
- Evaluate specific problems or management programs.

Descriptions of fish communities should be as precise and as complete as possible to facilitate comparisons with past and future data. It is imperative that sampling effort be standardized and accurately described. Data collected by various types of fishing gear should be analyzed separately since each has its own built-in bias.

A basic description of a fish community should include a list of species present; plus relative abundance, size frequency, and (usually) growth of important species.

More detailed analyses of fish populations should contain measures of rates of recruitment, growth, production, and mortality. Additional data might include standing crop population measurements or observations on endangered and threatened species (see Chapter 16).

1.3.5 Fishery Assessment

The objective of this module is to provide appropriate uniform methods for describing fisheries. Local reports of fishing quality and complaints are worth recording if they are carefully screened. However, an accurate analysis of a fishery requires a well planned and managed creel census to estimate fishing pressure, fish catch, and fishery value. Creel census methods can be found in Chapter 14, and assistance is available at the Institute for Fisheries Research (IFR).

1.4 Forms and Information Systems

The objective of this module is to provide appropriate and uniform methods for completing survey forms. Many of the survey forms were revised or replaced in 1981, and additional changes will occur as components are added to the computerized Fish Collection System. The main objectives in 1981were to require greater precision (e.g., more size intervals in the length-frequency records), simplify the recording of field data and its transfer to final forms, provide reminders and space for field notes, encourage and aid the analysis of survey results, and get data into formats adaptable to computerization. Paper files for forms not yet computerized should continue to be maintained at four locations (Local Office, Watershed Management Unit, Lansing, and Institute for Fisheries Research). It is strongly recommended that paper copies of both computerized and non-computerized forms be kept at local offices and IFR, even after computerization is completed. Certain types of computations (length-weight regressions, mark-and-recapture estimates, back-calculated growth) can be performed on spreadsheets which are available at IFR and elsewhere.

Forms are described in Chapter 4.

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The computerized Fish Collection System began operation in the mid1990s. It is based on the contents of The Manual of Fisheries Survey Methods. By the year 2000, some important paper forms (especially the FISH COLLECTION form) had been replaced by electronic versions featuring the same elements of information. These versions may be printed out or retrieved on-screen. Basic tables used in Status of the Fishery Resource Reports may also be automatically generated, formatted, and printed. Survey components of lesser importance are still to be added to the System. Refer to “Users Guide to the Fish Collection System” (1987 or updated version) for the current capabilities of the System and instructions on how to use it. It is available as a MS-Word document on file servers at most MDNR offices under the file name: FISCOL.DOC. The latest innovation is hand-held field computers into which survey data can be recorded while at lakes and streams, then easily downloaded into the master database back at the office. This eliminates the need to record data on paper, and eliminates potential errors when data is transcribed from paper to computer.

Written in 1981 by J. W. Merna and J. C. Schneider
Extensively revised 01/2000 by J. C. Schneider

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Chapter 2: Modules for Lake and Stream Surveys

James C. Schneider, Gaylord R. Alexander, and James W. Merna

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Chapter 2: Modules for Lake and Stream Surveys

James C. Schneider, Gaylord R. Alexander, and James W. Merna

This chapter will describe the five basic types of survey modules and related procedures introduced in Chapter 1. These modules are: drainage and basin descriptions (Section 2.1), limnology (Section 2.2), plants and invertebrates (Section 2.3), fish surveys (Section 2.4), and fishery assessment (Section 2.5). Both lakes and streams will be discussed.

2.1 Drainage and basin descriptions

2.1.1 Lakes

The LAKE PHYSICAL DESCRIPTION form (R-8057) is to be used to record observations of the watershed and the lake basin. Comments on the watershed should note potential problem areas requiring frequent observation. These would include areas of potential erosion, contamination, or alteration. Sources of contamination should be brought to the attention of Department of Environmental Quality enforcement personnel. Effects of dams and outlet flow on potential movement of fish should be noted.

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Several lake basin measurements (e.g., area and depth) can be taken from hydrographic maps, while others (e.g., flushing rate) must be calculated in the office and may not be determined until needed. Heating degree days is useful for predicting fish productivity (Chapter 21). All other information requested on the LAKE PHYSICAL DESCRIPTION form should be completed at the site.

Potential problem areas found on lakes (or streams) should be documented with notes and photographs. Such records are the basis for measuring short- and long-term trends.

2.1.2 Streams

The STREAM SURVEY SUMMARY form (R-8064) will be used to record characteristics of streams and their watersheds. Even though the form is designed to describe an entire stream, most of the recorded information will by necessity reflect study stations. A complete stream description will thus consist of the summation of data from several, or many, stations.

Conditions on streams or their watersheds which are creating (or may create) management problems should be recorded. These include such things as: (1) erosion from stream banks, roads, timber cutting operations, development, etc.; (2) impoundments made by man or beaver; (3) outflows from ponds dredged adjacent to streams; (4) barriers such as dams, culverts, waterfalls, etc.; and (5) pollution, which might involve chemical toxicants in the stream and/or aquifer, manure and commercial fertilizers, sewer effluents and seepage, sedimentation, temperature degradation, etc.

The quality of streams as sport fish habitat is largely determined by the relative size, depth and frequency of pools. In general, good pools are deeper and wider than the average width and depth of the stream. Current must be reduced and cover should be present for good fish habitat. Pools should be judged by their size, type, and frequency.

The following pool classification is modified from Lagler (1952):

Pool Size

1. *Large*: Wider or longer than average stream width.
2. *Average*: Width or length equal to average stream width.
3. *Small*: Narrower or shorter than average stream width.

Pool Type

1. *Deep*: Relatively deep (> 2 feet), with cover (vegetation, logs, roots, boulders, or overhanging bank).
2. *Moderate*: Intermediate in depth and cover.
3. *Shallow*: Shallow, exposed, without cover (scouring basins).

Pool Frequency

1. *Many*: More or less continuous pools; pool area to riffle area ratio approximately 3:1.
2. *Frequent*: Pool area to riffle area ratio about 1:1.
3. *Infrequent*: Extensive shallow riffles; pool area to riffle area ratio approximately1:3.

All streams have been classified by the 1967 Michigan Stream Classification System (Chapter 20), and that classification should continue to be listed on the STREAM SURVEY SUMMARY form. The 1967 system basically defines types of trout and warmwater streams and was used to generate a list of legally designated trout waters. An updated list is maintained at the Fisheries Division, Lansing. A new system for classifying streams is being refined (Seelbach et al. 1997).

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For a broader overview of drainage characteristics than space on the form allows, write a narrative describing soils, topography, vegetation, land use, unique features, and problems and include a topographic map. The most complete descriptions of a watershed, its uses, and fisheries potential should be detailed in a formal "Watershed Report." For an example, see Huron River Assessment (Hay-Chmielewski et al. 1995).

Surveys of stream habitat are based on zones and stations, and should include the important characteristics described below. Habitat data reflect not only the quality of the environment for fish, but also provide units for expressing fish density, such as number of fish per unit of stream length, area, volume, or discharge.

2.1.2.1 Zones.–First, partition the stream into segments (zones) about 8 km (5 miles) long. This can be done on drainage topographic maps. If you want to number these zones, start at the stream mouth and number consecutively as you proceed up the mainstem to its source. Then number the tributary zones similarly, beginning with the lowest tributary in the drainage (Figure 2.1).

2.1.2.2 Stations.–The station is the basic sampling unit where most measurements of the stream's physical, chemical, and biological parameters will be made. Select one (or more if necessary) sampling station near the center of each zone. The station must be representative of its zone and should be easily located from landmarks.

2.1.2.3 Length.–A sketch of the sampling station should be made on the Field Map Sheet (Figure 2.2). Use GPS (Global Positioning System) equipment to fix the locations of station boundaries and features, and note directional orientation and prominent landscape features (roads, bridges, etc.). Both upper and lower boundaries of the station should be permanently marked. Best markers are metal stakes placed at boundaries or pins driven into witness trees near boundaries. Describe locations of markers in field notes. Station length is measured down the center of the stream; station width is measured at 25-m intervals. Determinations of average stream width and station area can be made on the Field Map sheet. Establish the length of a station based on expected (a) density of targeted fish, and (b) efficiency of capture by a selected sampling method. A 400-m station is usually adequate for trout in northern Lower Peninsula streams. However, it appears that a length of 800 m may be required for trout in Upper Peninsula streams because, generally, trout densities are lower and electrofishing efficiency is reduced due to lower conductivity. As a rule of thumb, for determining the length of a sampling station, electrofish until at least five trout in each size class common to the population have been captured. Electrofishing for trout is used here as an example, but the rule applies for other target species and sampling gear. For sampling warmwater streams for species diversity, station length should be at least 35 times stream width (Lyons 1992). It is best to terminate a station at a 50-m interval to minimize problems of calculation. Record these length intervals as in Table 2.1.

2.1.2.4 Width.–Take width measurements at each 25-m interval as you progress downstream. Width is measured from water's edge (left bank) to water's edge (right bank) at a right angle to the bank. Record width as in Table 2.1. Area can be calculated by multiplying average width times the station length. When an island occurs in the stream, take width measurements across the entire stream, including the width of the island (Figure 2.3). Later, subtract area of the island to obtain water-only area. A fairly accurate estimate of most islands in streams can be made with the following formula: island length x maximum width of island x 0.6. If the island is not of typical form (teardrop), then an array of width measurements should be taken. Island area is then calculated by multiplying average width times length.

2.1.2.5 Depth.–Measure depth at 0. 5-m intervals along the stream width cross sections (i.e., at distances of 0.25 m, 0.75 m, 1.25 m., etc.). Record depth measurements as on Table 2.1. Measure from water surface to top of the substrate. Be careful not to disturb the top of soft bottom sediments.

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2.1.2.6 Cross section profiles.–Cross section profiles graphically indicate the quality of stream fish habitat, since a summation of stream profiles indicates morphological diversity of the stream channel. Good stream habitat consists of a diverse blend of pools and riffles. Profiles can be drawn and their area calculated from each set of width and depth measurements. To calculate area, multiply the width times the average depth at each particular cross section. These profiles can be used to calculate the static water volume of the study station.

2.1.2.7 Static water volume.–This parameter has considerable biological significance because it is the total potential living space available for fish. To calculate the static water volume within the sample section, first determine the average cross sectional profile area. The average profile area times the section length equals static water volume. This approach eliminates problems caused when islands occur within the sample station. Do not calculate static water volume by successively multiplying (a) average depth of the cross sections, (b) average width, and (c) sample section length. That procedure gives an overestimate of water volume.

2.1.2.8 Discharge.–The best place to measure stream discharge in the sampling station is where the stream channel is straight and canal-like. The more laminar the water flow, the better the velocity measurements will be. Discharge measurements should be made using standard procedures with a Gurley current meter (see Chapter 19). (Note: if the meter is calibrated in English units, discharge will have to be calculated in English units and transformed to metric units.) The best time of the year to measure discharge for our purpose is during October or November because, generally, flow is most stable then and approximates the average seasonal flow. Take measurements at least 3 days after the last large rainfall.

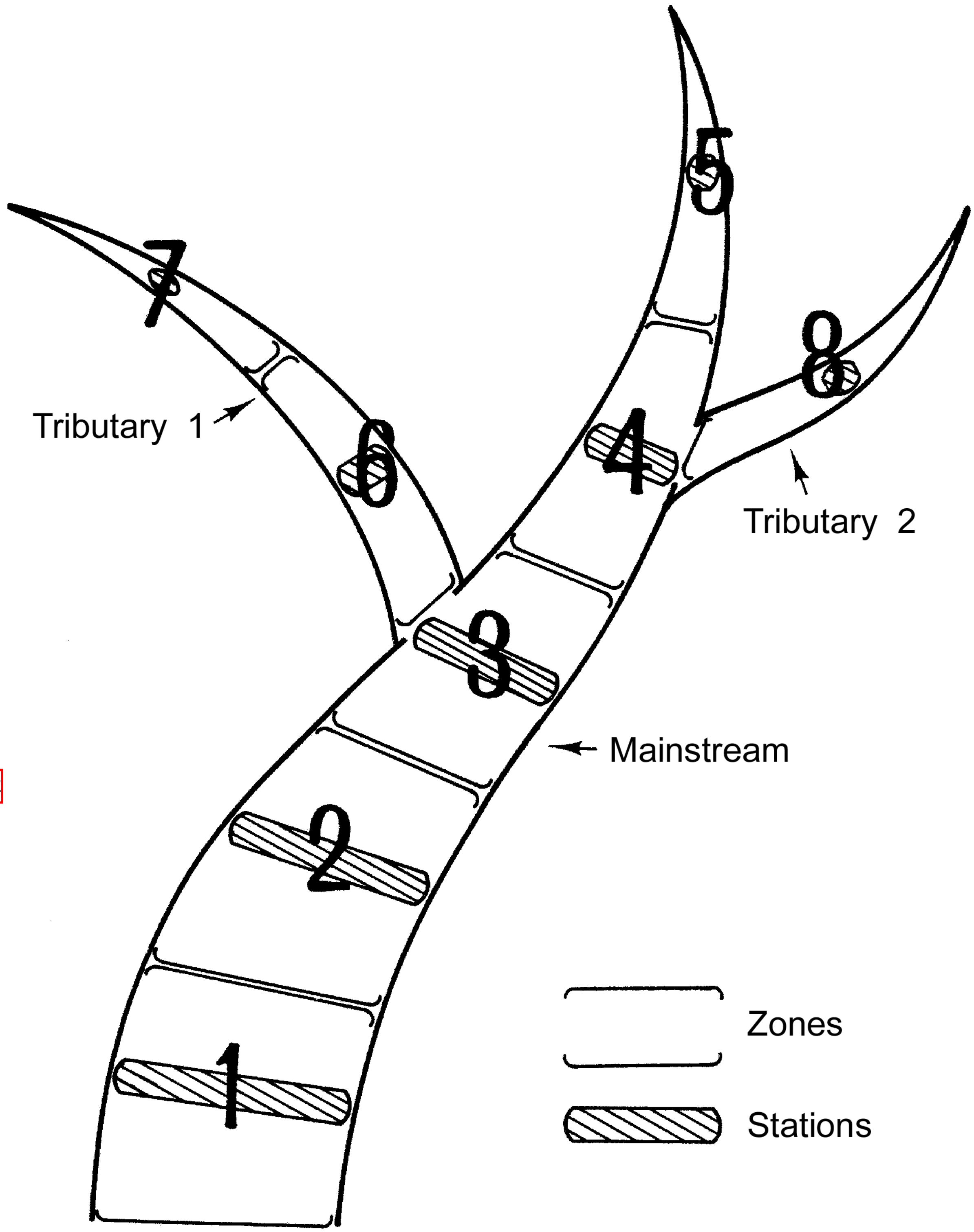

Figure 2.1.–A graphic view of the sampling zones and stations within the stream drainage.

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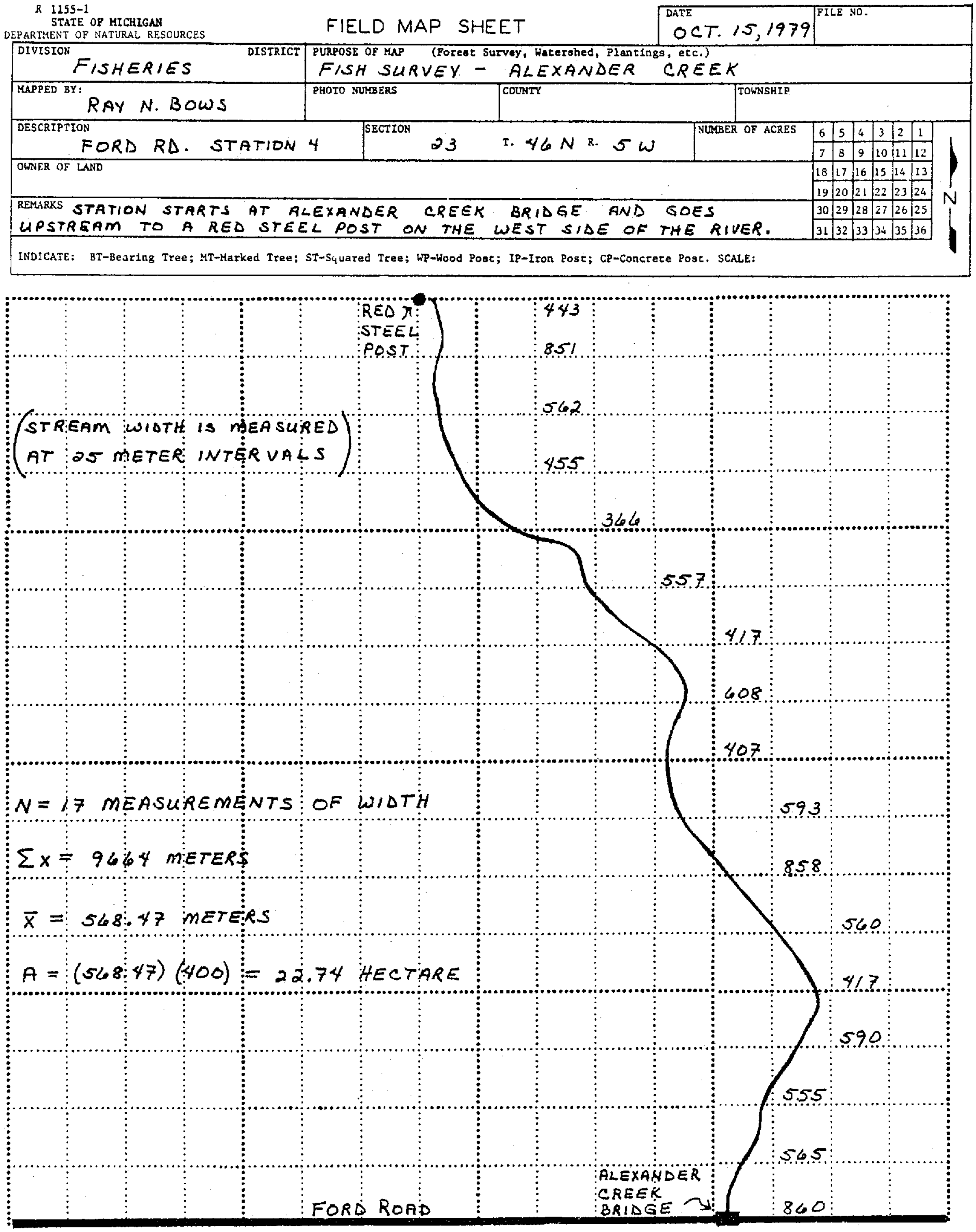

R 1155-1
STATE OF MICHIGAN
DEPARTMENT OF NATURAL RESOURCES

FIELD MAP SHEET

DATE: OCT. 15, 1979
FILE NO.

DIVISION: FISHERIES
DISTRICT
PURPOSE OF MAP (Forest Survey, Watershed, Plantings, etc.): FISH SURVEY – ALEXANDER CREEK

MAPPED BY: RAY N. BOWS
PHOTO NUMBERS
COUNTY
TOWNSHIP

DESCRIPTION: FORD RD. STATION 4
SECTION: 23 T. 46 N R. 5 W
NUMBER OF ACRES

6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

N

OWNER OF LAND

REMARKS: STATION STARTS AT ALEXANDER CREEK BRIDGE AND GOES UPSTREAM TO A RED STEEL POST ON THE WEST SIDE OF THE RIVER.

INDICATE: BT-Bearing Tree; MT-Marked Tree; ST-Squared Tree; WP-Wood Post; IP-Iron Post; CP-Concrete Post. SCALE:

Figure 2.2–Example of use of Field Map Sheet to indicate length, width, area, and orientation of stream study station.

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Table 2.1.–Example of measurements of station length, width and water depth.

River: Alexander Creek **Date**: Oct. 15, 1979

Station: Ford Rd. - Sta. H **Location**: T46N, R5W, Sec. 23

	Distance (m) between transect lines																
	0	**25**	**50**	**75**	**100**	**125**	**150**	**175**	**200**	**225**	**250**	**275**	**300**	**325**	**350**	**375**	**400**
	Total width (cm) of river at transects																
	860	565	555	590	417	560	858	593	407	608	417	557	366	455	562	851	443
Width intervals	Depth (cm) at width intervals on transect lines																
25	3	16	14	12	26	12	14	4	20	17	33	19	67	46	18	9	20
75	8	23	20	18	42	25	27	10	40	18	39	30	87	60	30	14	29
125	10	29	38	30	40	30	33	25	43	20	37	38	103	82	35	21	40
175	31	37	34	30	51	35	30	40	53	29	54	41	91	90	43	20	51
225	35	42	40	41	87	37	31	42	90	40	89	43	63	58	47	37	60
275	42	58	61	47	61	60	47	43	63	41	39	60	51	56	57	33	65
325	39	42	48	40	46	43	42	49	41	45	27	36	40	43	40	39	73
375	30	45	48	41	23	41	43	40	15	50	21	34		39	33	50	41
425	31	41	47	39		37	40	30		40		29			30	46	30
475	40	30	29	25		29	33	29		25		25			21	41	
525	29	20	18	15		21	30	19		15		12			10	37	
575	25			4				14		5						30	
625	20															25	
675	18															20	
725	16															17	
775	14															11	
825	8															4	

*Note: record zeros for depth intervals across island segments of transects when they occur.

Summary

Total length: 400 m

Average width: 5.68 m

Area (water plus islands): 2272 m^2

Area (water only): 2272 m^2

Average depth: 0.3585 m

Average cross section area: 2.0457 m^3

Volume (static): 818.3 m^3

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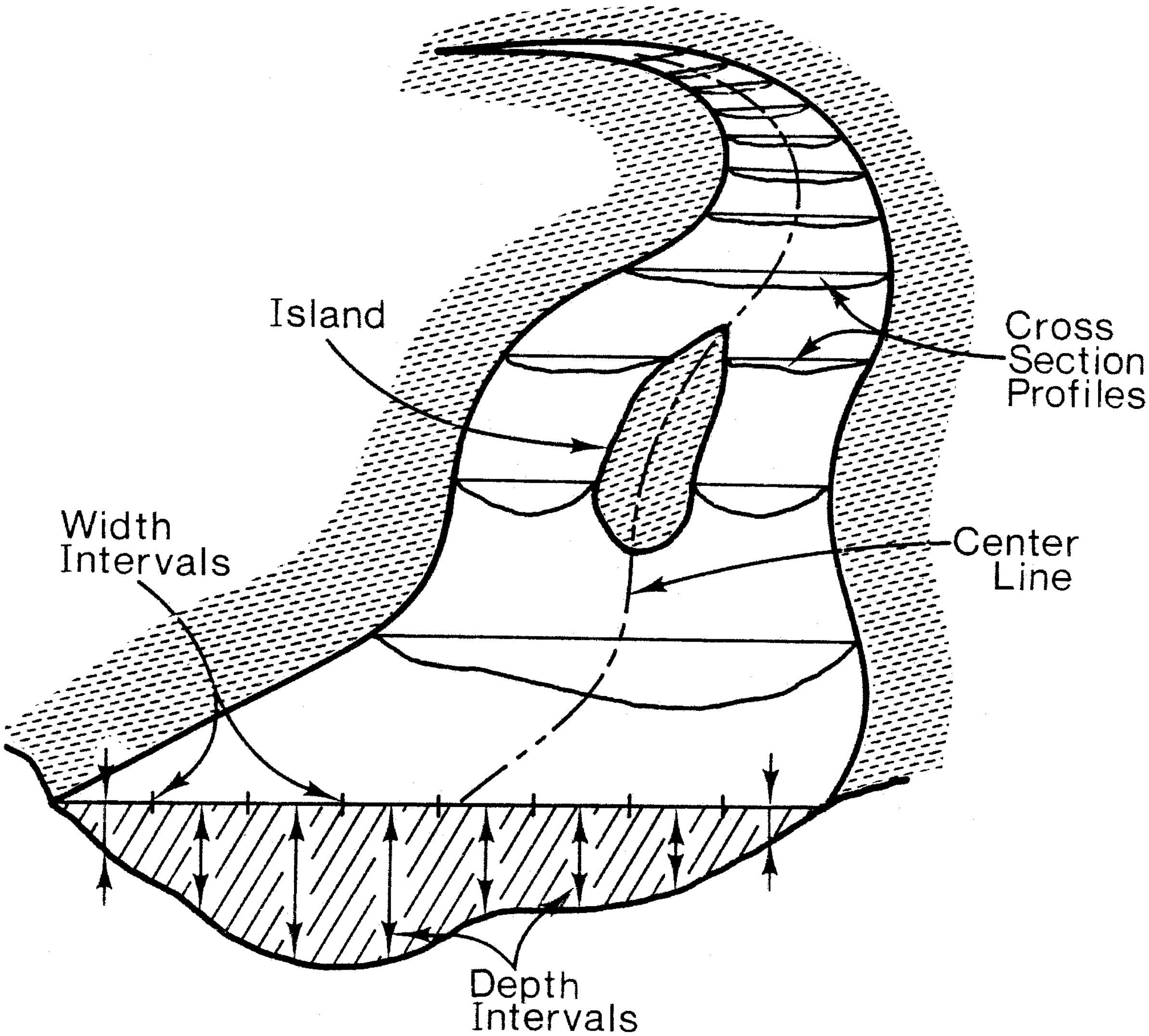

Figure 2.3–A stream sample station showing morphology measurements of length, widths, depths, and cross-section profiles.

2.1.2.9 Velocity.–Average stream velocity can be calculated by dividing discharge by average cross sectional area. Velocity is highly variable within a cross section, among cross sections within a stream reach, and at different stream stages or discharges.

2.1.2.10 Annual stream discharge.–In the future, we may wish to relate estimates of fish numbers, biomass, or production to total annual volume of flow. To obtain the annual discharge for a stream, it is best to have a continuous recording of the water height (stream stage). This, along with discharge measurements at an array of stream stages, provides the means to construct a rating curve from which annual discharge can be calculated. A second method is to calculate annual discharge from known monthly flow periodicity. A third method, that is less precise but satisfactory for our purpose, is to assume that discharge (in m^3/sec or ft^3/sec) during October or November equals the average annual discharge and multiply it by 31, 557, 600 (the number of seconds in a year).

2.1.2.11 Stream stage.–Stream stage is the relative change in water surface height as measured on a staff gauge. It is best to record this continuously with an automatic recorder. Next best is to read it daily or periodically. As mentioned earlier, if the stream stage is known, and there is a stream discharge rating curve for various stream stages, total river flow can be calculated.

2.1.2.12 Gradient.–Stream gradient, expressed as drop in elevation per kilometer or percent slope, can be estimated from contour lines of U. S. G. S. topographic maps. More precise measurement require the use of surveying instruments (transects or dumpy levels, along with measurement of drop below the line of sight).

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2.1.2.13 Bed type.–Streambed refers to the veneer of sediments at the earth-water interface. Bed types should be recorded when depth measurements are taken. These records can then be summarized as percentage sand, gravel, clay, detritus, etc., for the entire stream. Another way of measuring bed type or composition is to take scoop samples along the line transects with appropriate sampling apparatus, then sift samples through standard Tyler sieves to determine size distribution of the particles.

2.1.2.14 Spawning areas.–In the past, many surveys have attempted to assess spawning areas for salmonids based upon percentage of gravel in the stream bed. There are reservations as to the value of this approach because not all gravels are used by fish. Use depends upon factors such as groundwater upwelling, temperature, dissolved oxygen, bed porosity, bed permeability, and salmonid species and size. A more accurate assessment of spawning habitat can be made by walking or canoeing the stream during the spawning period and noting where nest-building activity and spawning actually occur.

2.1.2.15 Cover.–Cover can be in the form of logs, brush, rocks, turbulent water, turbid water, water depth, undercut banks, or objects hanging over the water – anything providing shelter for fish. Cover is highly variable, and its characteristics are not easily quantified. Subjective terms such as "good", "moderate", or "poor" are usually adequate for stream inventories.

For more rigorous methods of evaluating the quality of stream fish habitat, refer to literature on habitat suitability criteria, the Physical Habitat Simulation System, and Instream Flow Methodology (e.g., Zorn 1994; Baker and Coon 1995).

2.2 Limnology

2.2.1 Lakes

Most routine limnological measurements now can be recorded in the electronic Fish Collection System. However, the paper version (LIMNOLOGY form, R-8056) has a more flexible format. Full limnological surveys are to be conducted in mid summer. At that time, stratification is fully developed, dissolved oxygen may be limiting fish distribution, and production by algae and plants is high. Late winter is the best time to check for low dissolved oxygen and the threat of winterkill. Early spring is the best time to check soft-water lakes and streams for acidity and alkalinity, but these measurements should also be taken each time soft waters are visited. During fish surveys conducted when the lake is likely to be stratified, temperature and dissolved oxygen profiles should be taken in advance to avoid wasting effort by sampling depths devoid of target species.

A full mid-summer limnological survey includes temperature and dissolved oxygen profiles, alkalinity, Secchi disk, and observations of water color and influential weather conditions. Measurement of pH is desirable if reliable equipment is available and the lake has, or may have, a total alkalinity of less than 20 ppm. Such lakes are vulnerable to acidification from acid rain. Also to be included are observations on the types and densities of aquatic vegetation; these too are very important for documenting change.

2.2.2 Streams

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2.2.2.1 Temperature.–Temperature becomes critical to stream fish on the hottest and coldest days of each year. Therefore, the common procedure of recording air and water temperature and time of day during occasional visits to the stream is of little value. Continuous monitoring over at least one full year can be easily and inexpensively accomplished with self-contained recording thermometers. Thermometers should be placed at various locations along the stream drainage, including major tributaries. The best salmonid populations are in streams with the lowest average summer temperatures, the highest winter temperatures (due to groundwater), and the least amount of seasonal and daily fluctuation. Warmwater fish species also benefit from relatively stable water temperature regimes and warmer winter temperatures.

2.2.2.2 Water chemistry.–Analyses of dissolved oxygen, alkalinity, and pH are recommended for streams for they are key indicators of the general quality of the environment. More intensive and varied chemical analysis should be done if pollution is suspected or some abnormal condition occurs, such as large daily fluctuations in dissolved oxygen.

2.2.3 Limnological methods

2.2.3.1 Temperature.–In lakes, water temperature measurements should be made with an electronic thermometer at 2-foot depth intervals except:

- If, within the epilimnion or hypolimnion, there is no change from the reading of the previous depth;
- If, during the spring or fall overturns, temperature is uniform with depth.

The electronic thermometer should be standardized with a good laboratory thermometer at least once per year.

Temperatures can be taken with a pocket thermometer at the surfaces of streams and lakes. However, a pocket thermometer should not be used to record the temperature of a water sample that has been collected with a Kemmerer sampler and emptied into a glass bottle. Water is appreciably warmed as it is lifted through the epilimnion and emptied into a bottle. Temperatures taken in this manner can be in error by as much as 5 degrees.

When taking air temperature, be sure the thermometer is dry and shaded from the direct rays of the sun.

2.2.3.2 Dissolved oxygen.–Oxygen determinations must be made at sufficient depth intervals to accurately delineate oxygen stratification within the lake. Oxygen measurements should be determined after temperature strata have been defined, or better, measured concurrently with a combination temperature-oxygen meter. If a water sample bottle (e.g., Kemmerer) is used for collecting samples for oxygen analysis by the chemical method, samples should be collected at the surface; at the top, middle, and bottom of the thermocline; at the middle of the hypolimnion; and within 1 m of the bottom. These samples should be analyzed on the lake, and then additional samples taken to determine where dissolved oxygen becomes 1 and 2 ppm or changes rapidly. You should look also for an oxygen maximum in the thermocline, an indicator of phytoplankton abundance there due to water clarity. If oxygen samples cannot be titrated on the lake, then additional samples must be taken initially and promptly fixed as below.

The oxygen content of water can be measured either by an oxygen probe and meter or by Winkler chemical analysis. An oxygen meter is advantageous when a large series of samples is to be run frequently. However, infrequent analysis of a few samples can be done almost as conveniently by chemical methods. **An oxygen meter must be calibrated daily according to directions with the instrument, and frequently should be compared to a water sample previously analyzed by chemical method.** Thus, a few samples can be run chemically almost as fast as a meter can be standardized.

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The Winkler method of chemical analysis will be the standard. Several modifications of this method have been advocated for waters containing various interfering substances. However, these substances are sufficiently rare in unpolluted natural water that we will use the unmodified Winkler method. Water is collected from a desired depth with a Kemmerer (or similar) water sampler, and transferred to a 250-ml bottle by inserting the tube of the sampler to the bottom of the bottle. Care must be taken to flush the bottle about two times its volume and to not retain air bubbles when inserting the ground glass stopper.

1. Fixing: Three reagents are added to the sample with automatic pipettes, as follows:
   - 2 ml manganous sulfate ($MnSO_4$); deliver below the surface of the water so as not to introduce air bubbles.
   - 2 ml alkaline-iodide solution (potassium or sodium, KI-KOH or Na-KOH); add immediately following the $MnSO_4$. Deliver below the surface as before.
   - Replace stopper and mix thoroughly by inverting bottle repeatedly. Allow precipitate to settle until top half of bottle is clear.
   - 2 ml concentrated sulfuric acid (H_2SO_4); deliver carefully below the surface of the sample. Re-stopper and shake until precipitate dissolves. If precipitate does not dissolve immediately, allow bottle to stand for several minutes.
2. Titrating: The sample is now ready to titrate with 0.025 N sodium thiosulfate ($Na_2S_20_3$) for final analysis. Titration may be done immediately in the field, or samples may be returned to the lab and held for several days. If necessary to delay titration, store samples in the dark. The titration procedure is as follows:
   - Transfer 200 ml of sample to a 250-ml Erlenmeyer flask;
   - Titrate with $Na_2S_20_3$ until pale yellow color;
   - Add a "pinch" of Thyodene (starch substitute) for pale blue color;

- Continue titration until colorless. The number of ml of $Na_2S_20_3$ used in the total titration is numerically equal to the dissolved oxygen concentration in parts per million (ppm or mg/liter).

3. Reagents: The reagents used in the Winkler method of oxygen analysis are prepared as follows:

   - ***Manganous sulfate solution*:** Dissolve 480 g $MnSO_4 \cdot 4 H_2O$ or 400 g $MnSO_4$ • 2 H_2O or 364 g $MnSO_4$ • H_2O in distilled water, filter, and dilute to 1 liter.
   - ***Alkaline-iodide reagent*:** Dissolve 500 g sodium hydroxide (NaOH) or 700 g potassium hydroxide (KOH), and 135 g sodium iodide (NaI) or 150 g potassium iodide (KI), in distilled water and dilute to 1 liter.
   - ***Sulfuric acid*:** Purchase concentrated solution.
   - ***Sodium thiosulfate*:** Purchase Acculute brand (Anachemia Chemicals Ltd., P.O. Box 87, Champlain, New York 12919) of standard volumetric solution. This comes in a small bottle which is emptied into a 1-liter volumetric flask. The bottle is filled with distilled water and emptied into the flask three times (to assure complete rinsing) and the flask is then filled with distilled water. The liter of solution will be exactly 0.025 N, and does not need to be standardized. The solution will keep for at least 6 months if refrigerated.
   - ***Thyodene*:** Purchase (Fisher Scientific Co.) and use as supplied.

2.2.3.3 Alkalinity.–In lakes, water samples should be collected from the surface, middle of the thermocline, and within 1 m of the bottom. Determine both phenolphthalein (ph-th) and methyl orange (M. O.) alkalinities by standard chemical methods.

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1. Method:
   - Water is collected with a Kemmerer (or similar) sampler, and 100 ml is transferred to an Erlenmeyer flask.
   - Add 4-5 drops of ph-th indicator. If the sample remains clear, record 0.0 ph-th alkalinity. If the sample turns pink, titrate with 0.02 N sulfuric acid until clear. The number of ml of acid used multiplied by 10 equals the ph-th alkalinity.
   - To the same sample add 3-5 drops M. O. indicator and, without refilling burette, continue titration until yellow color changes to salmon pink. Record M. O. alkalinity (total alkalinity) as 10 times the total number of ml H_2SO_4 used in both titrations.
2. Reagents:
   - ***Phenolphthalein (ph-th) indicator*:** Dissolve 5 g phenolphthalein in 500 ml of isopropyl alcohol and add 500 ml distilled water. If necessary, add 0. 02 N sodium hydroxide (NaOH) drop-wise until faint pink color appears.
   - ***Methyl orange indicator solution*:** Dissolve 500 mg methyl orange powder in distilled water and dilute to 1 liter.
   - ***Sulfuric acid, 0.02 N*:** Purchase Acculute solution and dilute to 1 liter. See instructions for sodium thiosulfate in dissolved oxygen methods.

2.2.3.4 Secchi disk transparency.–The transparency of lake water is measured by determining the depth at which a Secchi disk disappears from view when lowered through the water column. A Secchi disk is a metal plate 20 cm in diameter, with the face divided into four quadrants. Two opposite quadrants are painted black and the other two are painted white. A graduated line is fastened to an eye bolt in the center of the disc. Standard conditions for the use of a Secchi disk are as follows: bright day with sun directly overhead; shaded, protected side of the boat; without polarizing sunglasses. The Secchi disk is lowered into the water, noting the depth at which it disappears, than lifted, noting the depth at which it reappears.

The average of the two readings is recorded as the Secchi disk depth or limit of visibility. The depth should be recorded to the nearest 0.1 m or 0.5 foot.

2.2.3.5 Color.–Michigan waters are either colorless (lakes may appear to be blue or green) or stained brown by humic acid from organic drainage. Color will be recorded as either clear, light brown, brown, dark brown, or turbid. Color may be determined by examination of a sample in a bottle, or as observed against the Secchi disk held a few centimeters beneath the surface.

2.2.3.6 pH.–Despite the fact that biologists have been recording the pH of water for many years, there still seems to be no easy method of field measurement. Portable pH meters are the preferred method if one is available that proves to be reliable. If a meter is not available, a HACH kit should be used. Most municipal sewage treatment plants will do pH analysis upon request.

2.3 Plants and invertebrates

These are important components of fish habitat and productivity, but are relatively difficult and expensive to quantify. Below are recommended methods for evaluations. In addition, watch for presence and relative abundance of amphibians, reptiles, mussels, and rare and endangered fish and organisms of all types. See also section 2.4.2.19.

2.3.1 Lakes

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2.3.1.1 Macrophytes.–Abundance of littoral vegetation is to be recorded on the LIMNOLOGY form. Abundance estimates are to be made for each of these types of aquatic plants: submergent, emergent, floating, and *Chara*.

Aquatic plants are good indicators of lake eutrophy and fish productivity (see Chapter 21), and they influence fish stunting (Theiling 1990; Schneider in press). Plant populations are changing rapidly due to cultural eutrophication, invasions of exotics, and herbicide use. Traditionally, biologists have made a single evaluation of macrophyte abundance throughout an entire water body. Plant abundance has the potential of giving us more information than we have utilized before if we are more careful in recording our observations.

Observe for each type of vegetation the percent of the littoral area where the type is sparse (S), common (C), abundant (A), or excessive (E). For example, if emergent vegetation is sparse in 60% of the littoral zone, common in 30%, and excessive in 10%, the recorded notation should read: Emergent 60 S, 30 C, 10 E. The recorded percentages should always total to 100% of the littoral zone.

2.3.1.2 Phytoplankton.–Secchi disk transparency will be used as a surrogate for phytoplankton density. Obvious blooms of blue-green and other algae should be noted. Chlorophyll analysis is another practical method that is more reliable, but it is not recommended for routine use by the Fisheries Division. Chlorophyll analysis requires special collection and handling techniques. A special composite sampler (Figure 2.4) is used to collect a composite sample throughout the water column from the surface to a depth of twice the Secchi disk transparency. The sample is placed in a 250-ml dark bottle, and one drop of magnesium carbonate is added as a preservative.

2.3.1.3 Fish food.–The sampling of zooplankton and benthos is a time consuming task and is not recommended for routine lake surveys. However, sampling for large zooplankters, as described in Chapter 18, is recommended for special surveys of lakes in which (1) stocked trout are not providing satisfactory returns; (2) survival of walleye fry or other young game fish is poor; or (3) growth of bluegill is poor.

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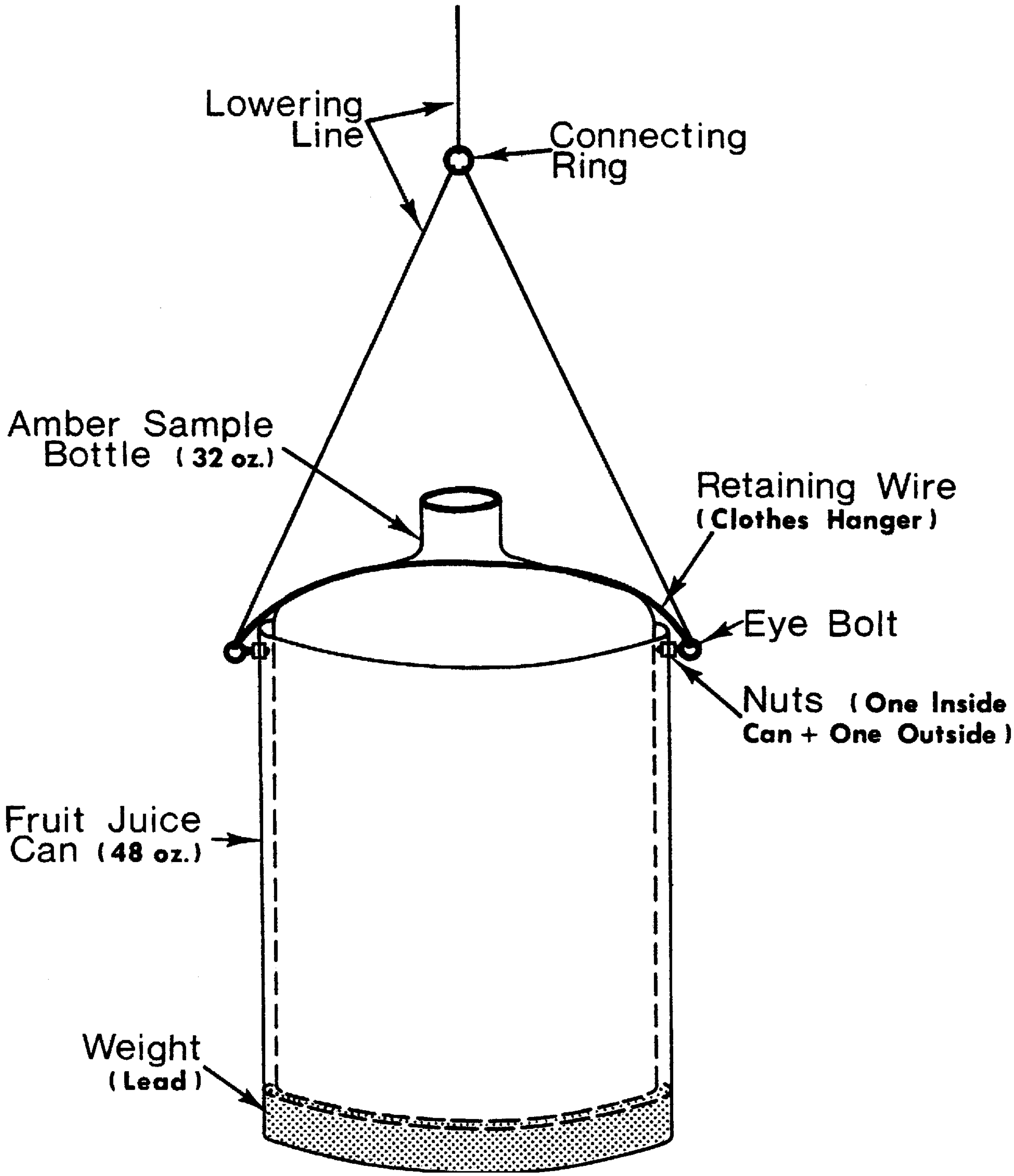

Figure 2.4–Phytoplankton (chlorophyll) sampler construction plans.

For routine surveys, simply make observations on fish food organisms while conducting other parts of the survey. Watch for zooplankton blooms, insect hatches, burrowing mayflies (or their burrows), crayfish, and forage fish. Report noteworthy observations on the Water Survey form (electronic version), LAKE SURVEY SUMMARY form, or on a NOTES AND REFERENCE form.

2.3.2 Streams

2.3.2.1 Vegetation.–It is extremely difficult to assess standing crop (or production) of plants growing in streams. For most surveys, just subjectively estimate percentage of the channel in which vegetation is "abundant", "moderate", or "sparse".

The type, size, and degree of shading provided by vegetation adjacent to the stream should be noted also. For example, note that canary grass overhangs a stream bank, or that dense tag alder up to 12 feet high form a closed canopy over the stream.

2.3.2.2 Fish food.–An estimate of the relative abundance of fish food can be made from two samples of bottom fauna – one from the middle of the stream and one from midway between center and a stream bank. Take the samples with a square-foot Surber Sampler, or a similar device, and calculate the average number and volume of organisms. The resulting estimates, based on only two samples, will be quite rough, but much more extensive sampling is required for good quantitative estimates of benthos abundance.

Use the average numbers and volume (or weight) of fauna per square-foot to classify the stream for food richness as follows:

Exceptional richness: Volume greater than 2 ml (2 g) and number of organisms greater than 50.

Average richness: Volume from 1 to 2 ml (1 to 2 g) and more than 50 organisms.

Poor richness: Volume of benthos less than 1 ml (1 g) and/or fewer than 50 organisms.

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In order to qualify for any richness category, both the numerical and weight or volume requirements must be met by the average sample.

2.4 Fish Surveys

2.4.1 Discussion

Samples of fish may be desired for information at one, two, or three levels: (a) community (species diversity and relative abundance of predators, prey, etc.), (b) population (abundance, distribution, length-frequency, age frequency, growth, etc. of a species population), or (c) individual (specimens for diet study, contaminant analysis, etc.). The sampling of communities and populations will be emphasized in the following discussion because it is essential to fisheries management and the most difficult part of fish surveys.

It is difficult to obtain a completely unbiased sample of fish living in natural habitats. Catches are nearly always affected by at least three factors: (a) gear selectivity (influencing species caught, relative abundance, size distribution, and sometimes whether the more active or the more passive individuals are captured), (b) differences in gear efficiency among habitats (e.g., most types of gear sample the shallow littoral zone most effectively), and (c) daily and seasonal changes in the behavior of fish which alter their vulnerability to capture. In addition, care must be exercised to avoid further bias when the catch is sub-sampled for length-frequency, age and growth, survival rate, etc.

Usually, our aim in field surveys is to obtain a representative sample of species and sizes of interest. Unless our interests are very narrow (i.e., targeted), a variety of gear types, habitat types, sample sites, and sample dates will be required for a good representative sample.

Within this context, fish sampling should provide:

a. Enough fish of the right species and sizes to be statistically meaningful;
b. An orderly and reliable information and data base;
c. A means of systematically identifying change;
d. The specific information needed to solve a specific problem.

Objective(s) of the survey, target species, and types of information needed must be defined in advance. Types of surveys include: (a) basic inventory of all species, (b) inventory of principal (target) species, and (c) check on a specific problem or management procedure. The purpose of the survey is to be recorded on the FISH COLLECTION form to aid others in the interpretation of survey methods and results.

Careful planning, as well as execution, is essential for meeting the objective. The SURVEY PLANNING form should be used to plan surveys. The purpose of this form is to assist with reviewing past surveys, setting objective(s) for the proposed survey, and communicating this information to others.

Other forms aid in recording and analyzing data. These allot some space to analysis and interpretation, but extensive surveys should culminate in narrative survey reports as well. Central to the forms are four tables and one figure that summarize key statistics of the fish community and its species populations. Usually, one or more of these summaries will be needed to answer your questions and diagnose management problems.

2.4.1.1 Catch summary, by gear type–

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Species		
Length		
Avg. Wt.		
	No.	Lb.
Total		
%		
CPE		
% L-A		

This table records species captured, average lengths and weights, total catches by number and weight, contributions of each species to the sampled portion of the fish community (total % by number and by weight), indices of population abundance (CPE), and proportions of the catch which exceeded the minimum legal size limit or was large enough to be acceptable to anglers (L-A). These key statistics generally reflect status of the community and its species populations, and are useful for detecting changes through time. If fish were not individually weighed during a survey, average length-weight relationships (Chapter 17) are to be used to convert numbers of fish caught to weight of fish caught. The electronic Fish Collection System has options for making weight calculations.

Some statewide standards are available for making comparisons (Chapter 21).

2.4.1.2 Length-frequency and length-biomass, by gear type–

Species		
Inch group	No.	Lb.
1	105	0.5
2	86	0.9
3	34	0.8
etc.		

This table, derived from a random sample of the catch, shows the size structure of a population and enables the calculation of average size and % L-A. A desirable size structure has both small and large fish, indicating that recruitment is taking place and survival and growth are adequate to produce large fish and a fishery. The optimum ratio of small to large sizes has yet to be defined for each gear type and species. However, a system for ranking bluegill size structure based on gear type is available (Chapter 21).

Catch Summary, Length-frequency, and Length-biomass tables are on the FISH COLLECTION form and are part of the electronic Fish Collection System. Some space is provided on this form for analysis and interpretation. Additional important parameters and statistics are recorded and interpreted on the forms below.

2.4.1.3 Age and growth (form R-8070; electronic version in Fish Collection System)–

Species	Age group	Number of fish	Length range in inches	Average length in inches	State average length	Growth index by age group	Avg. growth index for species
Bluegill							
Walleye							
etc.							

This table records the statistics of the growth sample and compares average length-at-age of each species to the corresponding state average (Chapter 9). In the analysis section of the form, evaluate that comparison and also how the recent growth indices compare to indices in previous samples. Growth rate is a very useful measure of a population's well being and is further discussed in Chapter 9. Slow growth commonly indicates that few large fish will be produced, food supply is constrained, and recruitment is not properly balanced by mortality. Conversely, fast growth suggests that recruitment and total production could be improved.

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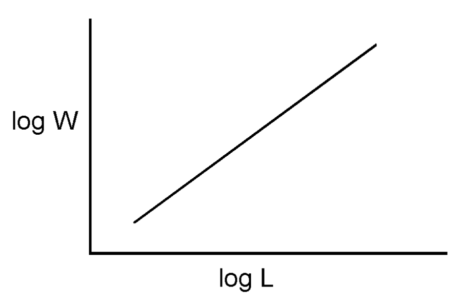
This table also provides less accurate information on age composition, weak and strong year classes, and mortality rate (see Chapter 21). In general, the number of fish in successive age groups will progressively decline due to mortality. Disruptions to this pattern may represent variations in year class strength. With relatively even year class strength and good sampling, mortality rate can be calculated by a catch-curve analysis based on age frequency. However, age-frequency analysis is vulnerable to large errors from quota sampling (e.g., 30 scale samples per inch group) and even random sampling can induce strong bias due to gear size (and age) selectivity. For further discussion of bias in age composition and average length induced by sampling see Chapter 15.

2.4.1.4 Length-weight regression (form R-8059-1)–



This figure, or its equivalent equation:

$$\log W = \log a + b \log L,$$

is a measure of the well being (plumpness, condition) of individuals in the population and is useful for converting length-frequency data to biomass-frequency data. State average length-weight regressions have been developed (Chapter 17) which serve as standards for condition.

2.4.1.5 Population estimates (form 8073)–

Species________ Estimated: No./acre____ Lb./acre____ %L-A: By No.___ By Lb.___

Inch group	No. marked	Recapture run		Estimates			Estimates by age group				
		Recaps	Unmarked	No.	95 % limits	Lb.	No. aged	0	I	II	..
Total											
							% survival				

More sophisticated management problems at population and community levels require absolute, rather than relative, measures of population abundance and size frequency. Mark-and-recapture methods or depletion estimation methods, stratified by size groups to eliminate bias caused by size selectivity of gear, are practical in some situations – especially in wadable streams. For more information, see Chapters 7 and 8, and textbooks such as Ricker (1975). Form 8073 (above) is suitable format for summarizing some types of mark-and-recapture information. Spreadsheets and narrative reports are often more appropriate formats but should convey the same elements of information.

While a population is being estimated, it is wise to take a large number of scale samples so that age composition of the population can be accurately determined. From these data, it is possible to make a good assessment of recruitment, survival, and biological production. However, the best method of determining survival is from age group estimates made in consecutive years. A low rate of survival commonly signals problems of overfishing or excessive natural mortality.

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2.4.2 Procedures

It is not possible to design a single (or a few) sampling plan suitable for all fish surveys. To a considerable extent, the design of each survey must be custom tailored to specific objectives, species, habitats, degree of precision required, budget and time limitations, and previous experience. The following discussion of procedures is specific in routine matters (where feasible), but hopefully the more general sections will broaden the reader's understanding of sampling problems and enable him/her to design efficient sampling plans as the need arises.

2.4.2.1 Planning.–Review Sections 1.2 and 2.4.1. Survey objectives, types of summaries needed, and forms required must be established before field work begins. An important aid to every survey is a map or sketch of the lake or stream. Use it to select and record locations of sampling stations, net sets, transects, and electrofishing areas, and also to note spawning areas, brush or rock shelters, land marks, and other information. The map should be stored for future reference, and as is practical and relevant, sketched on a FISH COLLECTION form or a NOTES AND REFERENCE form.

2.4.2.2 Forms and records.–The quality of our records reflects our degree of professionalism. In the field, use either (a) a new hand-held computer to directly enter data, or (b) paper forms (e.g., FISH COLLECTION forms or waterproof data paper) to record data for later entry. The LENGTH-WEIGHT FIELD DATA form is handy for taking weight data. Generally, avoid getting too complicated when recording data in the field as this increases errors and slows down the crew. For continuous recording during stream electrofishing, the formats of Tables 2.5 and 2.6 are recommended. **Keep separate records of catch and effort for each gear type, mesh size, collection site, and index site.** In the office, as soon as possible afterwards, check and summarize data and combine records for collection sites (if there is no reason to report them separately). Then, carefully enter data in the electronic Fish Collection System, or on appropriate summary forms, according to the instructions below, in Chapter 4, and in User's Guide for the Fish Collection System. Store the field sheets also, if they contain potentially useful data not on the summary version.

2.4.2.3 Fish identification.–All fish must be identified accurately. If there is any question about identity, save a sample for later examination. The Institute for Fisheries Research and the University of Michigan Museum staff can provide assistance. Species which are threatened, rare, or endangered, or outside of their normal range or habitat may be of special interest to the museum (see Chapter 16).

2.4.2.4 Measuring fish.–Standard units of measurement are inches and pounds (decimal).

Length.–Measure total length of fish to 0.1 inch or 1 mm if:

1. Fish are scale sampled for growth.
2. Fish are weighed individually or in small groups.
3. A more accurate (see below) estimate of average size is needed (e. g., small minnows or young sport fish).

Otherwise, measure fish to inch group. Inch groups are defined as: 0 inch group = 0.1-0.9 inch, 1 inch group = 1.0-1.9 inches, etc.

Weight.–Field measurements of weight are a waste of time unless carefully done. For determining weight of fish caught by species, it is as accurate and more practical to estimate weights from lengths using state average length-weight relationships (Chapter 17). Field measurements of the weights of individual fish should be taken if condition indices or a length-weight relationship are actually needed for the sampled population (see Section 2.4.1.4). Make measurements on a stable and level platform, out of the wind, with an electronic balance of appropriate accuracy for the size of the fish.

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2.4.2.5 Selection of sample sites.–Enough habitats and sites must be sampled (with appropriate types of gear) so that an experienced biologist feels confident that a **representative sample** has been obtained.

In surveys seeking one or a few target species, it is permissible to concentrate effort in habitats and at sites that previous experience suggests are likely to yield a representative random sample (within constraints of the gear) with respect to length-frequency, age-frequency, growth, or other population characteristics of interest. However, bear in mind that fish behavior is not completely predictable and broad coverage of areas and habitats is still needed.

Basic inventories require a representative sample of the entire fish community and some effort must be expended in all habitats to obtain information on species diversity and fish distribution. Additional sampling effort may be expended in habitats containing (or most likely to contain) species of greatest importance. This procedure provides an experienced surveyor with the greatest amount of useful information from the least amount of effort, but invalidates a strict comparison of CPE across species.

Lakes.–Use temperature and oxygen profiles to define habitats and select sample sites. Other criteria useful for defining habitats are vegetation, substrate, current, cover, and morphometric features such as bays, points, inlets and outlets. Use an echo sounder to locate sample sites. Record sample site depth, temperature, and other habitat data on the FISH COLLECTION form.

Streams.–Stream surveys should be conducted within the framework that the drainage unit is the ultimate management unit and the main survey unit (see Section 2.1.2). This can be accomplished by systematically subsampling various segments (reaches) of the stream drainage. Then by summing the values obtained from the subsamples, values for the drainage as a whole can be obtained. This approach is particularly important for assessments of fish populations and angling.

2.4.2.6 Index stations.–Index stations may be established to monitor seasonal or annual trends in the CPE index of abundance for a target species. An index station may be used for more than one target species, but ***at least*** 10 specimens of each species must be taken at each station, or among all stations combined, to provide useful statistics. In lakes, replicate sample each index station (e.g., at least two net nights per survey) and, for year-to-year comparisons, obtain CPE's at the same time of year with the same type of gear.

Select index stations after an understanding of habitats and fish distribution patterns within a lake or stream have been attained from a basic inventory. Choose some sites because large and consistent catches can be made there, others because they represent important habitats and geographic areas. Enough stations must be established, or enough supplemental sampling must be done, so that shifts in fish distribution are not misinterpreted as changes in abundance. Minimum guidelines are five index stations for lakes 25 to 250 acres and ten stations for larger lakes.

Record locations of index stations on maps and on records with GPS coordinates. Check previous surveys before assigning index station numbers to avoid duplication.

Sites sampled during a survey may be assigned a temporary number, called a "Collection Site No., " rather than a permanent index number. The location of numbered collection sites is to be recorded on the FISH COLLECTION form. Data may be summarized by collection site or index site, as indicated on the forms.

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2.4.2.7 Selection of gear and season.–All types of fishing gear (including poisons) are selective by size of fish and by species. Furthermore, their efficiency varies according to habitat and season. For lake sampling, Table 2.2 summarizes generally good seasons, habitats, and gear types for each species. This table is based on the pooled experience of several field biologists. Chapter 3 describes gear types in more detail.

To inventory a target species, the most effective gear should be selected. For comparison with an earlier survey, use the same gear as before.

For a basic inventory of the fish community, two or more gear types are needed to sample all habitat types and all species (ideally in rough proportion to their abundance). Basic lake surveys require the use of (a) gill nets, (b) trap nets or fyke nets, and (c) seines or 220-volt pulse DC (or 3-phase AC) electrofishing equipment. In shallow lakes (less than 30 feet deep), allot more effort to trap netting than to gill netting; in deep lakes, do more gill netting than trap netting.

In wadable streams, the best gear for sampling fish is the 220-volt DC stream shocker. Very small streams can be sampled with a back-pack shocker.

Non-wadable streams are difficult to sample. A 220-volt, straight DC, boom shocker is usually the best type of gear for salmonids. For other species, 220-volt, pulsed DC (or 3-phase AC) is best. In sluggish current, fyke nets or seines may be useful. Rotenone is an excellent tool for sampling river populations (Chapter 22). The fish (usually dead) can be collected in a blocking seine placed across the lower end of the sample area. The rotenone slug should be detoxified with potassium permanganate as it leaves the sample area.

Table 2.2–Summary of results of questionnaire to management biologists giving generally good times (best in bold), locations, and gear to sample lake fish populations.

T = trap net; F = fyke net; sm = smallmesh; G = gillnet; EN = electroshocker,night; ED = electroshocker, day; HL = hook & line; S = seine; Lit = littoral; shoal = hard substrates; ther = thermocline; veg = macrophytes

	Season and approximate temperature (F)							
Species, Size	Ice-out 32-40º	After ice-out 40-50º	Spring,early 55-65º	Spring,late 65-75º	Summer 75-62º	Fall,early 62-50º	Fall,late 50-40º	Winter 39-32º
Northern Pike								
Adult	**spawn** **marsh,inlet** **T,F**,G,EN	lit T,F,G				lit T,F	lit T,F,G	under ice G
Juvenile	[1]	lit G				veg EN		
White sucker								
Adult		**spawn** **shoal,** **inlet,outlet** **T,F**,G	sublit G,T	sublit G,T		lit, sublit T,F,G,EN		
Juvenile	[1]			lit EN,S	lit S	lit EN		
Walleye								
Adult		**spawn** **shoal,inlet** **T,F,EN**,G,ED	lit, sublit T,F,G	lit, sublit T,F,G		lit, sublit T,F,G		
Juvenile	[1]		shoal EN		shoal S,EN	**shoal** [2] **EN**,S,smF		
Smelt								
Adult		**spawn** **inlet,shoal** **S**,EN						pelagic HL
Juvenile								
Musky								
Adult		**spawn** **veg,inlet** **T,F**,G	lit T,F			lit T,F,EN		
Juvenile		[1]					**woody debris** **EN**	
Yellow perch								
Adult		**pre & spawn** **veg,shoal** **T,F,G,EN**	lit, sublit G,T,F		ther G	lit, sublit G,T,F,EN		
Juvenile		[1]	lit EN	lit EN,S	lit S	**lit** **EN**,smF		
Chubsucker								
Adult		**spawn** **lit** **T,F,G,ED,EN**	lit T,F,G,ED,EN			lit ED,EN		
Juvenile			lit ED,EN			lit ED,EN		
Bowfin								
Adult		lit T,F	**spawn** **lit** **T,F**	lit T,F				
Juvenile					lit ?EN			

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Table 2.2–Continued.

Species, Size	Ice-out 32-40º	After ice-out 40-50º	Spring,early 55-65º	Spring,late 65-75º	Summer 75-62º	Fall,early 62-50º	Fall,late 50-40º	Winter 39-32º
	Season and approximate temperature (F)							
Sturgeon								
Adult			**spawn** **river,shoal** **ED,T,F,G**	postspawn river ED	sublit G			
Juvenile			[1]	sublit smG	sublit smG			
Smallmouth bass								
Adult		lit T,F	**prespawn** **lit** **EN,T,F**	sublit G,T,F,HL		lit, sublit T,F,EN,G,ED	sublit G	
Juvenile			lit EN	lit EN	lit EN,S	**lit** **EN**,ED		
Largemouth bass								
Adult	warm bays T,F		**prespawn** **lit** **EN**,T,F	lit EN,T,F,HL	lit EN,HL	lit EN,T,F	lit T,F	
Juvenile			lit EN,ED	lit EN	lit EN,S	**lit** **EN**,ED		
Black crappie								
Adult		lit sublit T,F	**prespawn** **sublit** **T,F**,G			lit sublit T,F,G		
Juvenile			sublit smF,T,G			lit EN		
Carp								
Adult			prespawn lit T,EN,F,G	spawn lit F,T,G,ED				
Juvenile				lit EN,S		lit smF		
Gar								
Adult			**prespawn** **lit** **T,G**	spawn lit,inlet T,G,ED				
Juvenile								
Redear								
Adult			**prespawn** **lit,sublit** **T,F**	**spawn** lit T,F,EN				
Juvenile								
Bullhead, brown & yellow								
Adult		**lit** [2] **T,F**	**lit,** **sublit** **T,F**	**spawn** **lit** **T,F**	lit,sublit T,F,G	lit, sublit T,F		
Juvenile								

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Table 2.2–Continued.

Species, Size	Ice-out 32-40º	After ice-out 40-50º	Spring,early 55-65º	Spring,late 65-75º	Summer 75-62º	Fall,early 62-50º	Fall,late 50-40º	Winter 39-32º
				Season and approximate temperature (F)				
Warmouth								
Adult			lit T,F,EN	spawn lit T,F,EN		lit EN		
Juvenile			lit EN,ED	lit EN,ED		lit EN		
Rock bass								
Adult			lit T,F	spawn lit T,F	lit,sublit T,F	lit T,F,EN		
Juvenile					lit S	lit smF,EN		
Bluegill								
Adult		**lit** [3] **T,F**	lit, sublit T,F	**spawn** **lit** **T,F,EN**,ED,HL		lit sublit T,F,EN		
Juvenile			lit S,EN,ED	lit **S,EN,ED,smF**	lit S,EN	lit EN,smF,S		
Pumpkinseed								
Adult		**lit** [3] **T,F**	lit T,F,EN	**spawn** **lit** **T,F,EN,ED**		lit T,F,EN		
Juvenile			lit S,EN,ED	lit S,EN,ED,smF	lit S,EN	lit EN,ED,smF		
Grass pickerel								
Adult		spawn marsh,inlet **ED**,EN	lit **ED**,EN	lit **ED**,EN		lit ED,EN		
Juvenile			lit ED,EN	lit ED,EN	lit S	lit ED,EN		
Minnows								
Adult				lit S,ED,smF	lit S,ED,smF	lit EN		
Juvenile				lit S	lit S	lit EN		
Rainbow trout								
Adult		**spawn,springs,** **inlet,outlet** **G,F,T,ED**	lit G		ther G,HL	**lit** **G,EN**,F,T	lit G,EN,F,T	
Juvenile		[1]			inlet,outlet ED	**inlet,outlet** **ED**		
Brown trout								
Adult		lit G,T,F	lit G			**spawn,springs,** **inlet,outlet** **G,T,F,ED,EN**	lit G,T,F	
Juvenile					inlet,outlet ED	**inlet,outlet** **ED**		

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Table 2.2–Continued.

	Season and approximate temperature (F)							
Species, Size	Ice-out 32-40º	After ice-out 40-50º	Spring,early 55-65º	Spring,late 65-75º	Summer 75-62º	Fall,early 62-50º	Fall,late 50-40º	Winter 39-32º
Brook trout								
Adult		lit G,T,F			ther G,HL	**spawn,springs, inlet,outlet G,T,F,ED,EN**	lit G,EN,T,F	
Juvenile					inlet,outlet ED	**inlet,outlet ED**		
Whitefish								
Adult			sublit G,T	ther,bottom G	ther,bottom G	sublit G,T	**spawn shoal T,G**	
Juvenile							[1]	
Lake herring								
Adult	pelagic G,T				ther G		**spawn shoal G,T**	
Juvenile	pelagic smG				ther smG		[1]	
Lake trout								
Adult		sublit G,T	sublit G,T	ther,bottom G	ther,bottom G	lit, sublit G,T,F	**spawn shoal T,F,G**	
Juvenile						?smG	[1]	

[1] Some large juveniles (subadults) may accompany the spawning run.
[2] Juvenile walleye may be effectively sampled at temperatures as high as 70ºF.
[3] Especially lakes in southern Michigan.

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***2.4.2.8 Duration and effort*.**–A survey should continue long enough, and be intensive enough, to obtain a representative sample of all important species. Usually, this means a minimum of 30 fish of each of the primary species. This goal may not be feasible if fish are sparse or difficult to catch (e.g., mid-summer netting in lakes).

For good trout samples in rivers and streams, electrofishing should continue until at least 200 trout have been sampled or for a distance of approximately 1,300 feet or 400 m. For good estimates of species richness in streams, length of each sample station should equal 35 times mean stream width (Lyons 1992). For rapid estimates of community composition and indices of biological integrity (IBI), use guidelines in Procedure 51 (Chapter 25).

Netting in lakes should extend over two or more nights. The following table may be used as a guide for planning the amount of netting (trap + fyke + gill) required for an adequate sample:

Lake area (acres)	Net nights
1-25	5
25-250	5-15
250-2500	15-30
2500+	1 per 150 acres

***2.4.2.9 Catch per effort (CPE)*.**–Catch per effort is a useful index to fish abundance, especially for monitoring changes in a species at index stations. Standardized gear, season, and effort are prerequisites. For all fish surveys catch and effort are to be recorded for each gear type and mesh size, and corresponding CPEs are to be calculated on the FISH COLLECTION form unless the collector notes why the CPE statistic would not be representative. Possible reasons for a non-representative statistic include faulty gear, incomplete records of catch, or nets not being set overnight. CPE is expressed as both number and weight caught per unit of effort. CPE information should be a part of final reports and should be used for comparisons with past surveys within a lake or stream (e. g., Table 2.3). It should be understood that CPE is a highly variable statistic and only major increases or decreases or clear trends through time may reflect real changes in fish abundance. For comparing CPEs for a species across lakes, state average values are now available (Chapter 21 and Table 21.5).

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Selectivity of gear makes comparisons of CPE across species difficult. Rather, the relative abundance of species in the community should be expressed on a rank basis (rare, sparse, common, or abundant).

Table 2.3–Number of fish caught per trap net and gill net lift at East Twin Lake during 1940, 1966, 1969, and 1975. Number of lifts given in parentheses.

	Trap nets			Gill nets	
Species	1975 (38)	1969 (16)	1940 (560)	1975 (16)	1966 (18)
Yellow perch	0.08	10.00	-	5.06	17.94
Walleye	0.45	2.88	4.85	1.06	1.72
Smallmouth bass	4.26	-	1.68	0.06	0.17
Largemouth bass	2.39	0.06	0.11	0.25	-
Bluegill	0.18	0.06		0.26	0.11
Pumpkinseed	4.50	0.19	2.89	0.06	-
Rock bass	3.11	0.38	1.04	-	0.11
Tiger muskellunge	0.08	-	-	-	-
Northern pike	0.03	-	-	-	-
Channel catfish	0.03	-	-	-	-
Common white sucker	2.89	11.75	2.28	1.63	0.67
Brown bullhead	0.08	0.19	0.08	-	-

More precise measures of fish community structure require actual population estimates of each species, or CPEs adjusted for gear selectivity.

Table 2.4 presents units of effort required to calculate CPEs for various types of gear.

Table 2.4.–Standard units of effort for CPE (Part A); and comparison of three types of CPE for trap, fyke, and gill netting (Part B).

Part A

Gear	Standard units
Trap or fyke net Inland experimental gill net Great Lakes gill net	Catch per net lift (with overnight sets)
Large seine	Catch per acre seined
Minnow seine	Catch per haul
Toxicant sampling	Catch per acre of area sampled
Trawl	Catch per 5-minute unit of "actual fishing time" or catch per acre
Visual observations	Adjust as appropriate
Angling	Catch per hour per angler
Set hooks	Catch per set hook per lift
Electrofishing	
Lakes and non-wadeable streams	Catch per hour of actual fishing time (15 minutes minimum effort)
Wadeable streams	Catch per mile or catch per acre

Part B

		Number of CPE units		
Number of nets	Number of nights between lifts	Net lifts (standard)[a]	Net nights (optional)[b]	Nights of netting (optional)[c]
1	0	0	0	0
1	1	1	1	1
1	2 or more	1	0	2 or more
2	0	0	0	0
2	1	2	2	2
2	2 or more	2	0	4 or more
etc.				

[a] "Net lifts" are the standard divisor for trap, fyke, and gill netting CPE computations on the FISH COLLECTION form (R8058). A net lift is defined as one net set over one or more nights (i. e., excludes sets not made overnight).

[b] "Net nights" are an optional, more precise, unit of CPE. Record the number of net nights in the space provided on the front of the FISH COLLECTION form for possible use. A net night is defined as a l-night set.

[c] "Nights of netting" is another optional measure of CPE for use in reports or analyses. Nights of netting is defined as the total number of nights a net was fished, irrespective of the number of lifts.

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***2.4.2.10 Fish recruitment surveys*.–**Recruitment, as used here, means the addition of fingerling fish to populations by the processes of reproduction and subsequent survival through the earliest life stages. It is typically measured in fall of age 0, or as yearlings, after the extremely high rate of natural mortality from birth to fingerling size has diminished. Usually, the strength of a year class has been "set" by then, which means it will usually persist as relatively weak, average, or strong throughout all subsequent years. Recruitment may also be measured at yearling or older stages.

Annual variations in recruitment may be monitored by measuring annual fluctuations in catch per effort (CPE). Standardized methods are required to minimize sampling variation, which can be considerable because fish distribution is not very predictable. Electrofishing is the most important gear type because it can effectively sample small fish in all shallow waters. Seines, on the other hand, can only be used in shallow areas with firm, snag-free substrates.

For wadable streams, sampling of recruits is relatively straightforward because all areas can be sampled. Young-of-the-year trout and smallmouth bass tend to concentrate in shallow edges, and fall is the most effective season to sample them. In large rivers, small chinook salmon concentrate along edges as they work their way downstream in spring and are relatively easy to sample. However, small fish located in deep waters are very difficult to sample except with boom shocker or rotenone.

For lakes, sampling of recruits is difficult because small fish spend some time in deep water which cannot be sampled by electrofishing or netting. There, the key to effective indexing is to sample when small fish are inshore. This varies diurnally and seasonally, with water temperature, in a fairly predictable manner (Table 2.2).

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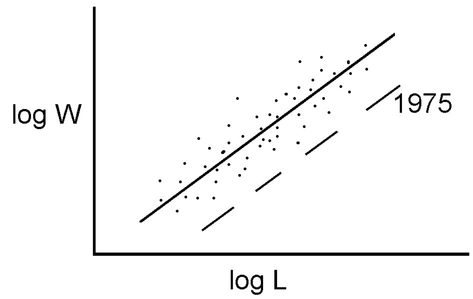
Methods for sampling and indexing the recruitment of walleye and muskie in lakes have been developed by Wisconsin biologists and verified by managers in Michigan (see Chapter 23). Basically, the methods involve electrofishing the edges of lakes during fall or spring, when young are inshore.

Detailed recommendations for sampling young pike, smallmouth bass, bluegill, and yellow perch in lakes have not been developed. However, as the cumulative lake experience summarized in Table 2.2 indicates, recruitment of those species can be indexed by appropriate CPE index sampling. We suggest using boom shockers, appropriately calibrated to stun small fish, to sample northern pike in late fall (same temperatures as muskie), and smallmouth bass and yellow perch in early fall (same temperatures as walleye). Bluegill, as yearlings, may be sampled in late spring, after water warms past 65°F. Pike may be indexed at the same time as muskie since both are relatively sparse and can be collected efficiently. If smallmouth bass, yellow perch, and walleye are all relatively abundant in the lake being sampled, it may be necessary to concentrate on picking up one or two species at a time. For example, concentrate on walleye collection for 2 hours then on perch collection for 0.5 hour.

***2.4.2.11 Length-weight relationship*.**–Individual lengths and weights of important species are not required for most surveys, but should be obtained during inventories in which accurate data on weight are needed, as for determining condition. Compute length-weight regressions to determine condition (Section 2.4.1.4), and to expand length-frequency data to length-biomass data and total biomass of the catch (Section 2.4.1.2).

Obtain individual lengths and weights for a sample of 5-10 fish per inch group per species. For small fish that are difficult to weigh individually, weigh a group of similar size fish together to obtain an average. Weigh panfish to 0.002 pound (1 gram), if possible. Take weights carefully, on stable and level footing, out of the wind, with an accurate electronic balance. Record lengths and weights on scale envelopes, if scale samples are being taken, or on LENGTH WEIGHT FIELD DATA forms. Later, transfer data to the Fish Collection System where computer analysis is available, saving step 1 below:

1. Calculate: $\log_{10}W = \log_{10} a + b*\log_{10}L$ or plot L and W on log-log graph paper:



2. Fill out the LENGTH-WEIGHT REGRESSION form. Evaluate relative plumpness by calculating relative weight (Murphy et al. 1991), or by comparing the regression slope (b) or the displacement of the line on a graph to prior samples. In the example graphed above, the fish are now heavier at the same length than they were in 1975. State standards (Chapter 17) may also be used for comparison. Keep seasonal changes in mind (e.g., spawning) when interpreting the significance of comparisons.

2.4.2.12 Length-frequency.–Samples taken for length-frequency analysis must faithfully reflect the size structure of the catch and, within the limits of gear selectivity, should reflect the true size structure of the population. The measured fish must be selected randomly or systematically. Generally for management surveys, the first 200 fish caught of each species should be measured to inch group, but very large catches should be subsampled so that a variety of sample sites and dates are represented. Lesser numbers may be measured if the range in fish size is unusually small. Avoid subsampling from catches held in tubs or other containers, as the subsample will almost certainly be biased. It is better to measure all the fish caught in every other net rather than to pool the total catch in a tub and try to randomly pick out half of the fish. Also, do not select specimens on the basis of size with one exception: the largest and the smallest specimen should be added to the length-frequency table if they were not included in the 200 already sampled. This allows the full range in size within the catch to be conveniently recorded.

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The length-frequency of the sample is to be reported in the FISH COLLECTION format, which is computerized in the Fish Collection System. A rough draft of the paper form is handy for tabulating data in the field.

2.4.2.13 Length-biomass and total biomass.–Biomass of fish is a better measure of population productivity and community structure than numbers of fish. On the population level, a length-biomass table (FISH COLLECTION and POPULATION ESTIMATE forms) indicates at which size a species has accumulated its greatest net production; after that size the population loses more biomass to mortality than it gains from growth. On the community level, expressing species composition as a percentage by weight compensates for the large differences in average lengths/weights of species and provides a better measure of trophic structure.

Obtain length-biomass data by inch group for the random sample of fish used for the length-frequency table by one of these methods:

1. Averaging empirical weights taken for each inch group;
2. Calculating weight of an inch group from a length-weight regression equation (or simply reading from the graph), by assuming average length of fish in the inch group was the midpoint (e.g., 6.5, 7.5, etc.);
3. Using state average length-weight tables and midpoints (Chapter 17).

The third option is the default choice in the Fish Collection System. The System will calculate average weight and total pounds caught for each species, then other statistics required for completion of forms.

Example: 80 perch (plus other species) were taken in two experimental gill nets. Of these, 68 were measured to inch group (shown) and 48 were measured to 0.1 inch and 0.002 lb. (not shown, recorded on a LENGH-WEIGHT DATA form). Average weights (lb.) for the inch groups were: 5-inch, 0.060; 6-inch, 0.101; 7-inch, 0.149; 8-inch, 0.230; 9-inch, 0.312. Biomass estimates were obtained by multiplying each average weight by the number of perch in each group (e. g., for 5-inch group: 0.060 x 12 = 0.72 lb.). The following table was then completed:

Avg. Wt.	= 12.08 lb./68	=	0.178
Total Lb.	= 0.178 lb. x 80	=	14.24
%L-A No.	= 41/68	=	60.3
%L-A Lb.	= 9.84 1b./12.08 1b.	=	81.4
CPE No.	= 80/2	=	40
CPE Lb.	= 14.24/2	=	7.12

Note the rounding.

Species	Y. perch	
Gear	EG	
Length	7.6	
Avg. Wt.	0.18	
	No.	Lb.
Total	80	14.2
%	--	--
CPE	40	7.1
% L-A	60	81
Inches		
1		
2		
3		
4		
5	12	0.7
6	15	1.5
7	8	1.2
8	20	4.6
9	13	4.0
10		
•		
•		
Sample Total	68	12.0

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2.4.2.14 Average length and weight.–Designated as "No." and "Lb." on the electronic version of Catch Summary By Gear form. Calculate from a random or systematic sample, usually from data in length-frequency and biomass-frequency tables.

The best estimate of the average length of small samples of fish is the simple average of individual measurements made to 0.1 inches. A satisfactory estimate of average length may be computed from a large length-frequency sample by a weighted formula that assumes 0-inch group fish average 0. 5 inch long, l-inch group fish average 1.5 inches long, etc.

Each median length is multiplied by number of fish in the inch group, the products are summed, then divided by the total number of fish. Below is calculated the average length of the 68 perch in the preceding example.

$$avg.length = \frac{(5.5\times12)+(6.5\times15)+(7.5\times8)+(8.5\times20)+(9.5\times13)}{68} = 7.6\,inches$$

The best estimate of average weight is obtained by dividing total biomass in the biomass-frequency table by number of fish in the length frequency table. Alternatively, divide empirical weight of the total catch by total number of fish.

2.4.2.15 Age and growth.–Samples taken for age and growth analysis should fairly represent the ages and growth rates within a species population. Sub-samples may be taken from the catch systematically (e.g., every other fish), randomly, or on a stratified-random basis (e.g., 15 randomly selected samples from within each inch group).

The stratified-random method is best when the catch is large, when a length-frequency sample is also taken, and when age groups cannot be clearly identified in advance on the basis of length or stocking records. For most management surveys of growth a sample of 10-

15 fish per inch group is adequate. That will usually result in a sample of at least 15 per age group. For more intensive studies of growth and age composition (as in conjunction with population estimates), a sample of at least 30 fish per inch group should be taken. Chapter 6 discusses general aspects of sample size in greater detail. It is better to take too many samples (not all of them need be examined) than too few.

Techniques of scale sampling, aging, and back calculation are discussed in Chapter 9. There are two methods for calculating average length of an age group of fish. If a sample was taken systematically or randomly, then a simple average of the data is appropriate. However, if a stratified sub-sample was taken, a simple average gives an overestimate in most instances and it is better to calculate a weighted average length with the aid of length-frequency information (illustrated in Chapter 15). This bias is potentially more severe when attempting to quantify age composition and survival rates (see Section 2.4.2.17 and Chapter 15). The method used for calculating average length is to be recorded in the space provided on the FISH GROWTH form.

Statewide growth averages and computed growth indices (see Chapter 9) may be used as standards for comparing the growth of one population with others. However, in judging if observed growth is satisfactory or meets expectations, factors such as lake productivity and type of fish population should be considered. The state averages have been broken down into four time periods per age so that more meaningful comparisons can be made between samples taken at different times of the year. For example, age-3 largemouth bass "should" average about 9.4 inches in January-May (prior to that growing season) and about 11.6 inches in October-December (after that growing season). If the observed length of age-3 bass in Example Lake was 10.4 inches in May 1960 (growth index = +1.0), and 10.6 inches in November 1970 (growth index = -1.0), then it is clear that bass growth has declined (2.0 inches).

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2.4.2.16 Population estimates.–Estimates of the actual density of fish may be obtained by (a) censusing the entire water body or a portion of it (e.g., draining or poisoning followed by ***complete*** recovery); (b) adjusting CPE for gear efficiency (e. g., catch per area times an avoidance factor); or (c) using one of the variations of mark-and-recapture or depletion techniques. Because complete recovery of fish is rarely possible and the efficiency of gear is difficult to assess, mark-and-recapture and depletion methods are usually better.

At present, mark-and-recapture and depletion computations are not in the Fish Collection System, but can be easily calculated within spreadsheets. Estimates derived from a variety of formulas should be summarized on the same POPULATION ESTIMATES form, if possible.

For details of mark-and-recaptured methodology, refer to Chapter 7 (streams), Chapter 8 (lakes), and to standard references such as Ricker (1975). For details on the depletion estimate method, see Chapter 7.

Several points about population estimates merit emphasis:

- It is usually wise to collect scale samples during population estimates so that growth, age-frequency, and survival can be studied concurrently.
- They are highly recommended for management surveys of wadable streams because much better information is obtained for only about twice as much effort as a once-through electrofishing survey. The Bailey modification of the Petersen formula is the most appropriate. See Section 2.1.2.3 for specifics on length of stations.
- They are more accurate (and sometimes less work) than a complete census of chemically treated waters. Mark native fish prior to the treatment and then examine a large sample of the dead fish to obtain the ratio of marked to unmarked fish.
- They must be stratified by species and size, then summed, to compensate for gear (and people) selectivity. If possible, use one type of gear to catch fish for marking, another type of gear for the recapture sample.

- The most critical underlying assumption is that marked fish have the same probability of recapture as any other fish in the population.
- Care must be taken to sample all parts of the study area. For example, use extra long electrodes to sample trout living in deep pools of streams. Alternatively, conduct the estimates when fish are mixing freely and are equally vulnerable to capture. Such mixing occurs on the shoals of lakes during spring and fall.
- Valid estimates can be obtained even after a long lapse of time between marking and recovery (e.g., fall to spring). Requirements are:

  Marks are not "lost";

  Marked and unmarked fish have the same survival rate;

  Fish are not subtracted or added to the population because of movement or recruitment by growth to catchable size.
- Concentrate sampling effort on target species. For example, when electrofishing wadable trout streams, concentrate on catching trout and do not attempt to make quantitative catches of other species (muddlers, minnows, suckers, darters, etc.) at the same time because trout catches (and estimates) will suffer. Simply note if other species are abundant, common, or rare. If better population data are needed for these non-target species, then conduct a depletion-type estimate (Chapter 7) in a short section of stream.

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Example.–Brook trout in a stream were sampled with a 220-volt DC stream shocker. They were marked by clipping the top lobe of the caudal fin. Scale samples were taken. Field data from the marking and recovery runs are shown in Tables 2.5 and 2.6.

In the office, data were tallied and population estimates were made by inch group using the Bailey modification of the Petersen formula (Table 2.7, see also Chapter 7). It is better than the simple Petersen formula when sample sizes are small, as is typically the case. Direct estimates of the 1-, 12-, 13- and 14-inch groups could not be made reliably because fewer than three recaptures were made. Therefore, data for the 1- and 2-inch fish were combined and a single estimate calculated. For the large trout, it is apparent that nearly 100% of them were caught and the best estimate is simply the sum of the catch. Alternatively, we could have calculated the ratio of marked fish to population estimate for every other size group, plotted those ratios versus size groups, fit a line or a curve to those points, read the ratio off the graph for the size group with insufficient data, then expanded the number of marked fish by this ratio. Population estimates should be expressed in fish per acre, fish per mile, or fish per unit of discharge (Table 2.7). Biomass of the population should be computed by methods in Section 2.4.2.13.

Using the age composition of the scale sample collection, estimates by inch groups were converted to partial estimates by inch groups and age groups as shown in Table 2.7. For example, of the 317 4-inch trout per hectare, 41.7% were age 0 (132 fish) and 58.3% were age 1 (185 fish). The total estimate for the age group is then the sum of those partials.

From the estimates by age groups just derived, the apparent survival rate of fish in the population was estimated. The survival rate is equal to the percentage of fish surviving to the next older age class, if recruitment is exactly the same each year. These rates were 32.9% from age 0 to1, 48.4% from age 1 to 2, 10.2% from age 2 to 3, and 13.3% from age 3 to 4. A plot of the abundance of each age class on semi-log paper gives a graphic picture of survival rate (Figure 2.5). Note the term "apparent" survival rate. One cannot be sure whether decreases in numbers at a particular station are due to mortality, uneven recruitment, or movement out of the station. That is why it is best to look at populations on a drainage basis.

Good population estimates at all sample stations in a drainage provide the means to estimate the population for the entire drainage. To do this, assume that the sampling station (located near the center of the drainage zone) is representative of the zone as a whole. Then, calculate the population within each drainage zone by multiplying population per acre at the station times number of acres in the zone. To arrive at the population of the drainage, the populations of all zones are summed.

From data on numbers of fish in each age and size class, a weighted estimate of growth rate was made (Table 2.7). For example: the number of age-0 (fall fingerlings) in each size class was multiplied by the mid-point of that size class to arrive at total inches. This was done for each size class where age-0 fish were represented. Total inches were summed and divided by total estimated number of age-0 fish to obtain average size of age-0 fish. The procedure was repeated for each age group. Another example is provided in Chapter 15. This method reduces most sampling bias but has limitations in that it requires rather extensive data. A graphic picture of this growth rate is in Figure 2.6.

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Table 2.5–Example of stream fish population estimate.

Marking Run - Brook Trout
Alexander Creek 8/30/80

Length group in inches:

1.0-1.9	2.0 - 2.9				3.0-3.9		4.0-4.9		5.0-5.9		6.0-6.9		7.0-7.9		8.0-8.9		9.0-9.9		10.0-10.9		11.0-11.9		12.0 - 12.9	13.0 - 13.9	14.0 - 14.9
1.7	2.2	2.5	2.6	2.8	3.4	3.3	4.6		5.1	5.7	6.3	6.4	7.7		8.0		9.0		10.0		11.0		12.0	13.0	14.3
1.8	2.0	2.7	2.6	2.7	3.2	3.1	4.4		5.1	5.9	6.3	6.2	7.0		8.5		9.0		10.6		11.0		12.2	13.5	14.5
	2.4	2.9	2.2	2.9	3.0	3.4	4.7		5.4	5.0	6.3	6.1	7.5		8.0		9.0		10.0		11.5		12.2	13.6	
	2.8	2.1	2.6	2.6	3.3	3.4	4.7		5.5	5.1	6.6	6.4	7.0		8.6		9.0		10.4		11.4				
	2.6	2.6	2.7	2.3	3.4	3.5	4.8		5.5	5.7	6.7	6.1	7.5		8.3		9.0		10.0		11.4				
	2.8	2.7	2.8	2.4	3.8	3.0	4.9		5.5	5.5	6.8	6.7	7.1		8.0		9.7		10.0		11.0				
	2.3	2.5	2.5	2.8	3.6	3.1	4.0		5.8	5.5	6.5	6.7	7.3		8.7		9.4		10.0		11.4				
	2.5	2.6	2.7	2.9	3.3	3.2	4.4		5.7	5.8	6.3	6.1	7.1		8.2		9.8		10.3		11.1				
	2.2	2.9	2.6	2.7	3.7	3.5	4.7		5.7	5.1	6.4	6.0	7.3		8.3		9.0		10.4		11.5				
	2.8	2.6	2.7	2.5	3.4	3.2	4.8		5.0		6.2	6.4	7.3		8.2		9.4		10.7						
	2.5	2.7	2.9	2.7	3.4	3.3	4.8		5.0		6.6	6.8	7.0		8.0		9.8		10.7						
	2.5	2.2	2.1	2.6	3.2	3.8	4.4		5.8		6.3	6.3	7.3		8.7		9.5		10.2						
	2.0	2.4	2.4	2.2	3.8	3.2	4.9		5.7		6.5	6.6	7.8		8.2		9.4		10.5						
	2.5	2.4	2.4	2.4	3.0	3.6	4.7		5.5		6.2		7.3		8.4		9.2		10.5						
	2.5	2.6	2.6	2.6	3.3	3.7	4.5		5.9		6.1		7.3		8.4		9.3								
	2.6	2.3	2.8	2.3	3.2	3.2	4.8		5.7		6.6		7.4		8.1		9.3								
	2.3	2.7	2.2	2.0	3.1	3.3	4.7		5.0		6.0		7.2		8.5		9.2								
	2.2	2.9	2.6		3.0	3.0	4.8		5.3		6.6				8.1		9.8								
	2.1	2.6	2.5		3.5	3.1	4.3		5.8		6.5				8.1		9.1		.						
	2.7	2.6	2.8		3.5	3.2	4.7		5.1		6.6				8.8		9.3								
	2.8	2.7	2.5		3.2	3.6	4.3		5.4		6.2				8.4		9.4								
	2.9	2.8	2.9		3.9	3.1	4.4		5.4		6.1				8.5		9.4								
	2.4	2.5	2.7		3.4	3.3	4.6		5.4		6.5				8.0		9.2								
	2.7	2.8	2.7		3.3	3.1	4.1		5.5		6.3				8.5		9.7								
	2.9	2.2	2.5		3.0	3.4			5.9		6.2				8.5		9.0								
	2.2	2.6	2.7		3.0	3.6			5.2		6.4				8.1		9.6								
	2.2	2.7	2.6		3.0	3.2			5.9		6.2				8.7		9.7								
	2.6	2.8	2.8		3.5	3.8			5.5		6.2				8.1		9.8								
	2.5	2.9	2.8		3.2	3.0			5.1		6.8				8.8		9.5								
	2.9	2.3	2.3		3.6	3.0			5.6		6.0				8.1		9.7								
	2.7	2.7	2.6		3.6	3.3			5.2		6.4				8.8		9.5								
	2.2	2.4	2.7		3.0	3.2			5.5		6.0						9.6								
	2.8	2.9	2.9		3.2				5.2		6.7														
	2.5	2.0	2.9		3.2				5.7		6.4														
	2.6	2.8	2.5		3.2				5.0		6.0														
	2.6	2.6	2.5		3.5				5.3		6.0														
	2.6	2.9	2.6		3.3				5.5		6.7														
	2.6	2.4	2.8		3.0				5.3		6.5														

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Table 2.6–Example of stream fish population estimate.

RECOVERY RUN - BROOK TROUT
ALEXANDER CREEK 9-1-1980

(length in inches) U = UNMARKED M = MARKED R1016-1

1.0 – 1.9		2.0 – 2.9		3.0 – 3.9		4.0 – 4.9		5.0 – 5.9		6.0 – 6.9		7.0 – 7.9	
u	m	u	m	u	m	u	m	u	m	u	m	u	m
|		卌	卌	卌	卌	卌	||||	卌	卌	卌	卌	卌	卌
		卌	卌	卌	卌	卌		卌	卌	卌	卌	卌	卌
		卌	卌	卌	||||			卌	||	卌	||		
		卌	卌	卌				卌		||			
		卌		卌				||||					
		卌		卌									
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8.0 – 8.9		9.0 – 9.9		10.0 – 10.9		11.0 – 11.9		12.0 – 12.9		13.0 – 13.9		14.0 – 14.9	
u	m	u	m	u	m	u	m	u	m	u	m	u	m
卌	卌	卌	卌	||||	卌	||	|||				|		|
卌	卌	||||	卌		|||								
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Table 2.7–Example of stream fish (brook trout) population analysis.

Brook Trout
Alexander Creek
Section A (Area = 0.227 ha.)

Inch Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
Mark-Recapture Population Estimates.															
Number Marked	2	131	70	24	47	51	17	31	32	14	9	3	3	2	
Number Recaptured	0	20	14	4	12	12	10	12	12	8	3	0	1	1	
Total Catch	1	103	52	14	36	29	20	22	21	12	5	0	1	1	
Est.= M(C+1) / (R+1)		665	247	72	134	118	32	55	54	20	14	3*	3	2	
Pop./ha.		2930	1088	317	590	520	141	242	238	88	62	13*	13	9	
Age Composition of Scale Samples by Percents and Numbers of Fish ( ).															
Age: 0		100	100	41.7											
		(28)	(28)	(10)											
I				58.3	100	100	36.4	7.7							
				(14)	(30)	(30)	(8)	(2)							
II							63.6	92.3	92.9	75.0	75.0	50.0	50.0		
							(14)	(24)	(26)	(18)	(16)	(4)	(2)		
III									7.1	25.0	25.0	50.0	50.0		
									(2)	(6)	(2)	(4)	(2)		
IV														100	
														(1)	
Population Estimates per Hectare by Age Group and Inch Group = Pop/ha x %.															
Age: 0		2930	1088	132											4150
I				185	590	520	51	19							1365
II							90	223	221	66	46	6	6		658
III									17	22	16	6	6		67
IV														9	9

Weighted Average Length of Age Group = Median Length x Age Est.

Age: 0 $\frac{(2.5 \text{ x } 2930) + (3.5 \text{ x } 1088) + (4.5 \text{ x } 132)}{4150}$ = 2.83 inches

I $\frac{(4.5 \text{ x } 185) + (5.5 \text{ x } 590) + (6.5 \text{ x } 520) + (7.5 \text{ x } 51) + (8.5 \text{ x } 19)}{1365}$ = 5.86 inches

II $\frac{(7.5 \text{ x } 90) + (8.5 \text{ x } 223) + 9.5 \text{ x } 221) + (10.5 \text{ x } 66) + (11.5 \text{ x } 46) + 12.5 \text{ x } 6) + (13.5 \text{ x } 6)}{658}$ = 9.19 in.

III $\frac{(9.5 \text{ x } 17) + (10.5 \text{ x } 22) + (11.5 \text{ x } 16) + (12.5 \text{ x } 6) + (13.5 \text{ x } 6)}{67}$ = 10.93 inches

IV $\frac{(14.5 \text{ x } 9)}{9}$ = 14.5 inches

*Estimated indirectly (see text).

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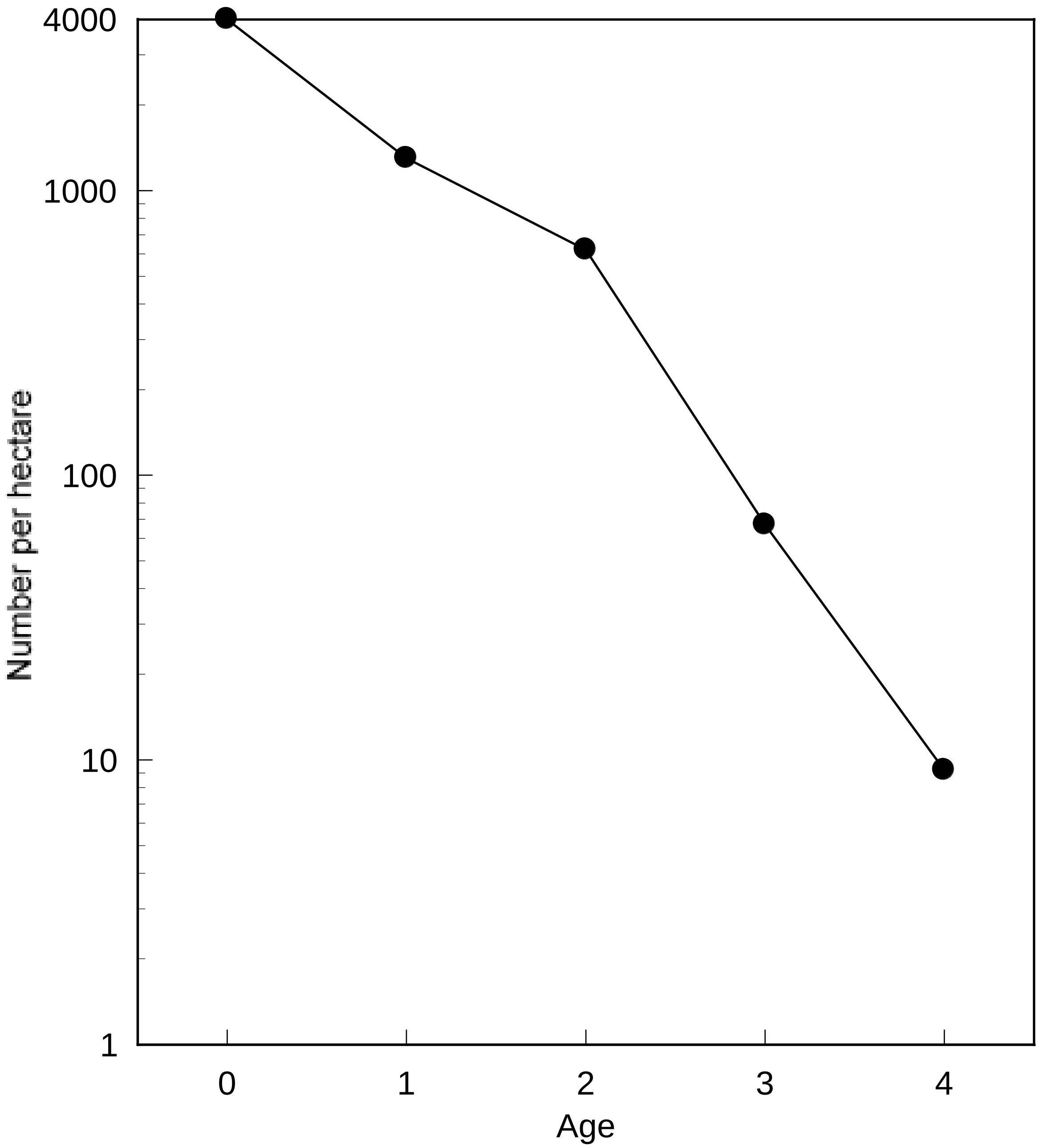

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Figure 2.5.–Example of a survivorship curve for brook trout from a stream population estimate.

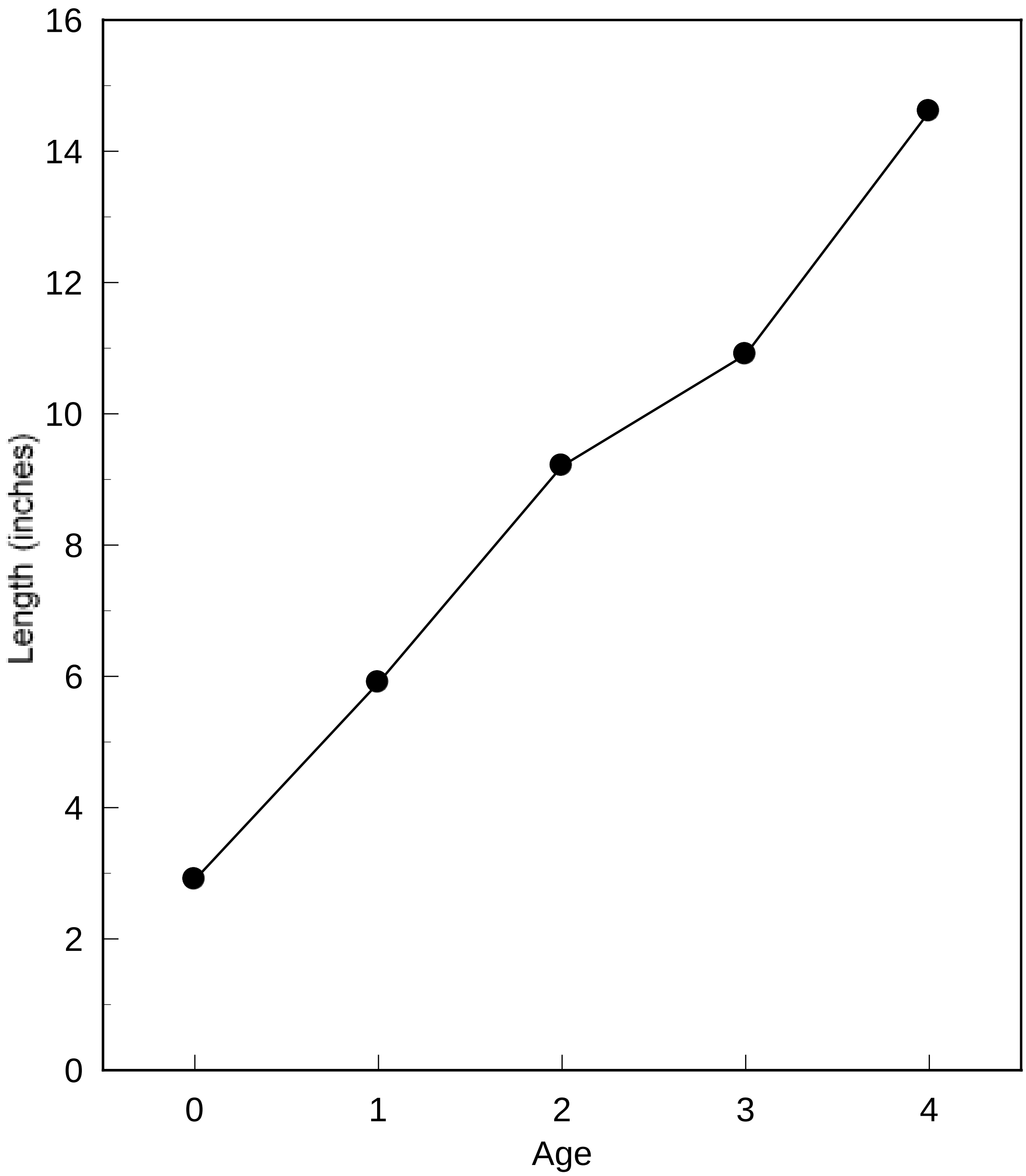

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Figure 2.6.–Example of a growth curve for brook trout from a stream population estimate.

2.4.2.17 Age-frequency and survival.–Age-frequency information may be used to simply identify weak and strong year classes or, more rigorously, to compute survival rates. Routine management surveys of growth often collect adequate information to rank the relative strength of year classes (note that stratified sub-samples must be weighted as in Chapter 15) and evaluate longevity (Section 21.1.1.2). However, careful planning and larger samples are needed for reliable estimates of survival.

For most purposes, studies of survival should be made in conjunction with population estimates. Obtain at least 30 scale samples per inch group. Methodology is presented in detail in Section 2.4.2.16 and Chapter 15. The computations are to be summarized on the POPULATION ESTIMATES form.

Survival may also be estimated from simple "catch curves" by substituting catch by age frequencies for mark-and-recapture population estimates by age. See textbooks (Ricker 1975) for discussions of methods and limitations. This method is not as reliable because catch frequencies are biased by gear selectivity and unusually weak or strong year classes.

Estimates of annual survival rates based on age frequencies taken on one date (whether based on mark-and-recapture estimates or simple catch curves) are subject to errors caused by uneven year class strength. Therefore, it is best to estimate the population in two consecutive years and compute the survival of each year class directly as number alive in year 2 divided by number alive in year 1.

For an example of computing survival rate, see preceding trout data (Section 2.4.2.16).

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2.4.2.18 Production.–Production, the result of the interaction between growth and mortality, is useful for computing maximum sustainable yields and in selecting the most appropriate fishing regulations. It is narrowly defined as the total elaboration of fish tissue during any time interval (usually a year), including individuals that do not survive to the end of the interval. It is obtained by multiplying instantaneous rate of increase in individual weight by average biomass of the population during that time interval. Thus, basic data required are growth, survival, and biomass of the population. Production can be determined by means of a graph (Allen method), equation, or computational table. See references such as Ricker (1968).

2.4.2.19 Natural history observations.–Record field observations on fish movements, spawning, disease, parasites, etc. on FISH COLLECTION or NOTES AND REFERENCES forms. These observations are important. If a number of fish have disease or unusual features, make accurate observations and count and weigh them. Save some specimens on ice for later examination by a pathologist or other specialist. Note unusual occurrences of fish-eating birds such as herons and cormorants, and the presence of noxious species such as rusty crayfish, zebra mussels, gobies, ruff, etc.

Also, record the presence of turtles and amphibians encountered during field work on the HERPS POPULATION ESTMATE forms and in the survey database. A number of these species are becoming rare due to continual elimination of small wetlands and unknown causes.

2.4.2.20 Nuisance control.–At the conclusion of surveys, and during other field work, care must be taken to prevent the spread of nuisance species to new waters. Examples of nuisance species of great concern are zebra mussels, spiny water flea, Eurasian water milfoil, curlyleaf pondweed, and purple loosestrife. Division policy and procedures for disinfecting equipment and preventing the spread of nuisance species are given in Chapter 24.

2.5 Fishery Assessment

Observations on the fishery should be recorded on the FISH COLLECTION or NOTES AND REFERENCES form. First-hand observations are preferred, but local reports of success or complaints may be recorded if the biologist or technician feels the account is reliable.

Creel surveys should be used to document the success of significant management programs. Creel census methods are reviewed in Chapter 14, and assistance with design is available at the Institute for Fisheries Research in Ann Arbor.

2.6 References

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Written in 1981 by J. W. Merna, G. R Alexander, and J. C. Schneider
Extensively revised 01/2000 by J. C. Schneider

Manual of Fisheries Survey Methods II: with periodic updates

Chapter 3: Fishing Gear

James C. Schneider and James W. Merna

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Chapter 3: Fishing Gear

James C. Schneider and James W. Merna

Gear for collecting fish samples continues to develop. Gear familiar to us now may not be familiar to our successors 100 years from now. The most common types of gear are described in the following sections. Consider these descriptions as standards; gear with other features must be more fully described in the electronic Fish Collection System or on the FISH COLLECTION form. Whenever you collect samples, make sure the gear is adequately described so that potential bias can be recognized, the information can be properly interpreted (both now and in the future), and the survey can be repeated at a later date. The Fish Collection System allows each net (or type of net) to be numbered so that its characteristics need be entered in the system only once. Then, in subsequent surveys, only net number need be recorded to link survey results to gear type and description.

New gear or techniques are sometimes needed, use your training and experience to the fullest.

3.1 Trap nets

Description

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There are two types of trap nets in use for inland surveys; the "3-foot trap" and the "6/3-foot trap." Walter Crowe (1950) described the 3-foot trap (Figure 3.1). Dave Havens and Joe Drew developed the 6/3-foot trap (Figures 3.1 and 3.2). Both nets have 1½-inch stretched mesh in the pots.

Use

Trap nets are effective in lakes. They readily take most of the warmwater species and trout when fish are actively moving. Size selectivity is primarily determined by mesh size, secondarily by the funnel opening. Fish caught in trap nets usually can be returned to the water unharmed.

Trap nets fish best when set off points, weed beds or other obstructions to fish movements which act as natural leads. Nets are usually set perpendicular to shore, on a gently sloping bottom, with the pot end deeper than the inshore lead. They do not fish as effectively on steeply sloping bottoms or in depths greater than about 30 feet. Trap nets should be fished one night between lifts. Size of mesh in the pot of the net used must be recorded.

3.2 Fyke nets

Description

The original design has 2-inch stretch mesh, is 4-feet high, and has a 150-foot lead (Figure 3.3). The same frames are sometimes hung with either 1½-inch or l-inch mesh, and fitted with shorter leads. A fourth variation has ½-inch mesh, a 25-foot lead, and a half-scale frame (2 feet high by 3 feet wide). In describing fyke nets on forms, record stretched mesh size and frame height. Size of mesh in the pot must be recorded.

Use

Fykes are easier to handle than trap nets, especially in water less than 6 feet deep. They are effective in lakes and in sluggish rivers. Selectivity is influenced by mesh size and fish movements. Fyke nets should be set perpendicular to shore or with the current. They fish better than trap nets on steep slopes. Fykes should be fished one night between lifts. They can be substituted in place of some trap net sets.

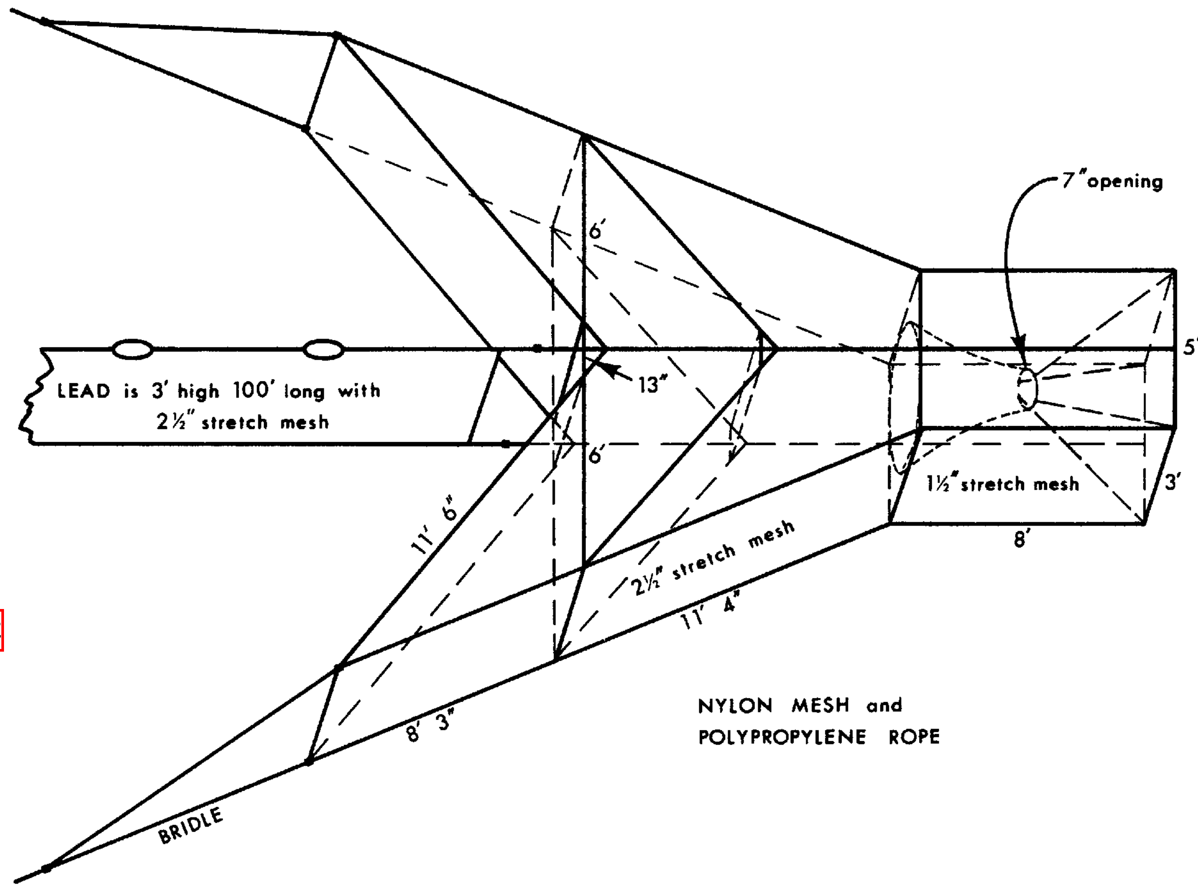

Figure 3.1–Construction details of a 3-foot trap net.

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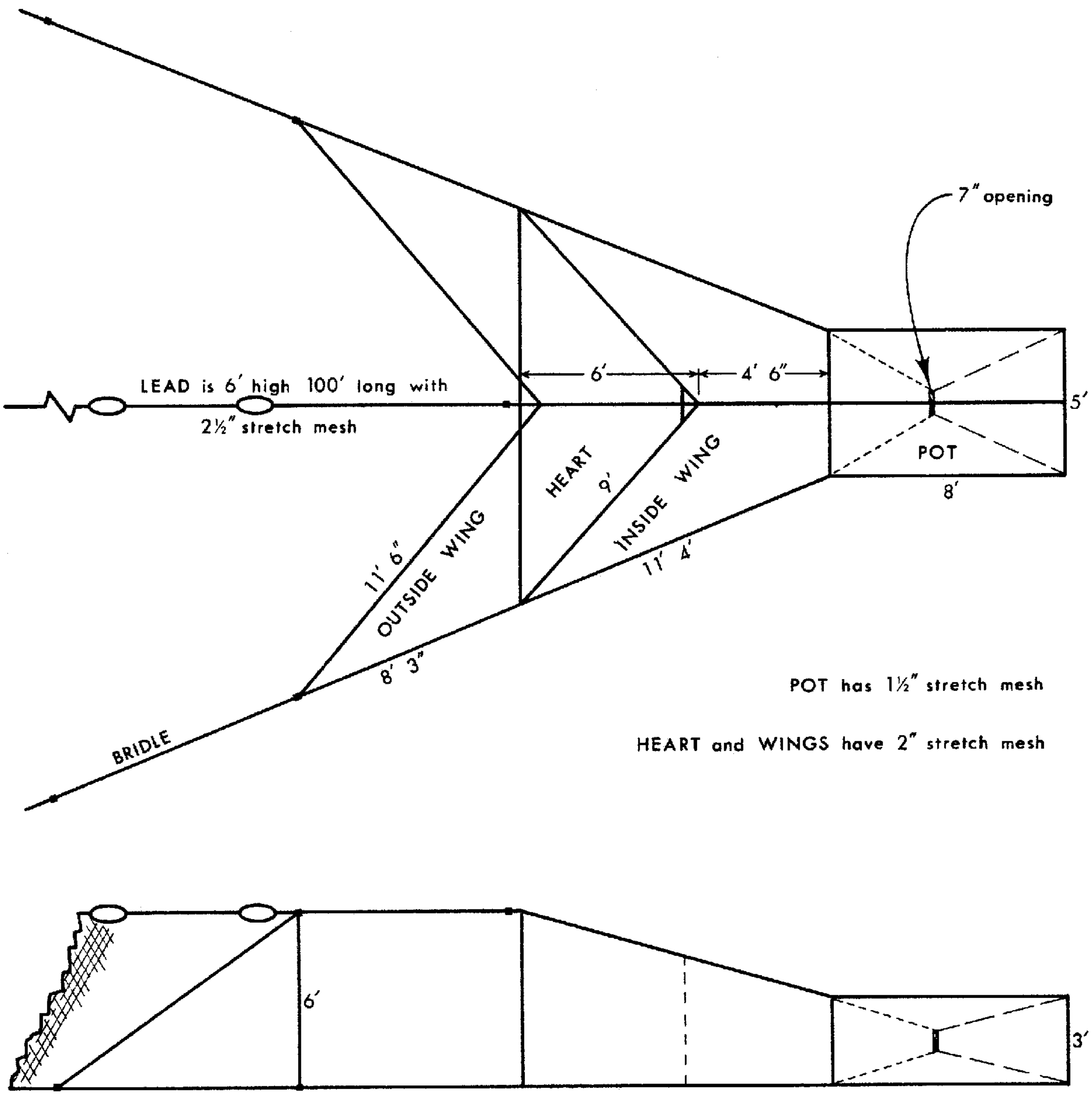

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Figure 3.2–Construction details of a 6/3-foot trap net (6-foot lead tapering to a 3-foot pot).

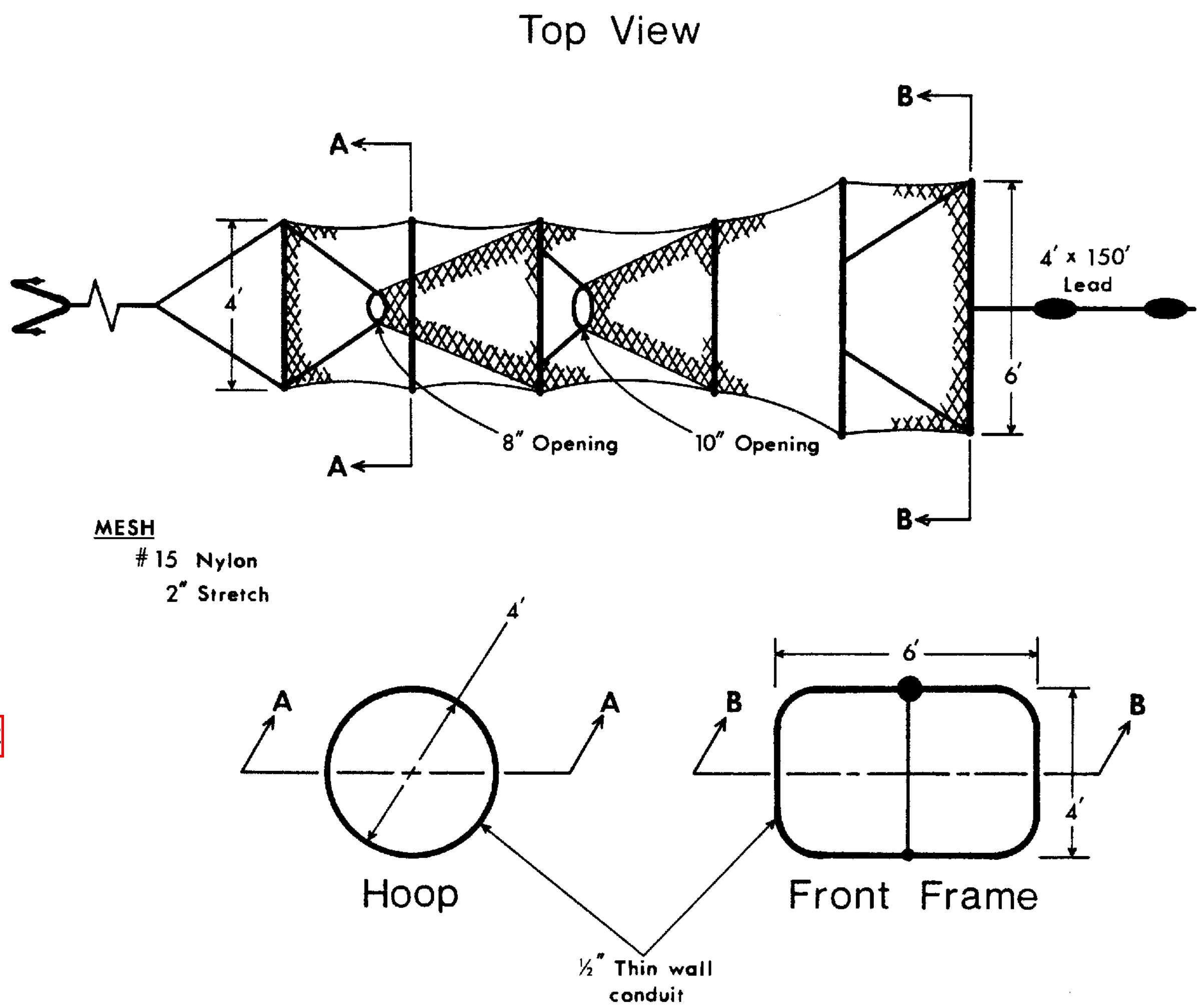

Figure 3.3–Construction details of a fyke net.

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3.3 Inland experimental gill nets

Description

This net is 125 feet long and 6 feet deep. It consists of five 25-foot sections of different mesh sizes. The mesh sizes (stretch measure) are 1½ inches, 2 inches, 2½ inches, 3 inches, and 4 inches, and are hung in that order on a 1:2 basis (2 feet of stretch mesh per foot of lead or float line). The mesh is made of nylon multifilament. Monofilament mesh is not standard, and if used must be duly reported and described. Weight of the solid core lead line should be sufficient to sink the net for bottom fishing.

Use

Gill nets are used in lakes or (very carefully) in sluggish streams. Gill nets are very selective, but effective in catching many fish, especially yellow perch, northern pike, and trout. Centrarchids are usually undersampled. Gill nets are to be fished one night between lifts for standard CPE. Set each net as an individual unit.

Gillnets may be rigged to fish at surface or midwater. They may also be used vertically. Such uses are unusual for routine surveys and each application must be described well.

3.4 Modified Great Lakes gill nets

Description

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This net is 500 feet long and 6 feet deep. It fishes on bottom. It consists of ten 50-foot sections of different mesh sizes. Mesh sizes (stretch measure) are 1½ inches, 2 inches, 2½ inches, 3 inches, 3½ inches, 4 inches, 4½ inches, 5 inches, 5½ inches, and 6 inches, and are hung in that order. Material is nylon multifilament: #46 (210/2) for 1½- to 3½-inch mesh; #69 (210/3) for 4- to 5½-inch mesh; and #104 for 6-inch mesh. The mesh is hung on a 1:2 basis with double selvage. One lead (three per pound) and one float per 8 feet of net; or equivalent balance of lead core and hollow core lines.

Use

This net has been used in larger inland lakes where a large sample is needed or where larger individual fish are found. Gill nets are to be fished one night between lifts. Set each net as an individual unit. Number of sets must be tailored to the survey needs.

3.5 Seines

Description

Various seines are in use. There seems to be no "standard" seine. Record length, mesh size, and bag mesh, if a bag is present.

Use

Generally, seines are effective on small fish, especially minnows. But larger seines are effective in sampling most species and sizes which occur in snag-free habitats in shallow water. Enough effort should be expended to obtain a representative sample of fish. Sample sites should be widely scattered and represent diverse habitats.

3.6 Toxicant sampling

Description

Toxicants may be used for total or partial reclamation (with approval) and for obtaining samples of fish. Currently, only rotenone and antimycin A are approved for use by the FDA. Safety precautions must be followed.

Use

Chapter 22 provides instructions for sampling sections of large rivers in Michigan with rotenone. In lakes, rotenone and antimycin can provide good samples of fish. When marked fish are present, more accurate estimates of the composition of the fish community and of standing crop can be made by mark-and-recapture methods stratified by species and size. Toxicants can sample all sizes and species of fish when applied in non-selective dosages, but not all sizes and species are recovered with the same efficiency. Enough collection effort should be expended to obtain a representative sample.

Cove sampling has not been used in Michigan (few Michigan waters have discrete coves) but is a potential tool. An abbreviated description of the procedure used for cove sampling by the Texas Parks and Wildlife Department follows:

> Place a barrier net of 1.5-inch stretch mesh across the cove 1 day prior to treatment. Bundle the net along the float line to permit free passage of fish. Release the net sometime between 2 hours after sunset and 2 hours before sunrise during the night before treatment. Place marked fish, similar to the species in the lake, into the area. Use enough toxicant for a total kill. Begin treatment on or before 8 AM. Recover fish on the day of treatment and the following day.

3.7 Electrofishing

Description

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There are two basic types of electrofishing gear, "boom" and "stream," but many variations. Power supplies and configurations vary greatly and must be adequately described on FISH COLLECTION forms.

"Boom" shocking equipment, used on lakes and large rivers, consists of a boat rigged with booms out front. From two to five electrodes are suspended from the booms. If DC current is used, the positive electrodes (usually two) are out front and the negative electrodes trail along the sides (see Novotny and Priegel, 1974). Common electrical outputs are 220-volt, AC, DC, or pulsed DC. Working output is normally 4 to 10 amperes, but it should be adjusted to water conductivity, size of fish, and fish recovery time to avoid injury to the spine or to the gills. Higher voltage and lower amperage should be used in soft water. Water conductivity should be measured before each survey.

"Stream" shocking equipment, used on wadable streams, are of two basic types: a) pulsed DC back-pack (powered by either battery or small generator); or b) 220-volt DC, with a small boat to carry the large generator. The latter supplies more power and is much more effective. The positive electrode (1, 2, or 3 may be used) is hand held; the negative electrode may be attached to the bottom of the boat or to a separate float.

Use

The powerful types of electrofishing gear are potentially less size selective than fyke, trap, or gill nets and can obtain a more representative sample of the size structure, age structure, and growth of the population. Battery-powered backpacks allow larger fish to escape their weak electrical fields; however they are the only sampling tool available for small and brushy streams. All types of electrofishing gear are ineffective in habitats over approximately 5 feet deep, and that may result in a sample which is unrepresentative of the water body as a whole.

Electrofishing is the most effective gear for sampling stream and river fish. It can be effective in lakes for routine sampling, or for special projects such as sampling bass in the spring or trout in the spring or fall. Some large fish, such as northern pike, often escape from the electric field. In lakes, usually a larger and more representative sample of fish is obtained after dark. Catch may vary greatly seasonally, and from night to night, depending on fish movements and species.

When boom shocking rivers, it is usually best to fish downstream, motoring slightly faster than the current, but pausing occasionally to allow fish stunned on the bottom to drift to the surface. A second boat, downstream, may be used to pick up many additional fish.

A minimum amount of effort is 15 minutes of actual fishing time. For routine inventories, permanent stations should be established and recorded on a map of the lake or stream. On small lakes, the entire shoreline may be covered; on larger lakes, select as many areas as necessary to sample all habitat types.

For additional information, refer to Electrofishing Safety and Procedure Manual, Michigan Department of Natural Resources, Fisheries Division. Also, see Section 2.4.2.10 and Chapter 23 for Serns indexing of walleye and other fish in lakes.

3.8 Trawl

Description

A 16-foot head rope otter bottom trawl is the standard for inland sampling. The trawl is 16 feet across the front opening and has 1½-inch stretch nylon mesh on the main part. The cod end has a liner of ¼-inch mesh. Otter boards with adjustable chains are used to hold out the sides. The foot line is weighted with chain and the head line is fitted with styrofoam floats. The net is fished with a boat powered by powerful motor and pulled by hand or winch. Towing speed is measured using a simple trolling meter. Towing lines must be long enough to maintain the trawl on the bottom.

Use

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Trawls have received very little use in inland lakes, mainly because of snags and weeds. Sampling with a trawl is similar to sampling with a bag seine, but more mobile and can be used in deeper water. Minnows and young fish are the main targets, but fish as large as adult perch can be sampled.

Several tows in each area are more meaningful than single spot tows. Where possible, tows should be 5 minutes long. Record time from when the trawl is started along the bottom to when you start to pull it in.

3.9 Visual observations

Description

Visual observations of spawning fish, unusual concentrations, movements, etc., are sometimes made. This can be done on calm days or at night with the aid of a light.

Use

Observations may pinpoint spawning habitats or the optimum time for population control, and may indicate the presence of species and sizes not taken in sampling.

3.10 References

Crowe, W. R. 1950. Construction and use of small trap nets. Progressive Fish-Culturalist 12:185-192.

Novotny, D. W., and G. R. Priegel. 1974. Electrofishing boats: improved designs and operational guidelines to increase the effectiveness of boom shockers. Wisconsin Department of Natural Resources, Technical Bulletin No. 73, Madison.

Written in 1981 by J. W. Merna and J. C. Schneider
Revised 01/2000 by J. C. Schneider

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Manual of Fisheries Survey Methods II: with periodic updates

Chapter 4: Forms – Uses and Points of Clarification

James C. Schneider and James W. Merna

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Suggested citation:

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Chapter 4: Forms – Uses and Points of Clarification

James C. Schneider and James W. Merna

Survey forms are listed and briefly described in this chapter. Only items that may be confusing to users are discussed in detail. Photocopies of forms may be found at the back of this chapter. For additional clarification, refer to related text in the Manual of Fisheries Survey Methods II and to the examples provided with the 1981 version of the Manual of Fisheries Survey Methods. Some equivalents are in the electronic Fish Collection System.

SURVEY PLANNING (R-8060)

Use to plan all surveys. The purpose of this form is to assist in reviewing past surveys, setting objective(s) for the proposed survey, and communicating this information to others. An electronic equivalent is available.

LIMNOLOGY (R-8056)

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Use to summarize water analyses and vegetation observations for a lake. Some data may be recorded in the electronic version. Most requirements are self-explanatory. Note that space is provided for certain chemical analyses for which most survey crews are not equipped. Two columns are available for temperature-oxygen depth profiles. These can be used for two stations, if desired, or for one station if the lake is exceptionally deep. One station located in the deepest part of the lake is adequate unless the lake consists of two or more distinctly separate basins.

Wave condition–Recorded as calm, choppy, rough, or white caps. These designations give a better indication of wind effects on a lake than simply recording wind velocity.

Maximum depth of vegetation–In most lakes it is possible to see the maximum depth of vegetation growth. The actual depth at the line of demarcation should be measured with a sounding line or an echo sounder. If plants are not easily seen, the limit of growth can be determined with a plant hook or boat anchor.

Percent shoal–Defined as percentage of total lake area shallower than 5 m or 15 feet. Measure on a hydrographic lake map with the aid of a planimeter or grid. If map contours are given in 5-foot intervals, use the 15-foot contour; if the map is scaled in meters, use the 5-m contour.

Pollution–Record any pollution observed. The "comments" section should mention if remedial steps are being taken and if a report has been filed through administrative channels.

Vegetation–Aquatic vegetation will be classified as to type (submergent, emergent, floating, and *Chara*), and ranked in abundance as: none, sparse, common, abundant, or excessive. A designation of excessive indicates nuisance conditions that interfere with recreational uses of the lake. (Excessiveness may be confirmed by frequent public complaints and requests for plant control programs.) The observations required for the form evaluate abundance of various types of vegetation throughout the entire littoral area. For each type of vegetation, list a combination of percentage and abundance designations to equal 100% of the littoral area. For example, submergent weeds might be excessive throughout 50% of the littoral (50E), common in 20% (20C), and sparse in 30% (30S). The entire designation for "submergent" would thus be: 50E, 20C, 30S. Give similar designations for all other vegetation types, even for types absent from that lake (Example: Floating 100N).

Additional comments–Observations worthy of comment might include (but not be limited to):

- Sensitive areas to be protected such as marshes, spawning shoals, etc.
- Evidence of dredging or filling or other perturbation.
- Residential development: percent developed, whether on septic tanks or sewers, etc.
- Immediate watershed: percent in agriculture, forest, old field, residential, urban, etc.
- Existing or potential erosion problems.
- Potential for water quality management or rehabilitation.
- On-going vegetation control programs.

LAKE PHYSICAL DESCRIPTION (R-8057)

Use to summarize information from various sources on the physical characteristics of a lake. Line items 1-5 are to be completed from available maps and reference materials listed on the form (data for public lakes larger than 100 acres are available now); other lines are to be completed by on-site surveys. Update form every 20 years or when new information becomes available.

LAKE AREA AND VOLUME ANALYSIS (R-8069)

Use for calculating the area and volume of a lake from its hydrographic map. See Chapter 12.

FISH COLLECTION (R-8058) and **FISH COLLECTION (CONT)** (R-8058-1)

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This form has been replaced with an electronic version in the Fish Collection System but the important elements remain the same. Intended primarily for distribution and permanent file storage, but may be adopted for use in the field as well. Use for fish collections from lakes, rivers, or streams. Summarizes information on sample site(s), year, catch, CPE, LENGTH-FREQUENCY, and LENGTH-BIOMASS. Extensive space is provided for maps, analysis, and comments. *Not every item of information requested is relevant to each survey.* These forms may be used in four ways to summarize catch:

a. By gear type and mesh size, for all collection sites. A compulsory use. More than one kind of gear may be listed sequentially on one sheet, as illustrated.
b. For all gear types, for all collection sites. An optional use in addition to (a). May be put on the same sheet as (a).
c. For an index station.
d. By individual collection site or net set.

Side 1

Summary of.–Indicate source of information on this form, i. e., site and gear.

Sample site(s).–Indicate number of locations and ranges in depth and temperature where gear was fished. If water temperature was uniform from surface to bottom, record only surface temperature.

Sample location(s).–Describe, or use space below for sketching a map.

Cover.–Rank abundance of cover (none, sparse, moderate, abundant) and describe type (vegetation, undercut banks, logs, etc.).

Fish foods.–Comment on foods observed in the habitat or in fish stomachs.

Water clarity and level.–Refers to conditions which might affect gear efficiency (especially electrofishing).

Conductivity.–Measure in microSiemens (µS) per cm^2. Record temperature elsewhere.

Electrofishing efficiency.–Either rank as poor, satisfactory, or good; or for mark-and-recapture studies, give recapture percentage on second "run" (i. e., number recaptures divided by total catch during second run).

Stream physical data.–It is recommended that length, average width, average depth, average velocity, and annual discharge be determined by the methods in Section 2.1.2. If those methods are not followed, prefix the estimates with "approx.". When a current meter is not available for the proper determination of average velocity, use "the wood chip method" and record the result as "surface velocity."

Bottom type.–Primarily intended for stream surveys, but also may be used to describe lake sample sites. Estimate percentage of bottom comprised of bedrock, boulder (diameter greater than 10 inches), cobble (3 to 10 inches), gravel (1/8 to 3 inches), sand, silt, clay, muck, and detritus.

Gear.–List number of units used, types, unusual features (see description of standard gear in Chapter 3) and, for trap and fyke nets, height and pot mesh size (stretched). For example: 5 exp. gill; 1 G. L. gill; 3 gill 100 ft. x 8 ft. x 1 inch suspended at surface; 2 traps 3 ft. x 1 1/2 inch; 7 traps 6/3 x 1 1/2 inch; 3 fykes 4 ft. x 1 inch; etc. For electrofishing gear, give AC or DC, voltage, amperage, number of electrodes, and day or night operation. For seines, indicate length, height, and stretch mesh as follows: seine 50 ft. x 6 ft. x 1-inch bag. For recording fishing effort, code gear as: T = trap, F = fyke, EG = experimental gill, GLG = Great Lakes gill, E = electrofishing, S = seine, and TR = trawl. Develop and define other codes as needed.

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Effort.–Standard units of effort are given in Table 2.4. For net lifts, record the total number of lifts which were fished one or more nights (e. g., four nets lifted once a day for 3 days = 12 net lifts; four nets lifted every third day = 4 net lifts). For net nights, record total number of lifts which were fished one night (net nights = net lifts if the nets were lifted once a day; net nights = 0 if four nets were lifted every third day). For area covered, record acres seined, trawled, or electrofished (for streams). For hours shocked, record actual fishing time spent in lake or stream (optional) electrofishing. Non-standard types of effort, such as nets lifted more than once a day, should not be recorded here but may be noted under "Analysis, map, remarks, fishing reports". Standard effort which is not representative (for example a torn net) should be footnoted and explained, and CPE should not be calculated from it.

Purpose of collection.–State survey objectives or stimuli, to aid in the interpretation of sampling methods and results. Examples: Reports of poor fishing, basic inventory, survey of walleye recruitment.

Data collected.–Indicate types of data collected and types of summaries prepared. The Catch Summary, Length-Frequency and Length-Biomass summaries are on the FISH COLLECTION form; the other summaries appear on other forms.

Analysis, map, remarks, fishing reports.—Use this space for (1) commenting about gear, methods, condition and disease of fish, etc.; (2) a map of sample sites; (3) analysis and interpretation of the collection; and (4) reliable fishing reports.

Side 2

Length.–Record average length or range in length (to 0.1 inch).

Avg. Wt.–Total lb. ÷ No., or from Length-Biomass sample. Round to 0. 01 lb.

Total.–Total catch, by species and gear, in both numbers and pounds. Total pounds may be estimated from the Length-Biomass sample (Section 2.4.2.13). Round pounds to nearest 0.1 when <50; to whole pound when >50.

Total %.–For each type of gear: total number (and pounds) caught of each species ÷ All Species Total x 100. Round to whole number when >1%.

CPE.–In terms of both numbers and weight (see Section 2.4.2.9). Standard units of effort are net lifts (overnight sets); area (in acres) for seine, trawl, and stream electrofishing; time (in hours) for lake electrofishing. Round to 0.1 when <20; to whole number when >20.

%L-A.–Percentages of the Length-Frequency and Length-Biomass samples which were of legal or acceptable size. See footnote on form for definitions. Space is provided on the bottom of the form for alternative definitions. Round to whole number when >1%.

Length-Frequency.–Measure to inch group all fish caught, or sample the first 200 (see Section 2.4.2.12). Record numbers of fish in each group in "No." column and total number in sample at bottom of column.

Length-Biomass.–Determine weight of fish in each inch group of the Length-Frequency (see Section 2.4.2.13). Record as pounds under "Lb." column, rounding to 0.1 when <50 and to nearest pound when >50. Sum to obtain sample total pounds and divide by sample total numbers to get an average weight for fish collected.

All Species Total.–Grand total for that gear in numbers and pounds.

LENGTH-WEIGHT FIELD DATA (R-8059)

Intended primarily for field use for recording lengths and weights of individual fish, or of small lots of fish. Add appropriate headings and calibrate as needed. Space is provided for computing average weight by inch group, as an aid in calculating biomass estimates for the FISH COLLECTION form. Data recorded on scale envelopes in the field may be added to the form. Data may be transferred to a spreadsheet or other computer program for calculating a length-weight regression. The information recorded on this sheet is to be summarized on FISH COLLECTION and LENGTH-WEIGHT REGRESSION forms for distribution and permanent storage. The field sheet may be stored by the collector.

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LENGTH-WEIGHT REGRESSION (R-8059-1)

A summary form for distribution and permanent storage of length-weight relationships of species taken in a fish collection. Conventional units of measurement are inches and pounds. Give the regression-equation on front of form, or plot the relationship on log-log graph on back of form.

FISH GROWTH (R-8070)

A computerized version is now in Fish Collection System that allows entries for individual fish samples, automatic tabulation, and comparison to state averages. Note *unusual* methods, such as: a random or complete sample of the catch instead of the usual stratified random size-selective sample; ages determined from otoliths, fins, etc., instead of scales; selection of key scales or scales from areas of the body other than the recommended areas; weighted mean lengths (see Chapter 15) instead of simple averages; etc. See Chapter 9 for the state average growth rates and the method for calculating growth indices. Note that space is provided for analysis of results.

POPULATION ESTIMATES (R-8073)

Use to summarize data and computations for population estimates of fish. See Chapters 7 and 8. The form provides space for (1) raw data, (2) estimates by inch groups, (3) estimates by age groups, and (4) survival rates. Items 3 and 4 should not be attempted unless data are adequate (see Section 2.4.17). The form is set up for one species per side, but more could be inserted.

Sum.–The sum of all inch-group estimates. Note that 95% limits on the sum of the estimates are not simply the sum of the limits on inch-group estimates. See Chapters 7 and 8.

Survival.–Round off to 0.1% (e.g., 47.3%).

Estimates, lb.–Obtain for each inch group by multiplying estimated number by average weight, then summing.

NOTES AND REFERENCES (R-8077)

Use to record any valuable information not contained on other forms.

LAKE SURVEY SUMMARY (R-8063)

Use for summarizing physical, biological, and fishery information about a lake. Most items on form are self-explanatory; items 20 and 23 are explained below.

20. *Oxygen-thermal types*.-Based on mid-late summer oxygen temperature profiles and history of winterkill:
    1. Stratified lakes with at least 2 ppm DO at all depths.
    2. Stratified lakes in which DO falls from a high level to 2 ppm in the hypolimnion.
    3. Stratified lakes in which DO falls from a high level to 2 ppm between the 5-foot level of the thermocline and the top of the hypolimnion.
    4. Stratified lakes in which DO falls from a high level to 2 ppm between the bottom of the epilimnion and the 5-foot level of the thermocline.
    5. Unstratified lakes in which surface temperatures exceed 72°F.
    6. Unstratified lakes in which surface temperatures do not exceed 72°F.
    7. Lakes subject to frequent, severe, fish kills (DO falls to near zero throughout the lake).

23. *Vegetation*.-Use ranking system for LIMNOLOGY form.

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STREAM SURVEY SUMMARY (R-8064)

Use for summarizing physical, biological, and fishery information about a stream. Most items on form are self-explanatory or are explained in the text (see Section 2.1.2). Items 2 and 3 are explained below.

2. *Stream*.–name stream on which study station is located.

3. *Drainage system*.–name streams and rivers (in downstream order) traversed by water passing through the study site on its way to the Great Lakes.

Example: Stream – Butternut Creek
Drainage system – Butternut Creek, Fish Creek, Maple River, Grand River.

MANAGEMENT RECORD (R-8076)

Discontinued in lieu of Prescriptions. Summarize management recommendations and actions.

HERPS OBSERVATIONS (R-8001)

A new form has been developed for the Fish Collection System. Use to record incidental sightings of turtles, lizards, salamanders, frogs, toads, and snakes.

Written 1981 by J. W. Merna and J. C. Schneider
Updated 11/99 by J. C. Schneider

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SURVEY PLANNING form, R-8060 (reduced to fit on this page).

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MICHIGAN DEPARTMENT OF NATURAL RESOURCES
Fisheries Division

SURVEY PLANNING

Water ______________________________ Date ____________________

County ______________________________ T. _____ R. _____Sec. ________

Objective:

Previous surveys:
Gear types and dates

Comparison of results

Fish population changes

Limnological data and dates

Recommendations:
Gear type

Timing

Limnological measurements

Special studies

Units of measurement

Data to collect

CATCH SUMMARY
LENGTH-FREQUENCY
LENGTH-BIOMASS
LENGTH-WEIGHT

GROWTH
MARK & RECAPTURE ESTIMATES
AGE-FREQUENCY & SURVIVAL

R8060 4/81

LIMNOLOGY form, R-8056 (reduced to fit on this page).

R-8056 4/81

MICHIGAN DEPARTMENT OF NATURAL RESOURCES

Fisheries Division

LIMNOLOGY

Water ______________ T. ______ R. ______ Sec. ______ Date ______

County ______________ Id. ______________ Station ______

Depth M	Temp. °C	O_2 ppm	Depth M	Temp. °C	O_2 ppm

Time AM PM	Temp. Air °C	Sky	Wave condition[1]	Preceding weather	Maximum depth of vegetation	Percent shoal (< 5M)	Water color[2]	Secchi disc (0.1m)	Chlorophyll a

Pollution (✓) None ______ Light ______ Moderate ______ Severe ______

Type (✓) Erosion ______ Organic ______ Chemical ______ Other ______

Comments: ______________

Vegetation: Percent of littoral where: none (N), sparse (S), common (C), abundant (A), or excessive (E).

Submergent ______________ Emergent ______________

Floating ______________ Chara ______________

Parameter	Surface	Mid-depth (____ M)	Bottom (within 1M)
pH			
Alkalinity	pHth MO	pHth MO	pHth MO
Conductivity			
Chlorides			
Suspended solids			
Total solids			
Total phosphorus			
Ortho-phosphorus			
Nitrate			
Nitrite			
Ammonia			
Organic nitrogen			

Maximum depth at station: ______ Prepared by ______________ Sec. ______

[1] Calm, choppy, rough, white caps. [2] Clear, light brown, brown, dark brown, turbid.

(over)

Optional observations:

1. Additional parameters analyzed by Inland Lake Management Unit:

Parameter	Surface	Mid-depth (____ M)	Bottom (within 1M)

2. Additional comments on condition of lake: ______________

3. Sketch map of lake with distribution of aquatic plants in littoral zone, and location of sampling station.

Copies to: Lansing ☐, Region ☐, District ☐, I.F.R. ☐, Lake Mgt. ☐.

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LAKE PHYSICAL DESCRIPTION form, R-8057 (reduced to fit on this page).

MICHIGAN DEPARTMENT OF NATURAL RESOURCES
Fisheries Division

R8057
Rev. 3/82

LAKE PHYSICAL DESCRIPTION

Lake ____ T. ____ R. ____ Sec. ____
County ____
Id. ____ Prepared by ____ Date ____

1. Lake: Area (ha) ____ Perimeter (km) ____ Shape factor ↓ ____ Ref. ____
2. Watershed: Area (km) ____ Perimeter (km) ____ Shape factor ↓ ____ Lake area ÷ watershed area ____ Ref. ____
3. Maximum depth (m) ____ Mean depth (m) ____ Volume (1000's of m^3) ____ Ref. ____
4. Heating degree days (base 55°F) ____
5. Flushing rate (years) ____ Ref. ____
6. Drainage type (✓): Seepage ____ Intermittent outlet ____ Permanent outlet ____
7. Inlets: Names ____
   Mean annual discharge (m^3/sec) ____ Ref. ____
8. Outlet: Name ____
   Mean annual discharge (m^3/sec) ____
   Name of main drainage system ____
9. Lake type (✓): Natural ____ Natural with dam ____ Impoundment ____
10. Dam: Height (m) ____ Boat lock (✓): No ____ Yes ____ Functional fish ladder (✓): No ____ Yes ____
    Effect on upstream fish movement (✓): None ____ Hinders ____ Completely blocks ____
    Comments: ____
11. Annual fluctuation in water level (✓): 0-0.5m ____ 0.5-1m ____ 1-2m ____ more than 2m ____
12. Maximum long-term fluctuation in water level (m) ____
13. Soils in 0-2m (%): Organic ____ Muck ____ Clay ____ Marl ____ Sand ____ Gravel ____ Rubble ____ Bedrock ____
14. Soils in 2m+. (%): Organic ____ Muck ____ Clay ____ Marl ____ Sand ____ Gravel ____ Rubble ____ Bedrock ____
15. Shoreline (% by type): Bog ____ Swamp ____ Marsh ____ Upland ____
16. Lake use (✓): Private ____ Semiprivate ____ Public ____
17. Approximate number of: Cottages and houses ____ Resorts ____ Boat liveries ____
18. Surrounding land use (%): Undeveloped ____ Agricultural ____ Urban ____
19. Describe topography, soil, vegetation: ____

↓Shape factor formerly called shore development factor. Equals perimeter ÷ 3.5449 $\sqrt{\text{area}}$.

COPIES TO: Lansing ( ), Region ( ), District ( ), I.F.R. ( )

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References for items 1, 2, 3, 5, 7, 8

Ref. code:

1. Marsh, William M. and Thomas E. Borton. 1974. Michigan Inland Lakes and their Watersheds (an atlas). Michigan Dept. Natural Resources, Water Resources Comm., 166p. (Data for lakes larger than 100 acres. Based on USGS topographic maps and may be in error if shoreline alteration has taken place since mapping.)
2. Fisheries Division lake maps (cite date of mapping).
3. Miller, J. B. and T. Thompson, 1970. Compilation of data for Michigan lakes. U.S. Dept. Interior Geol. Surv., in cooperation with Mich. Dept. Nat. Resources.
4. Anonymous. 1975. A compendium of lake and reservoir data collected by the National Eutrophication Survey in the Northeast and North-central United States. U.S. Environ. Protection Agency, National Eutrophication Survey Working Paper No. 474.
5. Humphrys, C. R. and R. F. Green. 1962. Michigan lake inventory bulletins 1-83. Mich. State Univ., Dept. Resource Devel., East Lansing, Michigan.
6. Fisheries Division files (e.g., lake volume analysis).
7. Land Resource Programs files.
8. Water Management Division files.
9. Water Quality Division files.
10. U. S. Forest Service files.
11. Derived by the preparer of this form.

Other publications and sources (number and cite below). (e.g., P. W. Laarman, Fisheries Research, has estimated many mean depths.)

Reference for item 4

Van Den Brink, C., N. D. Strommen, and A. L. Kenworthy. 1971. Growing degree days in Michigan. Mich. State Univ. Agr. Exp. Sta., Res. Rep. No. 131, 48 p.

Continuations (use item numbers):

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LAKE AREA AND VOLUME ANALYSIS form, R-8069 (reduced to fit on this page).

MICHIGAN DEPARTMENT OF NATURAL RESOURCES

Fisheries Division

R-8069 4/8

LAKE AREA & VOLUME

Lake ______________________

County ______________________ T. ________ R. ________ Sec. ________ Id. ____________

Metric Summary:

Area ______________ % Shoal[1] ____________

Volume ______________ Avg. depth[2] ____________

Computation in (✓):

☐ Acres, feet, acre-feet

☐ Hectares, meters, 1000's m^3

Map: Date ______________

Area ______________

Surf. el. ______________

Part of Map	Area enclosed by contour line														
	0														
Total															
%	100														

Part of Map	Volume in depth strata													Total	%
	0-														
Total															100
%														100	

Prepared ______________________ Section ______________________ Date ______________

Copies to: Lansing ☐, Region ☐, District ☐, I.F.R. ☐.

[1] % shoal = percent of lake area < 5M (15 ft.) deep.

[2] Average depth = volume ÷ area.

FISH COLLECTION form, R-8058 (reduced to fit on this page).

MICHIGAN DEPARTMENT OF NATURAL RESOURCES
Fisheries Division

FISH COLLECTION

Water ____________________

County ____________________ T. ________ R. ________ Sec. ____________ Date ____________________

I.D. ____________________ Sheet 1 of ____________

Summary of: ( ) All sites ( ) Coll. site No. ________ ( ) Index site No. ________ ( ) All gear ( ) Gear ____________

Sample site(s): Number of Depth Range Temperature range

Location(s) (describe or map below):

Cover (abundance, type):

Fish foods:

Water clarity, level, etc.: Cond.: Electro. eff.:

Weather: Present Preceding

Temperature: Air Water surface Time of day

Stream: Length Avg. width Avg. depth

Velocity: Ave. Surface Discharge

Bottom type:

Gear Description:

Effort: Net lifts Net nights Area covered Hours shocked

Purpose of collection:

Data collected (✓): ( ) CATCH SUMMARY ( ) LENGTH-FREQUENCY ( ) LENGTH-BIOMASS ( ) LENGTH-WEIGHT REGRESSION
( ) GROWTH ( ) MARK & RECAPTURE ESTIMATES ( ) AGE-FREQUENCY & SURVIVAL

Analysis, map, remarks, fishing reports:

FOLD HERE

Analysis by ____________________ Sec. ____________

Collection by ____________________ Sec. ____________ Identification by ____________________ Sec. ____________

COPIES TO: ( ) LANSING ( ) REGION ( ) DISTRICT ( ) I.F.R.

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FISH COLLECTION form, R-8058 reverse side (reduced to fit on this page).

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CATCH SUMMARY BY GEAR Gear = ____________________ or as indicated.

Species														
Gear														
Length														
Avg. Wt.														
	No.	Lb.	No.	Lb.	No.	Lb.	No.	Lb.	No.	Lb.	No.	Lb.	No.	Lb.
Total														
%														
CPE														
% L-A														
LENGTH-FREQUENCY & LENGTH-BIOMASS SAMPLE — Inches														
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														
11														
12														
13														
14														
15														
16														
17														
18														
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27														
28														
29														
30														
31														
32														
33														
34														
35														
36														
37														
38														
39														
40														
Sample total														

ALL SPECIES TOTAL

Gear	No.	Lb.

Record average length or range in length of fish.

Total % = percent contribution of the species to the total catch in the gear.

L-A = Legal- or acceptable- size game fish: bluegill, sunfish, rock bass-6"+ ; crappie, perch, bullhead-7"+ ; bass-12"+ ; walleye-15"+; pike-20"+ muskie-30"+ ; trout-7"+ in U.P. streams, 8"+ in L.P. streams, 10"+ in lakes.

*OR:

Inch groups: 1=1.0-1.9, 2=2.0-2.9, etc.

FISH COLLECTION (CON'T) form, R-8058-1 (reduced to fit on this page).

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MICHIGAN DEPARTMENT OF NATURAL RESOURCES
Fisheries Division

FISH COLLECTION (CON'T.)

Water ____________ T. ______ R. ______ Sec. ______ Date ____________

County ____________ I.D. ____________ Sheet ____ of ______

Summary of: ( ) All sites ( ) Coll. site No. ______ ( ) Index site No. ______ ( ) All gear ( ) Gear ____________

Species														
Gear														
Length														
Avg. Wt.														
	No.	Lb.	No.	Lb.	No.	Lb.	No.	Lb.	No.	Lb.	No.	Lb.	No.	Lb.
Total														
%														
CPE														
% L-A														

LENGTH-FREQUENCY & LENGTH-BIOMASS SAMPLE

Inches														
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														
11														
12														
13														
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27														
28														
29														
30														
31														
32														
33														
34														
35														
36														
37														
38														
Sample total														

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FISH COLLECTION (CON'T) form, R-8058-1 reverse side (reduced to fit on this page).

CATCH SUMMARY BY GEAR Gear = ____________ or as indicated.

Species														
Gear														
Length①														
Avg. Wt.														
	No.	Lb.	No.	Lb.	No.	Lb.	No.	Lb.	No.	Lb.	No.	Lb.	No.	Lb.
Total														
%②														
CPE														
% L-A③														
Inches④														
1														
2														
3														
4														
5														
6														
7														
8														
9														
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12														
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28														
29														
30														
31														
32														
33														
34														
35														
36														
37														
38														
39														
40														
Sample total														

LENGTH-FREQUENCY & LENGTH-BIOMASS SAMPLE

ALL SPECIES TOTAL

Gear	No.	Lb.

① Record average length or range in length of fish.
② Total % = percent contribution of the species to the total catch in the gear.
③ L-A = Legal- or acceptable- size game fish: bluegill, sunfish, rock bass-6"+ ; crappie, perch, bullhead-7"+ ; bass-12"+ ; walleye-15"+ ; pike-20"+ muskie-30"+ ; trout-7"+ in U.P. streams, 8"+ in L.P. streams, 10"+ in lakes.
*OR:
④ Inch groups: 1=1.0-1.9, 2=2.0-2.9, etc.

LENGTH-WEIGHT FIELD DATA form, R-8059 (reduced to fit on this page).

MICHIGAN DEPARTMENT OF NATURAL RESOURCES

Fisheries Division

Water ____________________ T. ____ R. ____ Sec. ________ LENGTH-WEIGHT FIELD DATA

County ____________________ Gear ____________________ Date ________________

Record species, individual weights, and total and average weight per inch group.

Fish length (Define inch groups)

.0	.0	.0	.0	.0
.1	.1	.1	.1	.1
.2	.2	.2	.2	.2
.3	.3	.3	.3	.3
.4	.4	.4	.4	.4
.5	.5	.5	.5	.5
.6	.6	.6	.6	.6
.7	.7	.7	.7	.7
.8	.8	.8	.8	.8
.9	.9	.9	.9	.9

.0	.0	.0	.0	.0
.1	.1	.1	.1	.1
.2	.2	.2	.2	.2
.3	.3	.3	.3	.3
.4	.4	.4	.4	.4
.5	.5	.5	.5	.5
.6	.6	.6	.6	.6
.7	.7	.7	.7	.7
.8	.8	.8	.8	.8
.9	.9	.9	.9	.9

.0	.0	.0	.0	.0
.1	.1	.1	.1	.1
.2	.2	.2	.2	.2
.3	.3	.3	.3	.3
.4	.4	.4	.4	.4
.5	.5	.5	.5	.5
.6	.6	.6	.6	.6
.7	.7	.7	.7	.7
.8	.8	.8	.8	.8
.9	.9	.9	.9	.9

.0	.0	.0	.0	.0
.1	.1	.1	.1	.1
.2	.2	.2	.2	.2
.3	.3	.3	.3	.3
.4	.4	.0	.4	.4
.5	.5	.5	.5	.5
.6	.6	.6	.6	.6
.7	.7	.7	.7	.7
.8	.8	.8	.8	.8
.9	.9	.9	.9	.9

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LENGTH-WEIGHT FIELD DATA form, R-8059 reverse side (reduced to fit on this page).

.0	.0	.0	.0	.0
.1	.1	.1	.1	.1
.2	.2	.2	.2	.2
.3	.3	.3	.3	.3
.4	.4	.4	.4	.4
.5	.5	.5	.5	.5
.6	.6	.6	.6	.6
.7	.7	.7	.7	.7
.8	.8	.8	.8	.8
.9	.9	.9	.9	.9

Fish length (Define inch groups)

.0	.0	.0	.0	.0
.1	.1	.1	.1	.1
.2	.2	.2	.2	.2
.3	.3	.3	.3	.3
.4	.4	.4	.4	.4
.5	.5	.5	.5	.5
.6	.6	.6	.6	.6
.7	.7	.7	.7	.7
.8	.8	.8	.8	.8
9	.9	.9	.9	.9

.0	.0	.0	.0	.0
.1	.1	.1	.1	.1
.2	.2	.2	.2	.2
.3	.3	.3	.3	.3
.4	.4	.4	.4	.4
.5	.5	.5	.5	.5
.6	.6	.6	.6	.6
.7	.7	.7	.7	.7
.8	.8	.8	.8	.8
.9	.9	.9	.9	.9

.0	.0	.0	.0	.0
.1	.1	.1	.1	.1
.2	.2	.2	.2	.2
.3	.3	.3	.3	.3
.4	.4	.4	.4	.4
.5	.5	.5	.5	.5
.6	.6	.6	.6	.6
.7	.7	.7	.7	.7
.8	.8	.8	.8	.8
.9	.9	.9	.9	.9

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LENGTH-WEIGHT REGRESSION form, R-8059-1 (reduced to fit on this page).

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Fisheries Division

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LENGTH-WEIGHT REGRESSION

Water ______________ T. ______ R. ______ Sec. ______

County ______________ Id. ______________ Collection date ______________

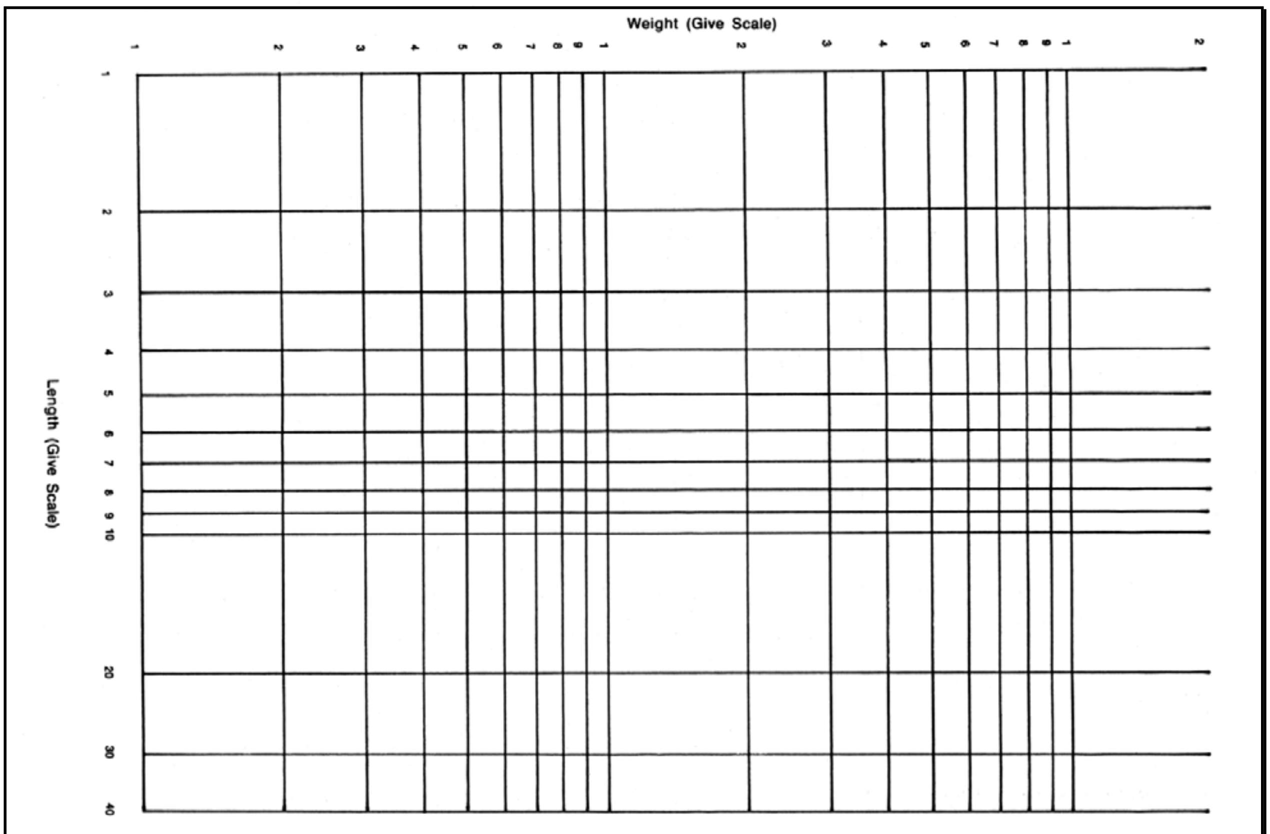
Gear ______________ Units of Measurement (✓): ( ) inches or ( ) mm; ( ) pounds or ( ) grams

Species	Number Measured	Length range	Equation: log W = log c + n log L

Analysis:

Prepared by ______________ Section ______________

Copies to (✓): ( ) Lansing, ( ) Region, ( ) District, ( ) I.F.R.



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FISH GROWTH form, R-8070 (reduced to fit on this page).

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MICHIGAN DEPARTMENT OF NATURAL RESOURCES

Water ______ T. ______ R. ______ Sec. ______ FISH GROWTH ANALYSIS

County ______ Id. ______ Collection Date ______

Gear and Methods ______

Collected By ______ Section ______ Aged By ______ Section ______

Species ↓	Age Group ↓2	Number of fish	Lenth range in inches	Mean length in inches	State avg. length	Growth index (by age group)	Mean growth index for species

↓ Several species may be listed on one sheet.

↓2 Age in years. Fish become one year older on January 1.

(over)

Species ↓	Age Group ↓2	Number of fish	Lenth range in inches	Mean length in inches	State avg. length	Growth index (by age group)	Mean growth index for species

Analysis:

Prepared by ______ Section ______ Date ______

Copies to: ☐ Lansing, ☐ Region, ☐ District, ☐ I.F.R.

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POPULATION ESTIMATES form, R-8073 (reduced to fit on this page).

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Fisheries Division

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POPULATION ESTIMATES

Water ____________________

County ______________ T. ______ R. ______ Sec. ______________ Sheet ______ of ______

Site ______________ Id. ______________ Date: Mark ______ Recap. ______

Gear ______________ Formula ______________ Acres ______

Species ______ Estimated: No./acre ______ Lb./acre ______ % L-A: By No. ______ By Lb. ______

Inch	No.	Recapture run		Estimates			No.	Estimates by age group						
Group	Marked	Recaps	Unmark	No.	95% limits	Lb.	Aged							
Total														
							% survival							

Methods, analysis, remarks:

Prepared by ______________ Sec. ______________ COPIES TO: ( ) LANSING ( ) REGION ( ) DISTRICT ( ) I.F.R.

Species ______ Estimated: No./acre ______ Lb./acre ______ % L-A: By No ______ By Lb. ______

Inch	No.	Recapture run		Estimates			No.	Estimates by age group						
Group	Marked	Recaps	Unmark	No.	95% limits	Lb.	Aged							
Total														
							% survival							

Methods, analysis, remarks:

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NOTES AND REFERENCES form, R-8077 (reduced to fit on this page).

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Lake or Stream ______________________

County ______________________ T. ________ R. ________ Sec. ________

NOTES AND REFERENCES

Subject:

Prepared by Section Date

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LAKE SURVEY SUMMARY form, R-8063 (reduced to fit on this page).

MICHIGAN DEPARTMENT OF NATURAL RESOURCES
Fisheries Division

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Lake ____________ T. ____ R. ____ Sec. ______

County ____________ Id. ______________

LAKE SURVEY SUMMARY

1. Other names of lake
2. Accessibility (how reached, condition of roads)
3. Outlet (immediate and main drainage)
   Permanency — Size
4. Dam in outlet — Distance from lake — Height
   Effect on level — Owner — Use
   Effect on fish movements
5. Inlets (name, size)
   Drainage area
6. Pollution (kind, source, severity)
7. Shoreline type (%): Bog — Swamp — Marsh — Upland
8. Surrounding country (topography, soil, cover)
9. Use (private, public, semi-private) — Public fishing site
10. Approximate number Cottages — Homes — Resorts — Boat Liveries
11. Intensity of fishing (heavy, medium, light, or angler days) Summer — Winter
12. Other uses
13. Area — Shore Development — Maximum depth
14. Area of Vegetation (acres) — Per cent shoal (less than 15 ft.)
15. Slope at drop-off (gradual, steep)
16. Bottom Soil: Shoal — Deep water
17. Color — Secchi disk (range)
18. Temperature (range): Surface — Bottom
19. Thermocline — Location — Temperature (range)
20. Dissolved oxygen (range): Above thermocline (in upper 20 feet if absent)
   In Thermocline — Below thermocline (near bottom if absent)
   Depth range where temperature is below 70° F., and O_2 above 4 ppm. — Oxygen-thermal type
21. pH (range) — CO_2 — Methyl Orange Alk. (range)

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(Over)

22. Cover (kind, abundance)
23. Vegetation (type, abundance)
24. Food (abundance, dominant organisms): Plankton
   Bottom: Shoal — Depths
   Vegetation
25. Spawning grounds (summarize observations and reports)
26. Predators (kind and abundance)
27. Fish parasites
   Fish mortalities (observed or reported)
28. Fishing: general reputation
   History
   Reported by
29. Recent stocking
30. Fish species — Abundance — Predominant size — Growth rate (poor, average, good)

Continuations (use item numbers):

Prepared by — Section — Date of survey(s)

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STREAM SURVEY SUMMARY form, R-8064 (reduced to fit on this page).

MICHIGAN DEPARTMENT OF NATURAL RESOURCES
Fisheries Division

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Stream ____________ T.____ R.____ Sec. ________

County ____________ Id. ____________

STREAM SURVEY SUMMARY

1. Drainage system ____________
2. Station: Location ____________
   Length (m) ________ Avg. width (m) ________ Area (ha) ________
   Avg. depth (m) ________ Velocity (m/sec) ________ Discharge ________
   Color and turbidity ____________
   Dredged? ____________
   Classification¹ ____________
3. Names of tributaries ____________
4. Water source (springs, groundwater, etc.) ____________
5. Stability of flow ____________
6. Barriers (dams, waterfalls, wiers, etc.) ____________

Location	Owner	Use	Head

7. Surrounding country (topography, soil, cover, use) ____________
8. Access ____________
9. Erosion (source, severity) ____________
10. Pollution ____________
11. Mortalities ____________
12. Parasites ____________
13. Diseases ____________
14. Predators ____________
15. Beaver ____________

16. Shade ____________
17. Pools (✓): Size -- large____ medium____ small____; Type -- deep____ moderate____ shallow____
    Frequency -- many____ frequent____ infrequent____
18. Bottom types²: Pools ____________
    Riffles ____________
19. Spawning grounds ____________
20. Aquatic vegetation (% of stream bed): Abundant____ Moderate____ Sparse____
21. Fish food organism abundance (✓): Exceptional____ Average____ Poor____
22. Fishing (reputation, history) ____________
23. Recent stocking ____________
24. Recent management ____________
25.

Fish species	Relative abundance	Predominate size	Growth (good, avg., poor)

26. Notes and continuations (use item number) ____________

Prepared by ____________ Sec. ____________ Date of survey ____________

¹See Michigan Stream Classification System (Appendix VI A15).
²Bedrock, boulder (10"), cobble (3-10"), gravel (⅛-3"), sand, silt, clay, muck, detritus

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HERPS POPULATION ESTIMATES form, R-8001 (reduced to fit on this page).

MICHIGAN DEPARTMENT OF NATURAL RESOURCES
FISHERIES DIVISION

Water ______________________________ HERPS POPULATION ESTIMATES

County ___________________________ T. ___ R. ___ Sec. ___ Sheet ____ of ____ Sheets

Site _____________________________________ Date: Mark _________________ Recapture ______________

Gear: ☐ Traps ☐ Seine ☐ Gill Net ☐ Electro ☐ Other ☐ Visual Acres ____________________

Turtles:									
Snapper					**Leopard**				
Softshell					**Mink**				
Spotted* **					**Wood**				
Wood* **									
E. Box* **					**Snakes:**				
Blandings* **					**Kirtlands** **				
Map					**Copperbelly** **				
Painted					**N. Water**				
Slider					**Queen**				
Musk					**Brown**				
					Red-Bellied				
Lizards:					**E. Garter**				
5-Lined Skink					**Butler's Garter**				
6-Lined Race Runner					**Ribbon**				
					Ringneck				
Salamanders:					**E. Hognose**				
Tiger					**Blue Racer**				
Spotted					**Black Rat**				
Blue Spotted					**Fox ***				
Marbled					**E. Milk**				
Small-Mouthed					**E. Smooth Green**				
4-Toed					**E. Massasauga*** **				
Mudpuppy									
Central Newt									
Red-Spotted Newt									
Red-Backed									
West. Lesser Siren									
Frogs-Toads:									
E.American Toad									
Fowlers Toad									
Blanchard's Cricket									
Gray Tree									
Spring Peeper									
Chorus									
Bullfrog									
Green									
Pickerel									

*Threatened ** Endangered ***Special Concern

Prepared by: ____ Date____________________

Copies to: ( ) Lansing; ( ) Region; ( ) District; ( ) Research

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Manual of Fisheries Survey Methods II: with periodic updates

Chapter 5: Survey Reports

James C. Schneider and J. W. Merna

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Suggested citation:

Schneider, James C. and J. W. Merna. 2000. Survey reports. Chapter 5 *in* Schneider, James C. (ed.) 2000. Manual of fisheries survey methods II: with periodic updates. Michigan Department of Natural Resources, Fisheries Special Report 25, Ann Arbor.

Chapter 5: Survey Reports

James C. Schneider and J. W. Merna

A final report is required for extensive surveys in addition to properly prepared forms. It will be used for departmental and public information. Make and distribute a NOTE AND REFERENCE form referring to reports not stored in the lake or stream filing system. Refer to Fisheries Division Policies and Procedures for Reports and Publications (Rev. May 1991) for additional information about report types, policies, and procedures for reviewing and editing. For report examples, see <http://www.dnr.state.mi.us/www/ifr/ifrlibra/ifrlibra.htm>.

5.1 Style

Reports of surveys can take the following forms:

1. Technical Report series – for information of statewide interest. River rotenone surveys are included in this series, with contents as outlined in 5.2.
2. Status of the Fishery Resource Report series – similar to Technical Reports, but less extensive distribution, including Management Unit, Region, Division Office, and Research. Narrative style, as outlined in 5.3.
3. Notes – on FISH COLLECTION form comments section or NOTES AND REFERENCE form.

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5.2 Content of River Rotenone Survey Reports

These reports compile survey information for small or large sections of rivers sampled with rotenone. Use the style and format of Towns (1987). The following outline, based on that document, is recommended:

I. Summary.
II. Introduction.
III. Methods.
IV. Results.
  A. Overview.
  B. Fishery description, by station.
V. Discussion.
  A. General.
  B. Management considerations.
VI. Literature Cited.
VII. Tables.
  1. Locations of sampling stations.
  2. List of species captured at each station.
  3. Percent of catch by weight, number and species. Chubs, shiners, minnows, darters, and individuals less than 3 inches long are excluded.
  4. Catch results.
  5. Numbers of common fish per surface acre collected at each station.

VIII. Figures.

1. Map showing locations of sampling stations.
2. Weight of gamefish, redhorses and suckers, carp, and all fish captured at each station.

5.3 Content of Status of the Fishery Resource Reports

These reports are to describe and analyze the current status of the fishery in a water body, using the results of the most recent survey of the fish community. They provide, for both biologists and the public, a summary and brief review of environment, history, fish, fishing, and management. Write in plain English and avoid technical jargon which would not be understood by most anglers.

Almost all the information and data required for these reports should already appear on forms prepared according to the Manual of Fisheries Survey Methods. The Fish Collection System can generate the appropriate tables. Status reports basically present the information on those forms in narrative style, with summary tables.

The concluding topics of the report are the formulation of management goals and a management plan. The logic leading to the management goals should be clear, and the supporting facts and observations should appear in the previous sections of the report. The management goals must be consistent with the goals of the Fisheries Division and the plan should be feasible. Reports and plans should be updated following all major surveys of the fish community.

Use the style and format of Dexter (1991) for the report and the associated Management Plan. The year of the fish survey should appear in the title, and the date of the report's preparation should appear following the text of the report, just before the tables. Names of fishes should follow the guidelines of the American Fisheries Society.

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CITATION Ch5

The following outline and content is recommended:

I. Environment.

A. Location. Include the distance to the nearest town.

B. Geology and geography. Briefly relate information relevant to aquatic systems, such as soil types in relation to ground water, productivity, and substrate.

C. Watershed description (inlets, outlets, connecting waters, and basin).

D. Chemical and physical characteristics.

E. Development, public ownership, and access.

II. Fishery resource.

A. History of the fishery. Describe fish stocks and the fishery in earlier years along with problems and management history.

B. Current status of the fish community with summary tables. Cover topics of species composition by number and weight, length, growth, recruitment and longevity. If the age composition sample is large enough, the mortality rate of the older fish can be estimated as described elsewhere (Section 2.4.17 and Chapter 15).

C. Analysis and discussion. Consider fish, environmental conditions, and resource users. Compare current to past status. All major species should be mentioned, including species which require no current actions. Compare fish stocks with those in similar waters and with statewide averages. This discussion places the known information about the water in perspective and lays the groundwork for long-range goals and expectations.

III. Management direction.

A. Current. In addition to stocking or other actions, management generally involves preservation of environmental quality and continued monitoring of fish population status.

B. Goals and expectations. Establish a long-term goal for the fishery based on its potential. The success of all future management efforts will be measured by how much they move the fishery toward the goals set down here. Use the history of this water, and performance of similar waters, as a guide to setting long-range goals for the fish stocks, the fishery, and the environment. Consider natural reproduction, growth, standing stocks (by age and size), species mix, access, and public use as factors in making a goal statement. Note that the relative health of the fish stocks and the fishery can be measured by how close the current status is to the long-term goals and expectations. On many of the best waters our long-term goal (or a major part of it) will be to maintain the good health of the fish community and the environment.

C. Obstacles to attainment of goals. List, in logical sequence, the impediments and problems that stand in the way of improving the fishery from its current status toward the expectations or vision for the future. This list sets the stage for the development of management objectives (described in Section VI) and management prescriptions (set down on prescription forms). Example: "Excessive fishing mortality on bass and bluegills."

IV. References. Cite in the scientific report format used by The American Fisheries Society.

V. Hydrographic map. Include one if available. It must be legible and neat. It need not show survey sites.

VI. Management Plan. This section starts on a new page because it may not always be distributed with the rest of the status report. This supplement is required when extensive management activity is planned. It elaborates on Management Direction, by giving proposed solutions to specific problems. For example, see Management Plan for Deep Lake. One to several prescriptions may be based on this plan.

A. Objectives. Must be specific and have measurable end points. There may be several per goal. Example: "Reduce angling mortality of adult bass from 0.50 to 0.35 by 1995."

B. Proposed management action. Give a more detailed description of proposal. For example: "Delay opening day on bass until last Saturday in June and raise the size limit to 18 inches."

C. Expected results. Make your best quantified prediction of the outcome of the action, even an educated guess. For example: "About 25% of the trout will be harvested by anglers, resulting in an annual harvest of 100-200 trout from this 100-acre lake."

D. Evaluation plan. State how you plan to evaluate the management action. For example: "We will evaluate trout fishing from voluntary angler reports and will evaluate trout survival and growth via a tagging study beginning in 1999."

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Chapter 6: Sample Size for Biological Studies

Roger N. Lockwood and Daniel B. Hayes

The goals of this chapter are to provide fisheries personnel with a better understanding of sampling issues related to data collection and to present methods for determining appropriate sample sizes. Much of this chapter is devoted to a discussion of variability in data since, essential to any data collection, is an appreciation of variability. This variability greatly affects our ability to show differences between groups (e.g., years, lakes, etc.). For example, if we consistently catch 10 fish per net lift every year it would be relatively easy to see an increase to 15 fish per net lift. However, if our catch varied from 1 to 50 per lift (still averaging 10 fish), it would be much more difficult to detect an increase to 15 fish per lift.

Data may be collected to characterize population parameters for descriptive purposes, or as part of a research or management study in which some type of "treatment" is administered and some level of change (either an increase or decrease) is anticipated. The variables measured may be continuous (e.g., length of fish at a chosen age) or discrete (e.g., fin ray count).

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This chapter presents various methods for estimating sample size corresponding to desired precision or power, given some prior measure or estimate of variability. These methods presume that the data at hand are approximately normally distributed for continuous variables, or binomially distributed for discrete variables. As data deviate from these assumptions, transformation of the data or different statistical methods become necessary.

Also included in this chapter is a discussion of bias associated with estimation of average fish length from average weight using weight-length regression. Appropriate methods to compensate for this bias are presented.

6.1 Precision

Precision is a measure of variability associated with a sample from a population compared to a descriptive statistic, such as the mean, of that sample. Variability is usually displayed in terms of standard deviations or standard errors. Standard deviation (s) is the variability of individual measures within a sample compared to the mean $\bar{x}$ of that sample and is calculated as:

$$s = \sqrt{\frac{\sum_{i=1}^{n} x_i^2 - \frac{\left(\sum_{i=1}^{n} x_i\right)^2}{n}}{n-1}}, \qquad (1)$$

where, n is the sample size and x_i are the individual measures. From a normal distribution, plus or minus one standard deviation encompasses about 68% of all values and two standard deviations about 95%.

The standard error ($s_{\bar{x}}$) is calculated as:

$$s_{\bar{x}} = \sqrt{\frac{\sum_{i=1}^{n} x_i^2 - \frac{\left(\sum_{i=1}^{n} x_i\right)^2}{n}}{n(n-1)}} = \frac{s}{\sqrt{n}}, \qquad (2)$$

and measures the variability of the mean through repeated samples. That is, if we randomly sampled a population again and again, we would expect about 68% of the means to fall within one standard error of the grand mean (average of all the means) and about 95% within two standard errors. This is one way to express confidence intervals for a mean. Another way is as a percent error or relative error. For example, we may wish to calculate a mean with two standard errors being 25% of that mean. Expressed this way, the relative error L (error relative to the mean) is the product of the sample mean and precision p:

$$L = \bar{x}p, \qquad (3)$$

where, the precision p is expressed as a fraction, say 0.25 or 25%.

To estimate an appropriate sample size (n), we need level of confidence (e.g., 95%, 99%), relative error, and a measure of variability of the population in question. Typically, a sample is collected and the mean ($\bar{x}$) and standard deviation (s) are calculated. Estimates of $\bar{x}$ and s from populations thought to be similar may also be used. However, if that assumption is incorrect, many more or far fewer samples than necessary may be collected. Sample size then is (Snedecor and Cochran 1989:52):

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$$n = t^2 \frac{s^2}{L^2}. \qquad (4)$$

Values for t are:

	Confidence level				
	70%	80%	90%	95%	99%
t	1.036	1.282	1.645	1.960	2.576

Example 6.1–A sample of 10 age-3 fish has the following lengths (inches): 2.3, 4.1, 3.9, 3.7, 3.0, 2.5, 3.0, 2.7, 2.9, 3.0. The mean length from the sample is 3.1 and the standard deviation is 2.4. We wish to sample enough fish to achieve precision ±25% of the mean with 95% certainty.

The first variable estimated is L, our relative error:

$$L = 3.1 * 0.25 = 0.775$$

Sample size then is:

$$n = 1.96^2 \frac{2.4^2}{0.775^2} = 36.8$$

Thus, a minimum of 37 age-3 fish should be measured.

An investigator may also wish to determine what fraction of a sample falls into some classification (e.g., percent males). This follows a binomial distribution where P is the fraction of a sample in one category and Q the fraction in the alternative category. Thus,

$$P = \frac{n_1}{n}, \tag{5}$$

and

$$Q = 1 - P, \tag{6}$$

where, n_1 is the count of individuals in the first category. As with continuous variables, measures of variability can be determined for P and Q. The standard deviation (s):

$$s = \sqrt{PQ}, \tag{7}$$

and standard error ($s_{\bar{x}}$):

$$s_{\bar{x}} = \sqrt{\frac{PQ}{n}}, \tag{8}$$

may both be calculated (Ferguson 1976:156). Similarly, confidence intervals can also be computed for P and Q. Sample size (n) and P control confidence interval coverage. That is, the standard error gets smaller as sample size increases or P deviates from 0.5. The reduction in standard error due to P is greatest when P>0.70 or P<0.30, with minimal change occurring for P between 0.30 and 0.70. Examples of confidence interval coverage for several different values of P and n are given in the following table:

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n	*P*	*Q*	1 Standard error	2 Standard errors
20	0.20	0.80	±8.9%	±17.8%
20	0.50	0.50	±11.2%	±22.4%
50	0.20	0.80	±5.7%	±11.4%
50	0.50	0.50	±7.1%	±14.2%
100	0.20	0.80	±4.0%	±8.0%
100	0.50	0.50	±5.0%	±10.0%
500	0.20	0.80	±1.8%	±3.6%
500	0.50	0.50	±2.2%	±4.4%

Estimating sample size to determine if some fraction of a population is at a chosen level with given certainty follows (Cochran 1977:72):

$$n = \frac{(4)(P*100)(Q*100)}{(\alpha*100)^2}, \tag{9}$$

where, α is 1 – the chosen level of certainty.

Example 6.2–Trout are fin clipped and placed in a raceway prior to stocking. The hatchery manager wants to be 95% certain that at least 90% of all trout are properly fin clipped. How many fish should be randomly sampled?

$$n = \frac{(4)(0.90*100)(0.10*100)}{[(1-0.95)*100]^2}$$

$$= \frac{(4)(90)(10)}{[5]^2}$$

$$= 144$$

Thus, a minimum of 144 fish must be randomly selected to determine if at least 90% of the fish in the raceway are properly clipped.

6.2 Power

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Another measure of data precision and reliability is power. Precision and power measure the probability of correctly concluding a hypothesis given a data set. Commonly, we express the null hypothesis as the sample mean of population A is not different than the sample mean of population B. Conversely, we express the alternate hypothesis as the sample means of populations A and B do in fact differ. Two types of statistical error apply to these outcomes, Type I and Type II. A Type I error is the probability of falsely concluding a significant difference exists when in fact there is no difference. Type I error is denoted as α (alpha). For example, we compare two samples using a t-test. Our results indicate that we are 95% certain that these samples, and the populations from which they were taken, are different; or there is only a 5% chance that they are not different. The probability that we have made a Type I error is 5% (α=0.05). If a Type I error is made, a treatment, method, etc. will be accepted and "wrongly" used. We may, for example, accept that some type of stream improvement increases survival of trout. While continuing to use this treatment may not have a negative effect, time and money are being spent on a treatment that has no effect. The cost of making a Type I error in this example is measured in time and money.

But if we show no difference between samples, what is the probability we are wrong? Type II error is measured by β (beta) and is the probability of concluding there is no difference when a difference does indeed exist. Power is 1-β. Power analysis then, provides an investigator with an estimate of sample size necessary to detect some anticipated outcome. If a Type II error is made, a treatment, method, etc. will not be accepted and may not be used. Using our stream improvement example, if no increase in survival of trout is shown the method will be rejected. The result of making a Type II error in this situation is an opportunity cost. That is, the opportunity to use a method that has benefits. While statistical confidence of differences (α) is routinely reported, power is rarely reported.

For decisions to be useful, an appropriate sample size must be taken. When sample sizes are too small, significant differences are rarely found and a treatment or method may be discarded when it may in fact be useful (Type II error occurs). Conversely, sample sizes which are larger than necessary, are not cost effective.

Numerous statistical methods for power analysis exist and presenting a complete review is beyond the scope of this chapter. (Commercial software packages are available for power analysis and suggestions are given at the end of this section.) However, methods for comparing samples collected from different periods or locations using a t-test are covered in this chapter.

To perform an *a priori* power analysis on data that will be evaluated using a t-test, some preliminary estimates of population characteristics ($\bar{x}$ and s) are necessary, as well as an estimate of anticipated change to the population. We may, for example, anticipate an increase in mean length at age of some fish species following some management technique (e.g., introduction of a predator to thin a bluegill population that is believed to be stunted due to overcrowding).

Several assumptions must be met to accurately measure power using the t-test:

1. Data are approximately normal;
2. Variances of both populations (before and after treatment periods, etc.) are equal;
3. The two populations are independent (that is one group, time period, etc. is not influencing the other);
4. Samples have been randomly selected and accurately represent their respective populations.

Numerous texts discuss power analysis methods, such as Dixon and Massey (1957) and Cohen (1988). Equations presented below were derived from Cohen (1988) and presented in Hintz (1996:59). The methods presented are for directional change (one-tailed test), because we typically expect to see a benefit due to a management action. This benefit could be an increase or decrease in the variable depending on the situation. For example, benefits might be increased abundance of trout, or decrease abundance of sea lamprey. One-tailed tests have greater power than two-tailed tests with equivalent sample sizes because we are focusing on only positive changes.

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Power analysis for a one-tailed t-test is done in the following manner. First, calculate standard deviation (s) from a preliminary sample s_1 following equation (1). Next, calculate pooled standard error of $\bar{x}$ using an estimate of before (n_1) and after (n_2) sample size:

$$s_{\bar{x}} = s_1\sqrt{\frac{1}{n_1}+\frac{1}{n_2}}\,. \tag{10}$$

Note that s_1 is assumed to be equivalent to standard deviation s_2 during the second period (or location). The measure of variability ($s_{\bar{x}}$) and the anticipated change (d) are then standardized following a normal distribution:

$$Z_p = \frac{Z_\alpha s_{\bar{x}} - d}{s_{\bar{x}}}\,, \tag{11}$$

where Z_α is the Z value from Table 1 at the chosen confidence level α (Area column). Power then is estimated as:

$$power = 1-\beta\,, \tag{12}$$

where β is the area value opposite the Z value (substituting Z_p for Z) from Table 1. Several iterations using different values for n_1 and n_2 may be necessary to establish acceptable sample sizes.

There are no set values for α or β. Traditionally, α=0.05 has been used for natural resource data because we generally feel that falsely concluding one method is better than another would be a substantial problem. β equal to 0.20 or less may be a reasonable level of certainty for protection against Type II errors where rejection of a treatment or method does not have severe consequences.

Example 6.3–Walleye are to be introduced in a lake having a stunted bluegill population. A trap net sample of 32 bluegill yielded a mean length of 6.4 inches with a standard deviation of 1.01. The goal of the project is to increase the average length of bluegill, sampled by trap net, to 7.0 inches. The manager wishes to be 95% certain that a Type I error has not occurred (α=0.05). To be certain that an effective treatment opportunity is not missed, 95% power that a Type II error (β=0.05) has not occurred is chosen. How many samples should be collected?

Starting with 32 fish before and 32 fish after:

$$s_{\bar{x}} = 1.01\sqrt{\frac{1}{32}+\frac{1}{32}} = 0.2525,$$

$$Z_p = \frac{(1.645)(0.2525)-(0.6)}{(0.2525)} = -0.7312\,.$$

Using Table 6.1, read under *Z* column to find a value as close to –0.7312 as possible, use –0.7388, then across to the right in the "Area" column find value 0.23 (β):

power = 1-0.23 = 0.77

Since we selected a power of 95%, more samples are required. Next try 50 before and 50 after samples:

$$S_{\bar{x}} = 1.01\sqrt{\frac{1}{50}+\frac{1}{50}} = 0.2020,$$

$$Z_p = \frac{(1.645)(0.2020)-(0.6)}{(0.2020)} = -1.3253,$$

β = 0.09 and *power* = 0.91

Next try 65 before and 65 after samples:

$$S_{\bar{x}} = 1.01\sqrt{\frac{1}{65}+\frac{1}{65}} = 0.1772,$$

$$Z_p = \frac{(1.645)(0.1772)-(1.3)}{(0.1772)} = -1.7410,$$

β = 0.04 and *power* = 0.96

By sampling 32 fish before and 32 fish after, we may not be able to show a difference in mean length when in fact a difference may exist. By roughly doubling our sample to 65 fish before and 65 fish after, power=0.96 and the risk of making a Type II error is minimal.

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Example 6.4–Sample sizes (e.g., before and after) may not always be equal. Once a sample has been collected, additional data may not be available for collection during a given time period or at a location. Using the data from Example 3, suppose the collection of 32 fish during our before period cannot be changed because no additional fish can be measured. How many fish must be collected following the introduction of walleye to detect an increase in the average length of bluegill to 7.0 inches? Again, the before period mean is 6.4 inches with standard deviation 1.01, α=0.05 and β=0.05.

This time start with 32 fish before and 300 fish after:

$$S_{\bar{x}} = 1.01\sqrt{\frac{1}{32} + \frac{1}{300}} = 0.1878,$$

$$Z_p = \frac{(1.645)(0.1878) - (0.6)}{(0.1878)} = -1.5499,$$

β = 0.06 and *power* = 0.94.

Substantially more fish need to be sampled during the after period to detect our anticipated 0.6 inch increase in average length. Approximately 600 bluegill need to be measured during the after period:

$$S_{\bar{x}} = 1.01\sqrt{\frac{1}{32} + \frac{1}{600}} = 0.1832,$$

$$Z_p = \frac{(1.645)(0.1832) - (0.6)}{(0.1832)} = -1.6301,$$

β = 0.05 and *power* = 0.95.

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Currently, the State does not have power analysis software on contract. However, Pass 6.0 is being used at the Institute for Fisheries Research, and is quite easy to use and does not require a systems administrator to install. Power estimates using Pass 6.0 may be done for a variety of parametric and nonparametric statistical tests. These include: t-test on one mean, t-test on two means, one-way ANOVA, fixed effects ANOVA, randomized block ANOVA, repeated measures ANOVA, bioequivalence-means, log-rank survival test, one proportion, two proportions, Fishers exact test, bioequivalence-proportions, matched case/control, one correlation, two correlations, multiple regression, and logistic regression. Trial copies of Pass are currently available on their web site (http://www.ncss.com/) and are good for 30 days.

6.3 Length-weight bias

Length-weight regressions are often used to estimate the weight of fish from their length. Similarly, length of fish may be estimated from their weight. These regression equations generally follow the form:

$$\log L = \log a + b(\log W), \tag{13}$$

for estimation of length L from weight W and:

$$\log W = \log a + b(\log L), \tag{14}$$

for estimation of weight from length. For either equation, a is the intercept and b the slope of the line. Equations (13) and (14) may also be written as:

$$L = aW^{b}, \tag{15}$$

and

$$W = aL^{b}. \tag{16}$$

When large numbers of fish are processed, individual lengths are seldom taken and mean length $\bar{L}$ is estimated from bulk weights using mean weight $\bar{W}$. Substitution of $\bar{L}$ for L and $\bar{W}$ for W in equation (15) produces a biased estimate of $\bar{L}$ (Nielsen and Schoch 1980).

For estimation of $\bar{L}$ using equation (15), b is usually about 1/3 and length is overestimated by about 2.5%, but may be greater depending on the range of fish lengths in the sample. Predicted $\bar{W}$ from equation (16) is underestimated by about 10% when b is around 3, but may also be greater depending on the sample. This under- or overestimation is due to the non-linear relationship between length and weight. As b deviates from 1 (when the relationship is linear), under- or overestimation occurs. While this current discussion relates to length and weight only, bias will occur for any power relationships – such as mean length and mean fecundity of female fish. (Note: Do not confuse power relationship with statistical power in previous section – they are entirely different.) The high bias associated with equation (15) is troublesome when the calculated mean length of hatchery-reared fish at the raceway differ from observed mean lengths at the stocking site.

To compensate for bias associated with prediction of mean length from mean weight in a hatchery setting, the following procedure is suggested.

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1. Prior to removing fish from a raceway for planting, obtain a sample of 150-200 fish, and measure their individual lengths and weights. From this sample, compute mean length, mean weight, and a weight-length regression specific to that raceway.
2. Using that raceway-specific regression, calculate the predicted mean length based on the mean weight determined in #1. The predicted mean length will be slightly larger than the actual mean length calculated in #1. This difference (expressed as a percentage) will be used to adjust predicted mean lengths planted.
3. During the planting operation, for each group of fish cut off from the rest of the raceway, obtain 5 subsamples (each about 100 fish) for weighing and counting. Subsample each time a portion of the raceway is segregated. (Based on samples from the Harrietta Hatchery, this should give you an average number of fish per kilogram±1.5 fish [95% confidence level]).
4. To compute the mean length of fish being planted, insert the mean weight, calculated in #3, into the weight-length regression. The predicted length is then reduced by the percentage determined in #2.

Similar procedures could be used to estimate mean weights from mean lengths of fish.

Example 6.5–A sample of 20 hatchery fish yield the following length (inches) and weight (grams) values (note this is less than the recommended sample of 150-200 and is done so for demonstration purposes):

Length	Weight
3.0	15.0
3.1	29.7
4.6	99.3
4.7	113.8
5.7	200.0
5.9	205.3
6.0	206.0
6.1	236.9
6.9	348.5
3.6	46.6
3.8	54.8
3.9	59.3
4.5	91.1
4.7	103.8
4.8	110.5
4.9	117.6
5.0	125.0
6.0	216.0
6.8	314.4
6.9	328.5

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Step 1 – Enter length weight data into SPSS (9.0.0) and calculate average length and weight using "Analyze Descriptive statistics   Descriptives". Average length is 5.0450 and average weight 151.1400. Output will appear similar to:

Descriptive Statistics

	N	Mean
LENGTH	20	5.0450
WEIGHT	20	151.1400
Valid N (listwise)	20	

Next calculate length weight regression using "Analyze Regression Curve estimation". Length is the dependent variable and weight the independent. For models check "Power". Output similar to the following should appear:

```
MODEL:  MOD_9.
_


Dependent variable.. LENGTH           Method.. POWER
Listwise Deletion of Missing Data

Multiple R            .98928
R Square              .97867
Adjusted R Square     .97748
Standard Error        .03782

Analysis of Variance:

               DF    Sum of Squares      Mean Square

Regression      1        1.1809908        1.1809908
Residuals      18         .0257447         .0014303

F =     825.71570       Signif F =  .0000

------------------- Variables in the Equation ------------------

Variable                B         SE B        Beta          T  Sig T

WEIGHT           .300109      .010444     .989275     28.735  .0000
(Constant)      1.177706      .059277                 19.868  .0000
```

Example 6.5–continued.

Reading under "Variables in the Equation" find 0.300109 and 1.177706 (both are in bold type). Substituting in our length-weight regression, *a*=1.177706, *b*=0.300109 and mean weight from above descriptive statistics:

$$L = 1.177706 \cdot (151.1400)^{0.300109} = 5.3099$$

We now have:

Observed mean length = 5.0450
Observed mean weight = 151.1400
Predicted mean length = 5.3099

Step 2 – Calculate correction factor:

$$correction = \frac{5.3099}{5.0450} = 1.0525$$

Step 3 – Each time fish are to be removed from a raceway and planted, collect 5 samples of 100 fish. Calculate the average weight from these 5 samples. This step is repeated each time that a raceway is segregated for removal of fish.

Step 4 – Estimate mean length using regression equation from Step 1 and correction factor from Step 2:

$$corrected\ \ mean\ \ length = \frac{1.177706 \cdot W^{0.300109}}{1.0525}$$

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Table 6.1.–Areas of the normal distribution. Table values were taken from Remington and Schork (1970).

z	Area	z	Area	z	Area
-2.3290	0.01	-0.4125	0.34	0.4399	0.67
-2.0540	0.02	-0.3853	0.35	0.4677	0.68
-1.8810	0.03	-0.3585	0.36	0.4959	0.69
-1.7510	0.04	-0.3319	0.37	0.5244	0.70
-1.6450	0.05	-0.3055	0.38	0.5534	0.71
-1.5550	0.06	-0.2793	0.39	0.5828	0.72
-1.4760	0.07	-0.2533	0.40	0.6128	0.73
-1.4050	0.08	-0.2275	0.41	0.6433	0.74
-1.3410	0.09	-0.2019	0.42	0.6745	0.75
-1.2820	0.10	-0.1764	0.43	0.7063	0.76
-1.2270	0.11	-0.1510	0.44	0.7388	0.77
-1.1750	0.12	-0.1257	0.45	0.7722	0.78
-1.1264	0.13	-0.1004	0.46	0.8064	0.79
-1.0800	0.14	-0.0753	0.47	0.8416	0.80
-1.0360	0.15	-0.0502	0.48	0.8779	0.81
-0.9945	0.16	-0.0251	0.49	0.9154	0.82
-0.9542	0.17	0.0000	0.50	0.9542	0.83
-0.9154	0.18	0.0251	0.51	0.9945	0.84
-0.8779	0.19	0.0502	0.52	1.0360	0.85
-0.8416	0.20	0.0753	0.53	1.0800	0.86
-0.8064	0.21	0.1004	0.54	1.1264	0.87
-0.7722	0.22	0.1257	0.55	1.1750	0.88
-0.7388	0.23	0.1510	0.56	1.2270	0.89
-0.7063	0.24	0.1764	0.57	1.2820	0.90
-0.6745	0.25	0.2019	0.58	1.3410	0.91
-0.6433	0.26	0.2275	0.59	1.4050	0.92
-0.6128	0.27	0.2533	0.60	1.4760	0.93
-0.5828	0.28	0.2793	0.61	1.5550	0.94
-0.5534	0.29	0.3055	0.62	1.6450	0.95
-0.5244	0.30	0.3319	0.63	1.7510	0.96
-0.4959	0.31	0.3585	0.64	1.8810	0.97
-0.4677	0.32	0.3853	0.65	2.0540	0.98
-0.4399	0.33	0.4125	0.66	2.3290	0.99

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Chapter 7: Stream Fish Population Estimates by Mark-and-Recapture and Depletion Methods

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Estimates of the total number of fish in sections of streams can be made reliably and inexpensively by subsampling a portion of the population. Two basic methods are available, mark-and-recapture and depletion. Either method is appropriate for shallow streams which can be waded and thoroughly sampled with electrofishing gear. Mark-and-recapture methods can also be used in deeper streams (as by electrofishing from a boat) if it can be reasonably assumed all targeted fish are vulnerable because either (a) all parts of the stream can be sampled or (b) marked fish are randomly mixed with unmarked fish.

7.1 Mark-and-recapture estimates

The mark-and recapture method is generally preferred over the depletion method and has been shown to be unbiased when more than 50% of a population is marked (Jensen 1992). The mark-and-recapture method requires the following conditions:

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1. Marked and unmarked fish have the same mortality rates;
2. Marked and unmarked fish are equally vulnerable to capture;
3. Marks are retained during the sampling period and all marks on recaptured fish are recognized;
4. Marked fish randomly mix with unmarked fish;
5. There is negligible emigration or immigration during the recapture period.

The general process for estimating a fish population using the mark-and-recapture method entails:

1. Collecting a sample of fish of the target species from a discrete section of stream during an initial "marking run";
2. Giving fish identifying marks, such as a tag or temporary fin clip;
3. Tabulating data by species and size;
4. Releasing fish in good condition back into the same area;
5. Allowing at least 1 day for marked fish to recover and become mixed in the population;
6. Collecting a random sample of fish during a subsequent "recapture run";
7. Noting the ratio of marked to unmarked fish by species and size (e.g., inch group);
8. Calculating for each combination of species and size group (to compensate for gear selectivity) an estimate of abundance by a Petersen equation;
9. Summing the size group estimates by species to obtain an estimate of the total population within the size range actually sampled.

7.1.1 Chapman - Petersen methods

Ricker (1975) discusses the calculation of population estimates in detail. He recommends a slight variation of the Chapman modification of the Petersen equation because it gives a statistically unbiased estimate for finite populations, such as we deal with in inland waters. The Chapman variation is very similar to the Bailey modification of the Petersen equation, which is also widely used, and both produce estimates slightly less than the simple Petersen equation. Estimation of population N and variance of N, with the Chapman modification, follow as:

$$N = \frac{(M+1)(C+1)}{R+1}\ , \tag{1}$$

$$Variance\ of\ N = \frac{(M+1)^2(C+1)(C-R)}{(R+1)^2(R+2)} = \frac{N^2(C-R)}{(C+1)(R+2)}\ , \tag{2}$$

$$\text{Standard error} = \sqrt{\text{Variance of } N}\ ,$$

95% confidence limits = N ± t(Standard error) ,

where,

C = total number of fish caught in second sample (including recaptures),

M = number of fish caught, marked and released in first sample,

N = population estimate,

R = number of recaptures in the second sample (fish marked and released in the first sample),

t = Student's t for C-1 degrees of freedom.

Variance Equation (2) should be used whenever variance estimates are to be combined, for example when summing estimates and variances for two to more size groups to obtain a total population estimate. However, it is not the best estimator of variance for single estimates (Ricker 1975). His recommendation is to use either binomial charts or a Poisson distribution (Table 7.1). These provide low and high ranges for R which are then substituted in Equation (1) to calculate the lower and upper confidence limits. These limits are typically asymmetrical and measure variability more accurately. While 95% confidence limits are often used for research, 68% limits (1 standard error) may be suitable for management purposes.

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Ricker (1975) stated that the probability of a systematic statistical bias in the population estimate can be ignored if recaptures number 3-4 or more. Therefore, if necessary, pool data from adjacent size groups to obtain **at least** 3-4 recaptures per estimate.

Example 7.1–If 100 fish were marked and released from the first run, and the second run contained 80 fish of which 10 were recaptures:

$$N = \frac{(100+1)(80+1)}{10+1} = 744\text{ fish},$$

$$\text{Variance of } N = \frac{(100+1)^2(80+1)(80-10)}{(10+1)^2(10+2)} = 39{,}834\,,$$

$$\text{Standard error} = \sqrt{39834} = 200 = 68\%\text{ confidence limit},$$

and approximate 95% confidence limits = N ±2(200) = N ±400,

i.e., Lower limit (N_L) = 344 and Upper limit (N_U) = 1,144.

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Example 7.1–Continued.

Better 95% confidence limits from the equation given in Table 7.1 are:

$$R + 1.92 \pm 1.960\sqrt{R + 1.0} = 11.92 \pm 6.501,$$

$$\text{or } R_L = 5.42 \quad \text{and } R_U = 18.42.$$

When substituted for R in Equation (1):

$$N_L = \frac{(100+1)(80+1)}{18.42+1} = 421,$$

and

$$N_U = \frac{(100+1)(80+1)}{5.42+1} = 1{,}274.$$

We conclude from this example that the population contains about 744 fish, but the statistical error is relatively large and with 95% certainty the true number lies between 421 and 1,274. Note that this measurement of error is for random error only, and any systematic error (e.g., avoidance of recapture by marked fish) is unknown.

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In many studies the investigator may desire to add several population estimates and have confidence limits for the total population ($\hat{N}$). For example, one might have separate population estimates for trout in inch groups 8, 9, and ≥10, which when added give the total number of catchable-size trout. The appropriate equation for computing a total variance for j inch groups is:

$$Var(\hat{N}) = \sum_{i=1}^{j} Var(N)_i \tag{3}$$

Example 7.2–Inch group 8 has an estimated population of 357 fish with a variance of 20,392; inch group 9 has an estimated population of 293 fish with a variance of 12,100; and inch group 10+ has an estimated population of 153 with a variance of 3,935:

$$\hat{N} = 357 + 293 + 153 = 803 \text{ fish},$$

$$\text{Variance of } \hat{N} = 20{,}392 + 12{,}100 + 3{,}935 = 36{,}427,$$

$$\text{Standard error of } \hat{N} = \sqrt{36{,}427} = 191,$$

and approximate 95% confidence limits $= \hat{N} \pm 2(191) = \hat{N} \pm 382$,

i.e., N_L = 421 and N_U = 1,185.

7.2 Depletion estimates

The depletion method (also known as the "Zippin" method, see Zippin 1958) is satisfactory if the stream is very small, it is expedient to collect all data within a short time period such as one day, and the population being estimated is relatively small (roughly less than 2,000 individuals). If fish are likely to migrate in or out of a study section soon (say in less than 1 week), the depletion method is superior to the mark-and-recapture method due to a shorter sampling time period. This method requires that an adequate number of fish be removed on each sampling pass so that measurably fewer fish are available for capture and removal on a subsequent pass. Two types of depletion methods are used, two-pass and multiple-pass. Because of differences in gear selectivity, partitioning estimates by species and size groups is recommended. For both two-pass and multiple-pass methods, size group estimates and their variances are summed, as with mark-and-recapture methods, to provide total population estimates. The following conditions must be met for accurate depletion method estimates:

1. Emigration and immigration by fish during the sampling period must be negligible;
2. All fish within a specified sample group must be equally vulnerable to capture during a pass;
3. Vulnerability to capture of fish in a specified sample group must remain constant for each pass (e.g., fish do not become more wary of capture);
4. Collection effort and conditions which affect collection efficiency, such as water clarity, must remain constant.

Depletion estimates are made following the general process:

1. Remove (or mark to simulate removal) fish within a discrete section of stream;
2. Record number of fish removed (or marked) by species and size group;
3. Repeat steps 1 and 2;
4. If steps 1 and 2 were completed twice, calculate population estimates using two-pass equations;
5. If steps 1 and 2 were completed more than twice, calculate population estimates using multiple-pass equations.

7.2.1 Two-pass depletion methods

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For two-pass depletion estimates, fish are captured and removed during two capture sessions. Equations provided here are described in greater detail in Seber and Le Cren (1967). Population estimate N and variance of N are calculated as:

$$p = \frac{C_1 - C_2}{C_1}, \tag{4}$$

$$N = \frac{C_1^2}{(C_1 - C_2)}, \tag{5}$$

$$\text{Variance of } N = \frac{C_1^2 C_2^2 (C_1 + C_2)}{(C_1 - C_2)^4}, \tag{6}$$

$$\text{Standard error of } N = \sqrt{\text{Variance of } N},$$

where,

C_1 = number of fish removed in first sample,

C_2 = number of fish removed in second sample,

N = population estimate,

p = probability of capture,

Two-pass depletion estimates are unbiased when $p \geq 0.80$ and quite unreliable when $p \leq 0.20$ (i.e., when less than 20% of the population is caught per pass).

Example 7.3–On the first pass 200 fish were collected and on the second pass 95 fish were collected. Estimated population and confidence limits are calculated as:

$$p = \frac{200 - 95}{200} = 0.525,$$

$$N = \frac{200^2}{(200 - 95)} = 381.$$

$$\text{Variance of } N = \frac{(200^2)(95^2)(200 + 95)}{(200 - 95)^4} = 876,$$

$$\text{Standard error of } N = \sqrt{876} = 30,$$

and approximate 95% confidence limits = $N \pm 2(30) = N \pm 60$,

i.e., N_L = 321 and N_U = 441.

7.2.2 Multiple-pass depletion methods

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This method requires three or more passes on the selected stream section and involves additional calculations to estimate the population. The multiple pass depletion method relies heavily upon consistent catchability ($p_1 = p_2 = p_3 = \ldots p_s = p$). Further description of these equations are found in Carle and Strub (1978). Estimation steps are as follows:

$$T = \sum_{i=1}^{k} C_i\ , \tag{7}$$

$$X = \sum_{i=1}^{k} (k - i) C_i\ , \tag{8}$$

where,

i = pass number,

k = number of removals (passes),

C_i = number of fish caught in i^{th} sample,

X = an intermediate statistic used below,

T = total number of fish caught in all passes.

The maximum likelihood estimate of *N* is determined by an iterative process by substituting values for *n* until:

$$\left[\frac{n+1}{n-T+1}\right] \prod_{i=1}^{k}\left[\frac{kn-X-T+1+(k-i)}{kn-X+2+(k-i)}\right]_i \leq 1.0, \tag{9}$$

where *n* is the smallest integer satisfying Equation (9). Note that results of Equation (9) are rounded to one decimal place. Probability of capture, *p*, and variance of *N* are then estimated by:

$$p = \frac{T}{kN - X}, \tag{10}$$

$$\text{Variance of } N = \frac{N(N-T)T}{T^2 - N(N-T)\left[\frac{(kp)^2}{(1-p)}\right]}, \tag{11}$$

$$\text{Standard error of } N = \sqrt{\text{Variance of } N}\,.$$

Since estimating *N* is an iterative process, a suggested initial value for *n* is *T*, and subsequent selections for *n* should progressively increase from *T*. These Equations should be setup in a spreadsheet to facilitate selection of *n*, and estimates of *N* and variance of *N*.

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Example 7.4–On the first pass 300 fish were removed, 130 on the second, and 69 on the third:

$T = 300 + 130 + 69 = 499,$

$X = [(3\text{-}1) * 300] + [(3\text{-}2) * 130] + [(3\text{-}3) * 69] = 600 + 130 + 0 = 730.$

We know there were at least 499 fish (*T*) in the population, so for our first *n* let's try 499 in Equation (9):

$$\left[\frac{499+1}{499-499+1}\right]\left[\frac{(3*499)-730-499+1+(3-1)}{(3*499)-730+2+(3-1)}\right]\left[\frac{(3*499)-730-499+1+(3-2)}{(3*499)-730+2+(3-2)}\right]\left[\frac{(3*499)-730-499+1+(3-3)}{(3*499)-730+2+(3-3)}\right]$$

= (500.0)(0.3515)(0.3506)(0.3498)= 21.5540 which is rounded to 21.6.

Since 21.6>1.0 we must select another number for *n* greater than 499. For our second try let's use *n* = 520:

$$\left[\frac{520+1}{520-499+1}\right]\left[\frac{(3*520)-730-499+1+(3-1)}{(3*520)-730+2+(3-1)}\right]\left[\frac{(3*520)-730-499+1+(3-2)}{(3*520)-730+2+(3-2)}\right]\left[\frac{(3*520)-730-499+1+(3-3)}{(3*520)-730+2+(3-3)}\right]$$

= (23.6818)(0.4005)(0.3998)(0.3990) = 1.5.

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Example 7.4–Continued.

Subsequent trials with *n* equal to 530, 540, 545 and 546 yield estimates for *N* of 1.2, 1.1, 1.1 and finally 1.0. Since our goal is to come close to 1.0 without going over, the maximum likelihood estimate of the population (*N*) is 546. We can now estimate probability of capture (*p*) and error statistics:

$$p = \frac{499}{(3*546) - 730} = 0.5496,$$

$$\text{Variance of } N = \frac{546*(546-499)*499}{499^2 - 546*(546-499)*\left[\frac{(3*0.5496)^2}{(1-0.5496)}\right]} = \frac{12{,}805{,}338}{94{,}109} = 136,$$

$$\text{Standard error of } N = \sqrt{136} = 11.7,$$

approximate 95% confidence limit = $N \pm 2(11.7) = N \pm 23$,

i.e., N_L = 523 and N_U = 569.

As previously mentioned, the depletion method assumes that all *s* capture probabilities for *k* passes are equivalent, that is $p_1 = p_2 = \ldots p_s = p$. When using the two-pass method and fish are removed from the section on the first pass, there is no way to verify this assumption. However, when fish are marked and released back into the section (to simulate removal) number of fish captured on each pass are expected to be similar. Consider the data presented in Example 7.1. On the first pass, 100 fish (C_1) were captured and marked. On the second pass, 80 fish were captured of which 70 (C_2) were unmarked. Treating these data as depletion data gives C_1 = 100, C_2 = 70 with *N* = 333 (using Equation 5). This result is substantially different from the mark-and-recapture estimate of 744 using Equation (1) and is caused by unequal catch probabilities. If capture probabilities had been equal, 100 fish would have been captured on the second pass and Equations (1) and (5) would have given similar results. This verification technique may only be used when 1 or more days elapse between passes.

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Example 7.5–On the first pass 120 fish are marked and released back into the section. On the second pass 60 marked fish and 60 unmarked fish are captured:

Using mark-and-recapture Equation (1):

$$N = \frac{(120+1)(120+1)}{60+1} = 240.$$

Using depletion Equation (5):

$$N = \frac{120^2}{120-60} = 240.$$

When more than two passes are made equality of *p's* can be verified in numerous ways. Seber and Le Cren (1967) suggest simply plotting each catch against the sum of all previous catches:

$$\sum_{i=0}^{k-1} C_i \ . \tag{12}$$

Example 7.6–Using data from example 7.4 where C_1 =300, C_2 =130 and C_3 =69, the following values would be plotted:

Pass	Sum of previous catches	Catch
1	0	300
2	300	130
3	430	69

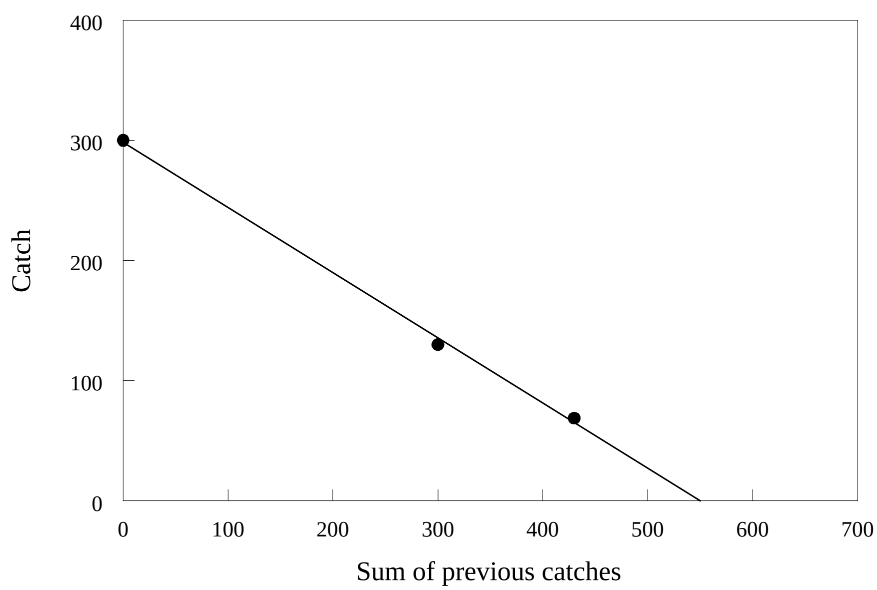

Figure 7.1–Individual catches plotted against the sum of previous catches from example 7.4.

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A goodness of fit test may also be used to evaluate equality of capture probability (White et al. 1982). This follows the χ^2 test form $(\text{Observed} - \text{Expected})^2 / \text{Expected}$. The first step is to calculate the expected number of fish collected on each pass using the estimated population *N*, from Equation (9), and estimated probability of capture *p*, from Equation (10):

$$E(C_1) = Np\,, \tag{13}$$

and for *i*>1.

$$E(C_i) = N(1-p)^{i-1}p \tag{14}$$

Calculated χ^2 then is:

$$\chi^2 = \frac{[C_1 - E(C_1)]^2}{E(C_1)} + \frac{[C_2 - E(C_2)]^2}{E(C_2)} + \cdots + \frac{[C_i - E(C_k)]^2}{E(C_k)}\,. \tag{15}$$

The test statistic χ^2 from Equation (15) is compared with $\chi^2_{0.95}$, Table 2, with *k*-2 degrees of freedom (df). Note that two degrees of freedom are lost because *N* is estimated (Snedecor and Cochran 1991:77). If $\chi^2 < \chi^2_{0.95}$, probability of capture did not differ significantly (at the 95% level of certainty) between passes; if $\chi^2 \geq \chi^2_{0.95}$, then probability of capture was significantly different with 95% certainty.

Example 7.7–Using the data from example 7.4: C_1=300, C_2=130, C_3=69, *N*=546 and *p*=0.5496:

$$E(C_1) = 546(0.5496) = 300\,,$$

$$E(C_2) = 546(1-0.5496)^1(0.5496) = 135\,,$$

$$E(C_3) = 546(1-0.5496)^2(0.5496) = 61\,,$$

$$\chi^2 = \frac{(300-300)^2}{300} + \frac{(135-130)^2}{135} + \frac{(61-69)^2}{61} = 0.000 + 0.185 + 1.049 = 1.234\,,$$

where df = 3-2=1, and $\chi^2_{0.95} = 3.841$.

Since $\chi^2 < \chi^2_{0.95}$ we show no significant difference (95% certainty) between capture probabilities and Equations (7-11) are appropriate.

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Variation in capture probability hinges on numerous factors. Of particular concern is increased wariness when fish are exposed to electrofishing. Heggberget and Hesthagen (1979) used the 2-pass depletion method to estimate Atlantic salmon *Salmo salar* and brown trout S*almo trutta* in two small Norway streams and suggested that populations were underestimated by as much as 50% due to electrical current avoidance on the second pass. On the other hand, Peterson and Cederholm (1984) found that probability of capture for shocked juvenile coho salmon *Oncorhynchus kisutch* was similar to previous capture rates after a minimum of 1 hour recovery time. To minimize error, the amount of effort used on each pass should be as constant as possible and estimates should be stratified by species and size group to avoid gear selectivity. Appropriate steps should be taken to minimize immigration and emigration of fish, as by using blocking nets on small streams to greatly reduce fish movement. When sampling streams where blocking nets are not practical, effect of fish movement on population estimates can be reduced by sampling longer sections.

When variation in capture probability is severe, and estimates of *N* and variance of *N* using Equations (7-11) are invalid, more computationally intense methods such as those given by Schnute (1983) or White et al (1982) are necessary. A copy of CAPTURE (White et al. 1982) is available at the Institute for Fisheries Research. This interactive software calculates an appropriate estimate of N and variance of N when capture probabilities are different.

The assumptions of the depletion method are rigorous regarding constant fish catchability for each sample and that more than 20% (better, >30%) of the population be captured in each sample. The assumptions of the depletion method are most suspect in large streams (more likely to have refuges) and for large fish (more likely to be agile or wary). Therefore, it is wise to design sampling procedures to retain the option of computing mark-and-recapture estimates while conducting depletion sampling. The option is left open by marking and releasing fish after the first pass, noting their recapture in subsequent passes, and ignoring marked fish for depletion method analysis or counting them as "recaptures" for mark-and-recapture method analysis. Note however, if more than one pass is made per day, the marked fish may not have recovered and become mixed, thereby violating the basic assumption of the mark-and-recapture method.

Mark-and-recapture methods also have essential constraints. If marked fish are more easily captured than unmarked fish on the second pass, the population will be underestimated. If marked fish are more difficult to capture than unmarked fish on the second pass, the population will be overestimated. Smallmouth bass *Micropterous dolomieu* in particular are difficult to recapture and mark-and-recapture methods are not recommended (Lyons and Kanehl 1993).

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Table 7.1–Poisson distribution of lower and upper 95% confidence limit coefficients[a] for number of recaptures (*R*), and Student's 95% confidence *t* values for number of degrees of freedom (df).

Poisson distribution						Student's *t* value	
R	Lower	Upper	*R*	Lower	Upper	df	t_{95}
0	0.0	3.7	26	17.0	38.0	1	12.706
1	0.1	5.6	27	17.8	39.2	2	4.303
2	0.2	7.2	28	18.6	40.4	3	3.182
3	0.6	8.8	29	19.4	41.6	4	2.776
4	1.0	10.2	30	20.2	42.8	5	2.571
5	1.6	11.7	31	21.0	44.0	6	2.447
6	2.2	13.1	32	21.8	45.1	7	2.365
7	2.8	14.4	33	22.7	46.3	8	2.306
8	3.4	15.8	34	23.5	47.5	9	2.262
9	4.0	17.1	35	24.3	48.7	10	2.228
10	4.7	18.4	36	25.1	49.8	11	2.201
11	5.4	19.7	37	26.0	51.0	12	2.179
12	6.2	21.0	38	26.8	52.2	13	2.160
13	6.9	22.3	39	27.7	53.3	14	2.145
14	7.7	23.5	40	28.6	54.5	15	2.131
15	8.4	24.8	41	29.4	55.6	16	2.120
16	9.2	26.0	42	30.3	56.8	17	2.110
17	9.9	27.2	43	31.1	57.9	18	2.101
18	10.7	28.4	44	32.0	59.0	19	2.093
19	11.5	29.6	45	32.8	60.2	20	2.086
20	12.2	30.8	46	33.6	61.3	21	2.080
21	13.0	32.0	47	34.5	62.5	22	2.074
22	13.8	33.2	48	35.3	63.6	23	2.069
23	14.6	34.4	49	36.1	64.8	24	2.064
24	15.4	35.6	50	37.0	65.9	60	2.000
25	16.2	36.8				∞	1.960

[a] Substitute the coefficients for *R* in Formula (1). For larger values of *R*, use the following equation (Ricker 1975) for 95% limit coefficients: $R + 1.92 \pm 1.96\sqrt{R + 1.0}$.

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Table 7.2–Percentiles of the χ^2 distribution for 70% and 95% certainty[a].

Degrees of freedom	$\chi^2_{0.70}$	$\chi^2_{0.95}$
1	1.074	3.841
2	2.408	5.991
3	3.665	7.815
4	4.878	9.488
5	6.064	11.070
6	7.231	12.592
7	8.383	14.067
8	9.524	15.507
9	10.656	16.919
10	11.781	18.307

[a] For additional degrees of freedom or alternate levels of certainty, see χ^2 tables in texts such as Snedecor and Cochran (1991).

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Chapter 8: Lake Fish Population Estimates by Mark-and-Recapture Methods

James C. Schneider

Estimating the actual numbers of fish in a lake is a difficult and time-consuming process for a number of reasons:

1. Populations of fishes in lakes are often extremely large (e.g., bluegills often number in the thousand per acre, most of which are very small); consequently, large numbers of fish must be marked and examined.
2. Any day's sample is likely to include only a very small portion of the total population; therefore, many days of effort may be required to obtain an adequate sample and realize stable ratios of marked to unmarked fish.
3. If sampling takes too long, small fish may grow (recruit) into the size being estimated or marked fish may die at a faster rate than unmarked fish (both cause an overestimate).
4. Fish may avoid sampling, and trap nets and electrofishing are ineffective in deep water (causing an underestimate and a tendency for biologists to study shallow lakes more than deep lakes). Consequently, precision of the estimate depends on random mixing of marked and unmarked fish in areas that can be sampled. Such mixing often occurs in spring or fall.
5. Individual fish may have territories, daily or seasonal movements, or other behavioral patterns which effect vulnerability to sampling.
6. Sampling gear is selective for species and size. Therefore, estimates should be stratified to compensate, then added together as appropriate.
7. There is no certain crosscheck on the accuracy of the population estimate unless known numbers of fish have been stocked or, in the case of reservoirs, the water can be drained and the fish directly counted.

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8.1 General procedures

1. Collect a random sample (within gear limitations) of the target species. Nets should be moved every day or every other day to randomly or systematically cover all areas of the lake where the gear is likely to catch fish.
2. Give fish in good condition identifying marks, such as a tag or temporary clip on the tail fin.
3. Tabulate data by species and size group (e.g., inch group).
4. Release fish away from the sampling gear to encourage mixing of marked and unmarked fish.
5. Allow at least 1 day for the marked fish to recover and become mixed.
6. Collect another random sample of fish.
7. Record the ratio of marked to unmarked fish by species and size group.
8. Repeat steps 1-7 until at least 4 recaptures have been made per species-size strata.
9. Adjust as necessary the daily records of marked fish available for fish that die from handling or are removed by anglers. Substantial losses will invalidate the estimate.
10. Calculate for each combination of species and size group (to compensate for gear selectivity), estimates of population abundance (and error) with appropriate formulas.

11. As appropriate, sum size group estimates (and variances) by species to obtain an estimate of the total population (and variance) within the size range actually sampled.

8.2 Variations

In the above general procedure, data is recorded per sampling trip and is summarized on a daily basis. But there are three variations to data collection and analysis:

Multiple-census–Continually mark fish and retain the multiple-sample format throughout the sample period with the goal of utilizing a multiple census formula, such as the Schumacher-Eschmeyer formula.

Bi-census–Plan an initial marking period, a rest period of 1 week or longer to allow fish to recover and mix, then a recapture period, with the goal of utilizing the Chapman modification of the Petersen formula.

Combination–As in the first multiple-census option, continually mark fish but arrange sampling into two periods – a marking period and a recapture period – with the goal of utilizing the Chapman formula. This entails pooling data from several early samples into a combined marking period, allowing a rest period if possible, resuming sampling and changing to a second type of fish mark, then pooling data from several later samples into a combined recapture period. During the recapture period, all unmarked fish are utilized as part of the unmarked catch and only the marks given during the early period count as recaptures (recaptures of the second marks are ignored in computing the ratio of marked to unmarked because they were already counted once as unmarked fish in the second period). Note that all data, derived from both types of marks, also can be used to compute population estimates by a multiple census formula.

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The combination approach is recommended because it is flexible. If data from the combination approach are sufficient to calculate a Chapman estimate, then it seems least likely to be biased in case marked fish are not well mixed in 1 day. If data from the study are sparse (as is often the case), they are used most efficiently by a multiple census formula, and the combined approach continually increases the numbers of marked fish available, maximizes number of recaptures, and utilizes all data.

There are some differences in application and interpretation of formulae. The population estimate by the Chapman method applies in the strictest sense to the day marking was completed. Therefore, recaptures obtained even months later can be used to compute an estimate for the last marking date provided marks are not “lost” (as by re-growth of clipped fins or shedding of tags), recruitment into the size group is negligible, and marked and unmarked fish experience similar rates of mortality or loss to emigration. Thus, fish marked in the fall can be recaptured the following spring. Also, fish readily caught and marked during spring spawning runs (such as walleye and northern pike) can be recaptured in early summer when the sexes are more likely to be well mixed. Note that attempts to both mark and recapture spawning fish are quite likely to be biased because males remain on the spawning ground longer than females and fish are freely migrating at that time (i.e., the population being sampled is not “closed”). This bias can be reduced (but not eliminated) by stratifying the data and estimates by sex.

The population estimate by the Schmaucher-Eschmeyer formula is not so closely attributed to one day, but represents the recapture interval, and is most heavily weighed toward the final day. For that reason, try to obtain large samples of fish and reliable ratios on the last day of sampling. One way to accomplish that is to not mark additional fish on the second from last day and pool sample data for the last 2 days.

8.2.1 Chapman variation of Petersen formulas for bi-census

From Ricker (1975); see also Chapter 7:

$$N = \frac{(M+1)(C+1)}{R+1} \ , \qquad (1)$$

where:

N = population estimate in numbers of fish;

M = number of fish caught, marked and released in first sample;

C = total number of fish caught in second sample (unmarked + recaptures);

R = number of recaptures in second sample (of fish marked and released in first sample).

$$\text{Variance of } N = \frac{(M+1)^2(C+1)(C-R)}{(R+1)^2(R+2)} = \frac{N^2(C-R)}{(C+1)(R+2)} \ , \qquad (2)$$

$$\text{Standard error } = \sqrt{\text{Variance of N}} \ ,$$

95% confidence limits of $N = N \pm t$(Standard error) ,

where t is Student's t for C–1 degrees of freedom. (See Table 8.1 for t values).

Variance equation (2) should be used whenever variance estimates are to be combined, as for example when summing estimates and variances for two or more size groups to obtain a total population estimate. However, it is not the best estimator of variance for single estimates (Ricker 1975). His recommendation for those is to use either binomial charts or a Poisson distribution (Table 8.1). These provide low and high ranges for R which are then substituted in equation (1) to calculate the lower and upper 95% confidence limits. While 95% confidence limits are often used for research, management can often settle for limits of 68% (±1 standard error).

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8.2.2 Schumacher-Eschmeyer formulas for multiple census

From Ricker (1975):

$$N = \frac{\sum_{d=1}^{n} C_d M_d^2}{\sum_{d=1}^{n} R_d M_d} \ , \qquad (3)$$

where:

N = population estimate in numbers of fish;

$C_d = U_d + R_d$ = total number of fish caught during day d;

U_d = number of unmarked fish caught during day d;

R_d = number of recaptures during day d (of the type of mark under consideration);

M_d = number of marked fish available for recapture at **start** of day d;

d = sample number (usually day), ranging from first (d_1) to last (d_n).

$$s^2 = \frac{\sum_{d=1}^{n}\left(\frac{R_d^2}{C_d}\right) - \left[\frac{\left(\sum_{d=1}^{n} R_d M_d\right)^2}{\sum_{d=1}^{n} C_d M_d^2}\right]}{m-1}, \quad (4)$$

where:

s^2 = variance of samples;

m = number of days (or samples) in which fish were actually caught.

$$\text{Variance of } N = N^2\left[\frac{Ns^2}{\sum_{d=1}^{n} R_d M_d}\right], \quad (5)$$

$$\text{Standard error of } N = \sqrt{\text{Variance of } N},$$

$$\text{95\% confidence limits of } N = N \pm t(\text{Standard error}),$$

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where Student's t (Table 8.1) is based on $m-1$ degrees of freedom.

Variance equation (5) should be used whenever variance estimates are to be combined, as for example when summing estimates and variances for two or more size groups to obtain a total population estimate with variance. However, as with the Chapman method, it is not the best estimator of variance for single estimates (Ricker 1975). His recommendation is to compute reciprocals of N (i.e., $1/N$) from equation (3) and variances and errors from equation (6) below:

$$\text{Variance of } 1/N = \frac{s^2}{\sum_{d=1}^{n} C_d M_d^2}, \quad (6)$$

$$\text{Standard error of } 1/N = \sqrt{\text{Variance of } 1/N},$$

$$\text{95\% confidence limits of } 1/N = 1/N \pm t(\text{Standard error}).$$

The reciprocals of those fractional limits are then taken to obtain whole number confidence limits. Note that when reciprocals are taken, the distribution of limits around the point estimate change from symmetrical to asymmetrical. The interval between the point estimate and the lower limit becomes less than the interval between the point estimate and the upper limit.

8.2.3 Alternative methods

The equation for multiple census developed by Schnabel (Ricker 1975) gives estimates very close to those obtained by the Schumacher-Eschmeyer, equation (3).

Depletion methods described in Chapter 7 of Manual of Fisheries Survey Methods II could conceivably be applied to some lake data sets if samples can be arranged into appropriate two-pass or multiple-pass formats. However, the restrictions of this method are more tenuous for lakes than for streams, and mark-recapture methods are usually better in lakes. Restrictions on the depletion method include (a) constant sampling effort; (b) 20% or more of the population is caught per sample (samples may be pooled); and (c) the population is less than approximately 2,000 fish. Constant sampling effort is more feasible in shallow streams, where active electrofishing can thoroughly sample all areas and all fish, than in lakes, where on a given day some fish may choose to avoid passive gear such as trap nets.

8.2.4 Bias

The above formulas provide an estimate of random statistical error but no measure of bias. Errors from bias can be much larger and more serious. Bias is very difficult to determine unless the fish population is known or can be logically bracketed. For example, if a lake was carefully stocked with known numbers of fingerling walleyes, the number of survivors estimated to be present at a later date obviously cannot exceed the number stocked and should decline progressively due to natural and fishing mortality. Likewise, the number of fish in each year class must progressively decline each year due to mortality.

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Bias can be introduced by either uncontrollable fish behavior or by failure to use the best procedures. Bias due to fish behavior includes "trap-happy" or "trap-shy" tendencies, territoriality or other distribution tendencies, and any other behavior which can cause non-random samples. Bias can also be introduced by failure to distribute marked fish fairly, sample the whole lake, move nets frequently, correct for loss of marked fish, stratify by species and size to compensate for gear selectivity, or any other procedural flaw which can cause non-random samples. Sometimes, behavior and distribution bias can be compensated for by using one type of gear to collect fish for marking and another for recapture. This works to the extent the gears have different types of bias, but it requires that the target species and size be vulnerable to both types of gear and that a large proportion of the population be handled to obtain tight confidence limits. Usually, random statistical errors are so large they preclude the ability to confirm the presence of bias errors.

At best, our estimates are approximations of numbers of fish present. The most trustworthy statistic is the number of fish actually handled during the procedure; it provides the minimum population size.

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Example 8.1–Jewett Lake is a small (12.9 acres), shallow (16 feet), landlocked lake containing only bluegill, yellow perch, and walleye. Population estimates for each species and size were made for many years during a study of population and community dynamics. In the fall and spring of the year, when water temperatures were 55-65^{o}F, large fish were readily collected with regular trap nets (RTN), and medium and small fish were sampled with small-mesh trap nets (STN) and electrofishing (EF). At such cool water temperatures, few fish were harmed by handling. Catches were usually much higher on the first day of netting, suggesting that marked fish may become less active and less vulnerable for a couple of days. Consequently, the lake was sampled the last week in September and the second week in October with a combination plan. If catches were large, a Chapman estimate was calculated; if relatively few fish were marked or recaptured, a Schmacher-Eschmeyer estimate was made. In the first week of sampling, fish were marked by clipping the top lobe of the caudal fin; during the second week of sampling fish were marked by clipping the bottom lobe of the caudal fin. A better procedure statistically would have been to give a unique fin clip for each of the three types of fishing gear; however, six different clips would have been required and the fish would have been unduly stressed. The following table was set up and filled out daily for each species and inch group to aid in tracking progress towards obtaining enough recaptures and for computing population estimates and CPE:

		6-inch bluegill						**7-inch bluegill**		
Date	Gear	M	U	R_t	R_b	R_{tb}	Notes	M	U	etc.
9/21	3RTN		55				1 U dead	etc.		
	2STN		13							
	2 hr ES		39							
	Total	0	107							
9/22	3RTN		23	2						
	2STN		8	0						
	2 hr ES		26	1						
	Total	106	57	3						
9/23	3RTN		18	3						
	2STN		11	2						
	1 hr ES		5	0						
	Total	162	34	5			1 R_t DOB			
End 1st week		196								
10/6	3RTN		16	2						
	2STN		2							
	3 hr ES		32	4						
	Total	196	50	6						
10/7	3RTN		20	2	2					
	2STN		4							
	2 hr ES		7	1		1				
	Total	246	31	3	2	1				
Combined 10/6-7			81	9	2	1				
Min. population		277								

Chapman-Petersen Method

$$N = \frac{(196+1)(81+9+1)}{9+1} = 1{,}793$$

$$\text{Variance of } N = \frac{(196+1)^2(81+9+1)(81+9-9)}{(9+1)^2(9+2)} = 285{,}740$$

$$\text{Standard error of } N = \sqrt{285{,}740} = 534.5$$

Symmetrical 95% limits = 1,793 ± 2(534.5) = 1,793 ±1,069 = 724 to 2,862 fish

Asymmetrical limits:

Poisson limits for R=9 are 4.0 and 17.1 (Table 8.1).

Substituting those for R in the N formula above gives 95% limits of 990 to 3,585 fish.

Schumacher-Eschmeyer method

Basic calculations: $\sum RM = 3{,}780 \quad \sum CM^2 = 6{,}088{,}064 \quad \sum R^2/C = 2.4068 \quad m = 5$

$$N = \frac{6{,}088{,}064}{3{,}780} = 1{,}610$$

$$s^2 = \frac{2.4068 - \left[3{,}780^2/6{,}088{,}064\right]}{5-1} = 0.0149757$$

$$\text{Variance of } N = 1{,}610^2\left[\frac{1{,}610(0.0149757^2)}{3{,}780}\right] = 16{,}534$$

Standard error of N = 129

Symmetrical 95% limits of N = ±2.776(129) = ±358 = 1,252 to 1,968

Asymmetrical limits:

$1/N$ = 1/1,610 = 0.0006209

$$\text{Variance of } 1/N = \frac{0.0149757}{6{,}088{,}064} = 2.4598\text{E-09}$$

95% limits of $1/N = \pm 2.776\sqrt{2.459E-09}$ = ±0.00013768 = 0.0004832 to 0.0007586

Reciprocals: Lower 95% = 1/0.000758 = 1,318; Upper 95% = 1/0.000483 = 2,070

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Explanation of Example 8.1 and calculations

On 9/20, nets were set. On 9/21, net lifting, electrofishing, and marking of top tails began. On 9/21, one fish in RTN was in poor condition and was not marked and released; therefore, M available for 9/22 was adjusted to 107-1=106. On 9/22, top tail fish were officially available for recapture. On 9/23, one R_t was found dead on the beach and subtracted from M available for that day (106+57-1=162). On 9/23, nets were pulled, and by the end of the 1st week total M_t available was 196. A rest period occurred 9/23 to 10/4 to allow mixing and resumption of normal behavior. On 10/5, nets were reset. On 10/6, net lifting, electrofishing, and marking of bottom tails began. On 10/7, it first became possible to collect R_b and R_{tb} clips as well as the original R_t clips. Unmarked fish caught on the 10/7 were not marked because it was anticipated that would be the last day of sampling.

For the Chapman estimate, a spreadsheet was setup for the computation, where M = marked fish available after the first week (196); R = total recaptures of those fish during the second week (R_t=9); U = total unmarked fish in the second week (81), and $C = U+R$ (=90). Note that R_b and R_{tb} are not used because those fish contributed to the ratio the first time they were caught during the second week. Student's t value for 90-1 degrees of freedom is essentially 2.0 (Table 8.1).

For the Schumacher-Eschmeyer estimate, a spreadsheet was setup to compute for each strata (combination of species and size) the intermediate statistics of RM, CM^2, and R^2/C for each day and their sums. Then the population estimates and both symmetrical and asymmetrical limits were computed. Note that M refers to the number of marked fish available at the **start** of the day's sampling – it does not include fish marked and released that day – and for this estimate includes all three types of fin clips (total of 246 by start of 10/7). Likewise, recaptures of all three fin clips count as recaptures (total of 20 for the entire period). Note that m, the number of days catches were made, was 5, and Student's t value for 5-1 degrees of freedom is 2.776 (Table 8.1).

For either formula, if recaptures for this strata (6-inch bluegills) had been less than 4, then data from adjacent strata, such as 5-inch bluegills, should have been pooled and a combined estimate calculated. Then, if necessary, the combined estimate could be apportioned between 5- and 6-inch groups according to catches by the least bias gear (probably electrofishing in this study).

For either formula, if estimates from two or more strata are to be combined, the symmetrical variances are to be used. For example, adding an estimate of 800 with a variance of 120,000 to the Jewett example yields for the Chapman method a combined estimate of 2,593 (800+1,793), a combined variance of 405,740 (120,000+285,740), and a combined 95% confidence limit of ±1274 (2 times square root of 405,740); and for the Schumacher-Eschmeyer method a combined estimate of 2,410 (800+1,610), a combined variance of 136,534 (120,000+16,534), and a combined 95% confidence limit of ±739 (2 times square root of 136,534).

Multiple-pass depletion methods were also applied to the Jewett Lake example for comparison (Chapter 7, formula 7). Only unmarked daily catches in trap nets were used. The resulting estimate was 202 bluegills, which was far too low since the population was known to exceed 277 bluegills. The plot of catch rate per sample had considerable scatter around the regression line, indicating the requirement of constant daily catchability was not met. Therefore, the depletion method was not a good choice for the Jewett Lake data set.

Which of the mark-and-recapture results are the best? We know for sure that at least 277 6-inch bluegill were present because that many different fish were handled. The population estimates differ by 11% (1,610 versus 1,792 fish), with the Schumacher-Eschmeyer result being lower (as usual). The Schumacher-Eschmeyer result has tighter confidence limits (asymmetrical: 1,318 to 2,069, a range of 751 fish; symmetrical: 1,252 to 1,968, a range of 716 fish) than the Chapman-Petersen (Poisson: 990 to 3,585, a range of 2,595 fish; formula (2): 724 to 2,862, a range of 2,138 fish) because more recaptures are utilized (20 versus 9). On the other hand, the multiple census method has a greater potential for bias if marked fish did not resume random behavior in 1 day. Some readers may find it disconcerting that the two methods for calculating confidence limits produce such different results. Keep in mind that both point estimates and their error bounds are

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but approximations. The choice of which numbers and methods to accept may be influenced also by (a) the need to statistically combine estimates for other strata; (b) the desirability of maintaining consistent methodology across strata and years; and (c) evidence for bias as indicated by unreasonable trends in year class estimates across successive years.

Table 8.1.–Poisson distribution of lower and upper 95% confidence coefficients[a] for number of recaptures (*R*), and Student's t values (∝=0.05) for number of degrees of freedom (df).

Poisson distribution						Student's *t* value	
R	Lower	Upper	*R*	Lower	Upper	df	t_{95}
0	0.0	3.7	26	17.0	38.0	1	12.706
1	0.1	5.6	27	17.8	39.2	2	4.303
2	0.2	7.2	28	18.6	40.4	3	3.182
3	0.6	8.8	29	19.4	41.6	4	2.776
4	1.0	10.2	30	20.2	42.8	5	2.571
5	1.6	11.7	31	21.0	44.0	6	2.447
6	2.2	13.1	32	21.8	45.1	7	2.365
7	2.8	14.4	33	22.7	46.3	8	2.306
8	3.4	15.8	34	23.5	47.5	9	2.262
9	4.0	17.1	35	24.3	48.7	10	2.228
10	4.7	18.4	36	25.1	49.8	11	2.201
11	5.4	19.7	37	26.0	51.0	12	2.179
12	6.2	21.0	38	26.8	52.2	13	2.160
13	6.9	22.3	39	27.7	53.3	14	2.145
14	7.7	23.5	40	28.6	54.5	15	2.131
15	8.4	24.8	41	29.4	55.6	16	2.120
16	9.2	26.0	42	30.3	56.8	17	2.110
17	9.9	27.2	43	31.1	57.9	18	2.101
18	10.7	28.4	44	32.0	59.0	19	2.093
19	11.5	29.6	45	32.8	60.2	20	2.086
20	12.2	30.8	46	33.6	61.3	21	2.080
21	13.0	32.0	47	34.5	62.5	22	2.074
22	13.8	33.2	48	35.3	63.6	23	2.069
23	14.6	34.4	49	36.1	64.8	24	2.064
24	15.4	35.6	50	37.0	65.9	60	2.000
25	16.2	36.8				∞	1.960

[a] Substitute the coefficients for *R* in formula (1). For larger values of *R*, use the following equation (Ricker 1975) for 95% limit coefficients: $R + 1.92 \pm 1.96\sqrt{R + 1.0}$.

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8.3 References

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Written 3/1947 by W .R. Crowe.
Revised 3/1976 by G. P. Cooper and J. R. Ryckman.
Rewritten 8/1998 by J. C. Schneider

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Manual of Fisheries Survey Methods II: with periodic updates

Chapter 9: Age and Growth Methods and State Averages

James C. Schneider, Percy W. Laarman, and Howard Gowing

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Chapter 9: Age and Growth Methods and State Averages

James C. Schneider, Percy W. Laarman, and Howard Gowing

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Scales of fishes are remarkable structures. Much information can be obtained about the growth history and longevity of individual fish by close examination of their scales or other bony structures. On the population level, also, age and growth is an excellent index to well being.

Scales are bony structures that grow shingle-like from pockets within the skin. Scales are covered with a very thin, outer layer of skin called the epidermis. Among Michigan fishes there are basically two kinds of scales: the ctenoid scale found on spiny-rayed fishes such as bass, sunfish, perch, and walleye; and the cycloid scale found on soft-rayed fishes such as trout, suckers, and northern pike (Figure 9.1). The ctenoid scale has small, sharp projections (ctenii) which give a rough texture to spiny-rayed fish. The cycloid scale lacks ctenii; thus soft-rayed fish tend to be smooth textured.

Scales start to form when a fish is about an inch long. The number of scales covering the body remains constant throughout life, and in general, scale growth is proportional to fish growth. As the scale grows, circuli (ridges) form on the edge. Circuli form a concentric pattern over the course of a year that is related to environmental and growth conditions. During the colder months, when fish eat little and growth ceases, the circuli are crowded together and may be incomplete. In the spring, when feeding and growth resume, new circuli form that are spaced further apart. Also, the first new circuli in the spring cut across the incomplete circuli (Figure 9.1). Annuli (true year marks) are characterized by crowded ridges and consistent "cutting across" at both sides of the scale.

Unusual events may cause false annuli to form on scales. Examples are extreme water temperatures, injury, or any other stress that causes growth to stop for a period of time during the normal growing season. False annuli may be very similar in appearance to true annuli, but often "cut across" on only one side of the scale or are not evident on all scales from a particular fish.

Old fish are often under-aged from scales. As a fish becomes older, growth rate slows down and annuli become closer together. The result is that it is difficult (sometimes impossible) to recognize the most recent annuli on very old fish scales.

Typical and atypical scale patterns, and aging difficulties, are illustrated in a report by Schneider (2000). That report contains examples of known-age scales of walleye, yellow perch, and northern pike

Some fish (such as bullheads and catfish) have no scales, and other species (such as bowfin) have no recognizable pattern on their scales. For those fish, a cross-section of a spine or a vertebra should be examined for age rings similar to rings on trees. Ear bones (otoliths), spines, and vertebrae are also more reliable than scales for aging walleye, perch, bass, sucker, pike, salmon, and burbot. In addition, cleithra have been recommended for aging musky and northern pike, and opercula bones for aging yellow perch.

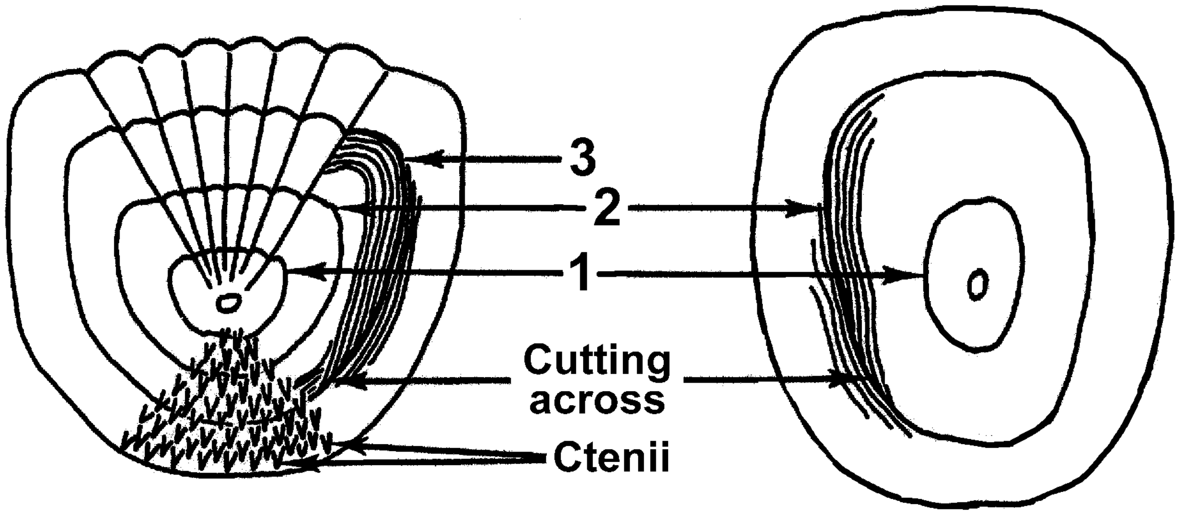

Figure 9.1–Ctenoid scale of bluegill (left) and cycloid scale of sucker (right). Annuli are indicated by numerals.

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9.1 Procedures

9.1.1 Recording data on scale envelopes

Record accurate and complete information on the scale envelope. Give the following information:

Species–Give common name of fish.

Locality–Give the name of the lake or stream from which fish was taken.

County–The name of the county in which lake or stream is located.

T. R. Sec–Give the Township, Range, and Section in which body of water is located. This is especially needed when two lakes with the same name occur in the same county.

Date–Date when fish was collected.

Length–Total length is defined as a straight-line measurement (not over the curve of the body) from the tip of the snout (with mouth closed) to the end of the caudal fin with the lobes squeezed together (Figure 9.2).

Weight–Total weight, accurately measured under good conditions.

Sex–Determine and record the sex when possible.

State of organs–This refers to sex organs. Record here whether the fish is immature or mature; and if mature, whether ripe or spent.

Gear–Record the method used in capturing the fish, such as gill net, trap net, seine, or angling.

Collector–Name of person who caught the fish.

9.1.2 Taking the scale sample

Age determination is easier if care is used when taking the scale sample. Scale samples should be taken from a definite area on the fish. The recommended location on spiny-rayed fishes is just below the lateral line and below the middle of the spiny dorsal fin (Figure 9.2). For most soft-rayed fishes the area between the lateral line and the dorsal fin is preferred; for trout the best spot is directly below the lateral line beneath the posterior end of the dorsal fin (Figure 9.3).

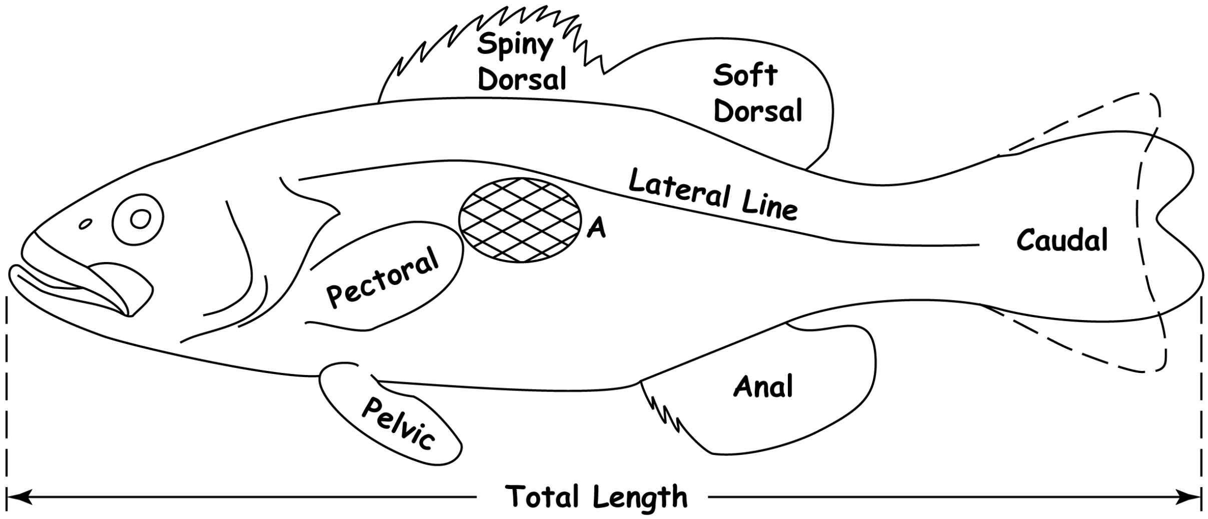

Figure 9.2–Area for taking scale samples from a spiny-rayed fish.

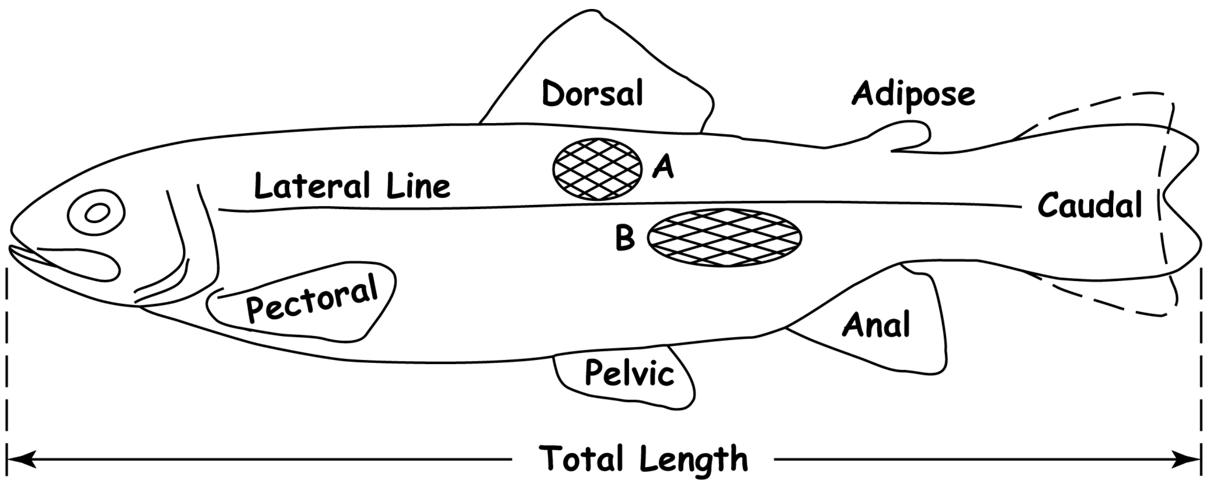

Figure 9.3–Areas for taking scale samples from most soft-rayed fish (A) or trout (B).

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About 10-20 scales should be taken from a fish. First, scrape mucous from the spot where scales are to be removed. This cleans the scales and makes processing easier. Then, remove scales with a knife blade and insert them into the envelope. Wipe the knife blade clean between samples to prevent cross contamination.

9.1.3 Making age determinations

To prepare scales for age determination, place four to six scales on a slide of clear plastic (vinyl or cellulose acetate, 0.5 mm thick) with sculptured side (side with ridges) down. Then, sandwich the slide with the scales between two more pieces of plastic and run through a roller press, using enough pressure to make a distinct impression of the scales on the plastic slide. Store the plastic slide with the scale impressions in the scale envelope from which the scales were taken. Only complete and normal scales can be used for age determinations. Abnormal or regenerated scales are often found on fish. When a fish loses a scale, it grows a replacement lacking circuli and annuli in the center. Consequently, the early part of the growth history is lost.

To make age determinations (i.e., to "read" the scale), the plastic impression is viewed through a microprojector or microfiche reader that magnifies the impression up to 90 times, as needed. A binocular microscope provides suitable magnification for counting year marks, but if the scales are to be measured, as is done in "back calculation", a microprojector is needed.

The age of a fish is determined by counting completed annuli (year marks) on the scale. Age is recorded on the scale envelope in Arabic numerals (use of roman numerals has been discontinued).

All fish are considered to have a birthday on January 1. Therefore, fish collected between January 1 and the time of annulus formation in spring or early summer are recorded as 1 year older than the number of visible annuli on the scale. The presence of this unseen (or virtual) annulus is recorded by adding 1 year to the number of visible annuli, and adding an asterisk to the numeral. To illustrate: a fish at the end of its second growing season, say in October, is designated as 1; the same fish the following February, prior to new growth, would be 2*; and 6 months later, after new scale growth, it is recorded as 2.

For anadromous salmonids, such as steelhead, there is a more complex system of counting annuli. First, the number of annuli during stream residence is counted, then the number of annuli during Great Lakes residency (usually obvious by faster growth pattern). The two numbers are separated by a decimal. Thus “1.2” indicates 1 year in the stream and 2 years in the Great Lakes. Scale characteristics may be used for identifying steelhead of wild and hatchery origin as well as aging (Seelbach and Whelan 1988).

9.1.4 Back calculation

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The back-calculation technique is useful for determining more precisely a fish's growth during each year of life prior to the sampling date. The results might reveal, for example, that a fish which is of average size for its age now, grew fast in certain earlier years and slow in other years. The technique is especially useful if no growth samples were taken prior to a management activity or if only a few fish were sampled afterwards.

There are problems to be considered, however. Back-calculated lengths at age 1 and age 2 are imprecise if small fish were not sampled adequately. Generally, it is not wise to extrapolate the fish length vs. scale radius relationship beyond the sizes actually sampled. Another problem is "Lee's phenomenon". This is the tendency for the computed lengths of the older fish in their early years of life to be systematically lower than those of younger fish at the same age. That is, it *appears* that the slower-growing fish live the longest. This error can be minimized by sampling a wide range of fish sizes.

The procedure for back calculation is as follows:

1. Obtain scale samples from the same area of each fish. Ideally, use key scales (identical area) because they have the same shape.
2. While projecting the scale and counting annuli, measure with a ruler the radius of the scale and the distance to each annulus. Select a standard axis for measuring along (such as the axis from the focus to the middle of the anterior field) and use the same magnification for all samples in the collection.
3. Compute the relationship between fish length (L) and scale radius (S). This linear equation will usually give a satisfactory fit:

$$L = a + bS$$

4. Compute the length at each annulus (L_n) from the distance from the focus to that annulus (S_n). The following equation is appropriate to use with the equation just given:

$$L_n = \frac{S_n}{S}(L - a) + a$$

The process may be automated by projecting the scale image onto a digitizing pad or video monitor linked to a computer and "marking" each annulus with an electronic mouse or stylus. Available software will then perform all the computations.

The intercept (a), also called the correction factor, is a very important parameter that is difficult to estimate. It may be thought of as the length at which scales begin to form, but in a practical vein it just helps make the data fit mathematically. The intercept should be determined for each species and each population. Normal values of (a) are approximately 1 inch for centrarchids and percids; unrealistically high values often result from samples containing only large fish. Back calculation with a high correction factor causes inflated estimates of the lengths of age-1 and age-2 fish. When samples are inadequate, or empirical estimates of (a) are unrealistic, the following standard intercepts are recommended (Carlander 1982): 10 mm (0.4 in) for green sunfish; 20 mm (0.8 in) for bluegill, largemouth bass, and warmouth; 25 mm (1.0 in) for pumpkinseed and rock bass; 30 mm (1.2 in) for yellow perch; 35 mm (1.4 in) for smallmouth bass, black crappie, and white crappie; and 55 mm (2.2 in) for walleye.

9.2 Michigan average growth summaries

Statewide average growth rates for many species of fish in Michigan have been determined from many years of collecting data in Michigan (Tables 9.1-9.3). More than 122,000 fish, representing 25 species, were used to calculate average length at age. The basic statistical unit used in determining the averages for each species was the mean length for each age group in each collection from each body of water; each mean was given equal weight in determining the final growth rate averages.

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Sufficient data were available to compute average lengths attained at various months of the growing season for eight species of warmwater fish (Laarman 1963a). These data were plotted on graph paper and a smoothed stair-step curve was fit by eye which reflected the known seasonal growth pattern (virtually all growth in length occurs between mid-May and mid-September). Similar curves were developed for walleye (Schneider 1978), tiger musky, and redear sunfish (data provided by Gary Towns). Comparable curves were developed for stream-dwelling brook, rainbow, and brown trout by graphing annual averages, smoothing them with straight lines, and then superimposing the seasonal growth pattern (determined by Cooper in 1953 for age-0 and age-I brook trout in three streams). In 1996, averages were developed for lake-dwelling trout and lake herring by plotting seasonal lengths at age and fitting linear regressions because no seasonal growth pattern was evident. [Trout growth does retard in mid-winter; however, considerable growth occurs in late fall and early spring, when warmwater fish are inactive.] In 1999, the statewide average lengths for age-1 bluegill and pumpkinseed were reduced based on better information obtained from well-studied lakes. Also in 1999, a tentative annual average for channel catfish was developed based on spine samples from four populations (there are relatively few channel catfish populations in Michigan). For the most important species, Tables 9.1 and 9.2 contain the estimated average lengths at four-time periods during each age. For other species, refer to Table 9.3 for annual averages.

For simplicity, the lengths in Tables 9.1-9.3 will be taken as representative of waters throughout the state. Actually, there are regional differences in time of annulus formation, length of growing season, and growth rates (Beckman 1943; Laarman 1963b). Surprisingly, the average growth of bluegill and largemouth bass is better in the Upper Peninsula than in the southern Lower Peninsula. This indicates growth is more dependent on population density and relative food availability than on length of growing season. An additional problem with any average figure is that the time of annulus formation is not fixed but varies from year to year, depending upon spring weather. Even with these limitations, the lengths in Tables 9.1-9.3 are very useful and are to serve as standards for comparing the growth of fish populations in Michigan.

9.3 Growth index

A growth index has been devised for expressing the degree to which the growth of a species in a given body of water differs from the statewide average. The index is calculated as follows:

1. Use only those age groups represented by five or more fish.
2. For each age group, determine the deviation (difference) between the observed average length and the statewide seasonal average length.
3. Add the deviations and divide the sum by the number of age groups.

A growth index of 0.0 means that the sampled population is growing at exactly the state average rate for the species in question. An index of +1.0 inch means that the sampled population is growing 1.0 inch faster than average. In the following illustration, the bluegills sampled at Example Lake in June were growing, overall, 0.2 inch below the statewide average. The age group deviations ranged from +0.8 to -0.7; the growth index was -0.2 inches.

	Average length of each age group (Number of fish in parentheses)					
Species	**1**	**2**	**3**	**4**	**5**	**6**
Bluegill, Example Lake	3.2 (15)	4.5 (3)	5.2 (6)	5.5 (17)	6.4 (15)	7.0 (5)
State average	2.4	4.2	5.3	6.2	6.9	7.4
Deviation	+0.8	–	-0.1	-0.7	-0.5	-0.4

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$$\textit{Growth index} = \frac{0.8 - 0.1 - 0.7 - 0.5 - 0.4}{5} = \frac{-0.9}{5} = -0.2\ \textit{inch}$$

As a rule of thumb, satisfactory growth indices are in the range of +0.5 to -0.5 inch for panfish, and +1.0 to -1.0 inch for game fish. Thus, bluegills in Example Lake were growing rather slowly (-0.2 inch), but satisfactorily. Panfish populations with growth rates less than -1.0 inch are generally stunted and dominated by small-size fish.

Table 9.1.–State average total length (inches) by age and month for important Michigan fishes.

Age	Month	Bluegill	Pumpkin-seed	Redear sunfish	Rock bass	Black crappie	Yellow perch	Lake herring
0	Jan-May							
	Jun-Jul							
	Aug-Sep							
	Oct-Dec	1.8	1.8	1.9	2.4	4.2	3.3	7.6
1	Jan-May	1.8	1.8	1.9	2.4	4.2	3.3	7.9
	Jun-Jul	2.4	2.4	2.8	3.0	4.8	4.0	8.2
	Aug-Sep	3.3	3.3	3.6	3.5	5.6	5.0	8.4
	Oct-Dec	3.8	3.8	4.4	3.9	6.0	5.2	8.7
2	Jan-May	3.8	3.8	4.4	3.9	6.0	5.2	8.9
	Jun-Jul	4.2	4.2	5.0	4.3	6.5	5.7	9.2
	Aug-Sep	4.7	4.6	5.6	4.8	7.2	6.3	9.5
	Oct-Dec	5.0	4.9	6.2	5.1	7.5	6.5	9.7
3	Jan-May	5.0	4.9	6.2	5.1	7.5	6.5	10.0
	Jun-Jul	5.3	5.2	6.9	5.4	7.9	6.8	10.3
	Aug-Sep	5.8	5.4	7.4	5.9	8.4	7.2	10.5
	Oct-Dec	5.9	5.6	7.6	6.1	8.6	7.5	10.8
4	Jan-May	5.9	5.6	7.6	6.1	8.6	7.5	11.0
	Jun-Jul	6.2	5.8	8.0	6.4	8.9	7.8	11.3
	Aug-Sep	6.6	6.0	8.3	6.7	9.2	8.2	11.6
	Oct-Dec	6.7	6.2	8.7	6.9	9.4	8.5	11.8
5	Jan-May	6.7	6.2	8.7	6.9	9.4	8.5	12.1
	Jun-Jul	6.9	6.3	9.0	7.2	9.7	8.7	12.4
	Aug-Sep	7.1	6.5	9.1	7.6	10.0	9.2	12.6
	Oct-Dec	7.3	6.6	9.6	7.8	10.2	9.4	12.9
6	Jan-May	7.3	6.6	9.6	7.8	10.2	9.4	13.1
	Jun-Jul	7.4	6.8	9.8	8.1	10.4	9.7	13.4
	Aug-Sep	7.6	7.0	10.1	8.4	10.7	10.1	13.7
	Oct-Dec	7.8	7.1	10.3	8.6	10.8	10.3	13.9
7	Jan-May	7.8	7.1	10.3	8.6	10.8	10.3	14.2
	Jun-Jul	8.0	7.2	10.5	8.8	11.1	10.5	14.4
	Aug-Sep	8.1	7.4	10.7	9.2	11.3	10.9	14.7
	Oct-Dec	8.2	7.5	10.8	9.3	11.4	11.1	15.0
8	Jan-May	8.2	7.5	10.8	9.3	11.4	11.1	15.2
	Jun-Jul	8.4			9.4	11.6	11.3	15.5
	Aug-Sep	8.5			9.6	11.8	11.5	15.8
	Oct-Dec	8.6			9.8	11.9	11.6	16.0
9	Jan-May	8.6			9.8	11.9	11.6	16.3
	Jun-Jul	8.7					11.7	
	Aug-Sep	8.8					11.9	
	Oct-Dec	8.9					12.1	
10	Jan-May	8.9					12.1	

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Table 9.1.–Continued:

Age	Month	Largemouth bass	Smallmouth bass	Walleye	Northern pike	Tiger musky
0	Jan-May					
	Jun-Jul					
	Aug-Sep					
	Oct-Dec	4.2	3.8	7.1	11.7	12.5
1	Jan-May	4.2	3.8	7.1	11.7	12.5
	Jun-Jul	5.4	5.5	8.2	14.5	14.7
	Aug-Sep	6.9	7.0	9.8	16.6	19.5
	Oct-Dec	7.1	7.5	10.4	17.7	22.0
2	Jan-May	7.1	7.5	10.4	17.7	22.0
	Jun-Jul	8.7	8.8	11.4	19.0	23.3
	Aug-Sep	9.3	10.1	13.3	20.1	25.5
	Oct-Dec	9.4	10.8	13.9	20.8	27.0
3	Jan-May	9.4	10.8	13.9	20.8	27.0
	Jun-Jul	10.6	11.1	14.4	21.8	28.0
	Aug-Sep	11.2	12.0	15.2	22.8	29.7
	Oct-Dec	11.6	12.6	15.8	23.4	30.7
4	Jan-May	11.6	12.6	15.8	23.4	30.7
	Jun-Jul	12.0	13.0	16.2	24.2	31.5
	Aug-Sep	12.7	14.0	17.2	25.0	33.0
	Oct-Dec	13.2	14.4	17.6	25.5	33.7
5	Jan-May	13.2	14.4	17.6	25.5	33.7
	Jun-Jul	13.7	14.7	18.0	26.1	34.2
	Aug-Sep	14.4	15.2	18.6	26.9	35.2
	Oct-Dec	14.7	15.3	19.2	27.3	35.8
6	Jan-May	14.7	15.3	19.2	27.3	
	Jun-Jul	15.0	15.5	19.6	27.8	
	Aug-Sep	16.0	16.0	20.3	28.8	
	Oct-Dec	16.3	16.3	20.6	29.3	
7	Jan-May	16.3	16.3	20.6	29.3	
	Jun-Jul	16.7	16.6	20.8	30.0	
	Aug-Sep	17.1	17.1	21.3	30.7	
	Oct-Dec	17.4	17.3	21.6	31.2	
8	Jan-May	17.4	17.3	21.6	31.2	
	Jun-Jul	17.6	17.4	21.7		
	Aug-Sep	18.0	17.8	22.1		
	Oct-Dec	18.3	18.1	22.4		
9	Jan-May	18.3	18.1	22.4		
	Jun-Jul	18.6	18.3	22.6		
	Aug-Sep	19.1	18.7	22.9		
	Oct-Dec	19.3	18.9	23.1		
10	Jan-May	19.3	18.9	23.1		

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Table 9.1.–Continued: State average total length (inches) by age and month for trout in lakes and streams.

		Trout in lakes[a]					Wild trout in streams		
Age	Month	Brook	Brown	Rainbow	Lake	Splake	Brown	Brook	Rainbow
0	Jan-May						1.0	1.0	1.0
	Jun-Jul						2.5	2.3	2.0
	Aug-Sep						3.2	2.9	2.7
	Oct-Dec						4.0	3.6	3.4
1	Jan-May	6.8	8.4	8.2	5.8	9.7	4.1	3.8	3.7
	Jun-Jul	7.5	9.3	9.0	6.8	10.3	5.8	5.3	5.2
	Aug-Sep	8.1	10.1	9.7	7.9	10.9	6.2	5.7	5.7
	Oct-Dec	8.8	11.0	10.5	8.9	11.5	6.9	6.4	6.5
2	Jan-May	9.4	11.9	11.2	9.9	12.1	7.2	6.6	6.7
	Jun-Jul	10.0	12.7	12.0	10.9	12.6	8.8	8.1	8.0
	Aug-Sep	10.7	13.6	12.8	11.9	13.2	9.2	8.5	8.7
	Oct-Dec	11.3	14.4	13.5	12.8	13.8	9.9	9.2	9.5
3	Jan-May	12.0	15.3	14.3	13.7	14.4	10.2	9.4	9.8
	Jun-Jul	12.6	16.1	15.0	14.6	15.0	11.8	10.9	11.0
	Aug-Sep	13.3	17.0	15.8	15.4	15.6	12.2	11.3	11.7
	Oct-Dec	13.9	17.8	16.5	16.3	16.1	12.9	12.0	12.4
4	Jan-May	14.6	18.7	17.3	17.1	16.7	13.2	12.2	12.7
	Jun-Jul	15.2	19.5	18.0	17.9	17.3	14.8	13.7	14.0
	Aug-Sep	15.9	20.4	18.8	18.7	17.9	15.2	14.1	14.7
	Oct-Dec	16.5	21.2	19.5	19.4	18.4	15.9	14.8	15.4
5	Jan-May	17.2	22.1	20.3	20.1	19.0	16.2	15.0	
	Jun-Jul	17.8	23.0	21.0	20.8	19.6	17.8	16.5	
	Aug-Sep	18.4	23.8	21.8	21.5	20.2	18.2	16.9	
	Oct-Dec	19.1	24.6	22.6	22.2	20.8	18.9	17.6	
6	Jan-May	19.7	25.5	23.4	22.8	21.4	19.2		
	Jun-Jul		26.4		23.4	21.9	20.8		
	Aug-Sep		27.2		24.0	22.5	21.2		
	Oct-Dec		28.1		24.6	23.1	21.9		
7	Jan-May		28.9		25.1	23.7	22.2		
	Jun-Jul				25.6	24.3	23.8		
	Aug-Sep				26.2	24.8	24.2		
	Oct-Dec				26.6	25.4	24.9		
8	Jan-May				27.1	26.0	25.2		
	Jun-Jul				27.5	26.6	26.8		
	Aug-Sep				27.9	27.2	27.2		
	Oct-Dec				28.3	27.8	27.9		
9	Jan-May				28.7	28.3			
	Jun-Jul				29.0				
	Aug-Sep				29.3				
	Oct-Dec				29.6				
10	Jan-May				29.9				

[a] There is much variation in lake data due to length at stocking and strain, as well as growing conditions. For example, data for brook trout includes the old "domestic" and the newer Assinica and Temiscamie strains.

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Table 9.2.–State average total length (millimeters) by age and month for important Michigan fishes.

Age	Month	Blue-gill	Yellow perch	Pump-kin-seed	Redear sunfish	Rock bass	Black crappie	Wall-eye	Small-mouth bass	Large-mouth bass	Northern pike	Tiger musky	Lake herring
0	Jan-May												
	Jun-Jul												
	Aug-Sep												
	Oct-Dec	61	84	61	48	61	107	180	97	107	297	318	194
1	Jan-May	61	84	61	48	61	107	180	97	107	297	318	201
	Jun-Jul	76	102	71	71	76	122	208	140	137	368	373	208
	Aug-Sep	89	127	88	91	89	142	250	178	175	422	495	214
	Oct-Dec	97	133	97	112	99	152	264	191	180	450	559	221
2	Jan-May	97	133	97	112	99	152	264	191	180	450	559	228
	Jun-Jul	107	145	105	127	109	165	292	224	221	483	592	234
	Aug-Sep	119	160	116	142	122	183	338	257	236	511	648	241
	Oct-Dec	127	165	124	157	130	191	353	274	239	528	686	247
3	Jan-May	127	165	124	157	130	191	353	274	239	528	686	254
	Jun-Jul	135	165	131	175	137	201	366	282	269	554	711	261
	Aug-Sep	147	183	137	188	150	213	386	305	284	579	754	267
	Oct-Dec	150	191	142	193	155	218	401	320	295	594	780	274
4	Jan-May	150	191	142	193	155	218	401	320	295	594	780	280
	Jun-Jul	157	198	147	203	163	226	411	330	305	615	800	287
	Aug-Sep	166	208	152	211	170	234	437	356	323	635	838	294
	Oct-Dec	170	216	157	221	175	240	447	366	335	648	856	300
5	Jan-May	170	216	157	221	175	240	447	366	335	648	856	307
	Jun-Jul	175	221	160	229	183	246	457	373	348	663	869	314
	Aug-Sep	180	234	165	231	193	254	472	386	366	683	894	321
	Oct-Dec	185	240	170	244	198	259	488	389	373	693	909	327
6	Jan-May	185	240	170	244	198	259	488	389	373	693		334
	Jun-Jul	189	246	173	249	206	265	498	394	381	706		340
	Aug-Sep	193	257	178	256	213	272	516	406	406	732		347
	Oct-Dec	198	262	180	262	217	276	523	414	414	744		354
7	Jan-May	198	262	180	262	217	276	523	414	414	744		360
	Jun-Jul	203	267	183	267	224	282	528	422	424	762		367
	Aug-Sep	206	277	188	272	232	287	541	434	434	780		374
	Oct-Dec	208	282	191	274	236	290	549	439	441	792		380
8	Jan-May	208	282	191	274	236	290	549	439	441	792		387
	Jun-Jul	212	287			240	295	551	442	446			394
	Aug-Sep	216	292			244	300	561	452	457			400
	Oct-Dec	218	295			250	302	569	460	466			406
9	Jan-May	218	295			250	302	569	460	466			414
	Jun-Jul	221	297					574	465	472			
	Aug-Sep	224	302					582	475	485			
	Oct-Dec	226	307					586	480	491			
10	Jan-May	226	307					586	480	491			

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Table 9.2.–Continued: State average total length (millimeters) by age and month for trout in lakes and streams.

		Trout in lakes[a]					Wild trout in streams		
Age	Month	Brook	Brown	Rainbow	Lake	Splake	Brown	Brook	Rainbow
0	Jan-May						24	24	24
	Jun-Jul						64	58	51
	Aug-Sep						81	74	69
	Oct-Dec						103	91	86
1	Jan-May	173	215	209	148	246	105	96	94
	Jun-Jul	189	236	228	174	262	148	136	132
	Aug-Sep	206	258	247	201	277	157	145	145
	Oct-Dec	222	279	266	227	292	175	162	165
2	Jan-May	239	301	285	252	306	182	168	170
	Jun-Jul	255	323	305	277	321	224	207	203
	Aug-Sep	272	344	324	301	336	234	216	221
	Oct-Dec	288	366	343	325	351	252	233	241
3	Jan-May	304	388	362	348	366	258	239	249
	Jun-Jul	321	409	382	370	380	300	278	279
	Aug-Sep	337	431	401	392	395	310	287	297
	Oct-Dec	354	453	420	414	410	329	304	315
4	Jan-May	370	474	439	434	424	335	310	323
	Jun-Jul	387	496	458	454	439	377	349	356
	Aug-Sep	403	518	477	474	454	386	358	373
	Oct-Dec	419	539	496	493	469	405	375	391
5	Jan-May	436	561	516	511	484	411	381	
	Jun-Jul	452	583	535	529	498	453	420	
	Aug-Sep	467	605	554	547	513	463	429	
	Oct-Dec	485	626	573	563	528	481	446	
6	Jan-May	500	648	594	579	543	487		
	Jun-Jul		671		595	557	529		
	Aug-Sep		691		610	572	539		
	Oct-Dec		714		624	587	557		
7	Jan-May		735		638	602	563		
	Jun-Jul				652	616	605		
	Aug-Sep				664	631	615		
	Oct-Dec				676	646	633		
8	Jan-May				688	661	640		
	Jun-Jul				699	675	681		
	Aug-Sep				709	690	691		
	Oct-Dec				719	705	710		
9	Jan-May				728	720			
	Jun-Jul				737				
	Aug-Sep				745				
	Oct-Dec				753				
10	Jan-May				759				

[a] There is large variation in lake data due to length at stocking and strain, as well as growing conditions. For example, data for brook trout includes the old "domestic" and Assinica and Temiscamie strains.

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Table 9.3.–Average annual total length (inches and mm), at age, for Michigan fishes lacking established seasonal averages.[a]

Species	Age group 0	1	2	3	4	5	6	7	8	9	10
Muskellunge	6.8	15.7	19.9	25.4	31.9	34.7	36.8	39.2	41.7	45.3	48.7
	173	399	505	645	810	881	935	996	1,059	1,151	1,237
Channel catfish		6.5	11.2	13.6	15.8	17.7	19.3	20.6	22.0	23.2	23.8
		165	284	345	401	450	490	523	559	589	605
Grass pickerel	3.1	7.8	9.5	9.6	10.2	10.4	10.9				
	79	198	241	244	259	264	277				
Warmouth		3.1	4.4	5.2	5.5	6.2	6.7	6.9	6.6	7.5	
		79	112	132	140	157	170	175	168	191	
Green sunfish		3.0	3.9	4.7	5.1	5.7	5.7				
		76	99	119	130	145	145				
Longear sunfish	1.5	2.5	3.2	3.8	4.0	4.3					
	38	64	81	97	102	109					
Rainbow smelt		5.3	6.9	7.7	8.1	8.8	9.6				
		135	175	196	206	224					
White sucker	3.5	8.6	12.0	14.3	16.3	16.9	18.1	18.1			
	89	218	305	363	414	429	460	460			

[a] Averages apply to the middle of the growing season, except for age-0 fish which were usually collected in the fall and channel catfish which were mostly collected in the spring. The channel catfish data represent a smoothed average based on only four populations and is a tentative statewide average. Fish become 1 year older on January 1. All data are from inland lakes and reservoirs.

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9.4 References

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Rewritten 1981 by J. C. Schneider, P. W. Laarman, and H. Gowing
Revised 7/1985, 11/1991, 2/1996, 1/2000 by J. C. Schneider

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Chapter 10: Mapping Lakes with Echo Sounders

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Chapter 10: Mapping Lakes with Echo Sounders

B. V. Hughes and C. M. Taube

[Editor's note: New equipment for lake mapping is being developed and may be ready for use in summer 2000. This new equipment consists of an electronic depth sounder, a real-time global positioning (GPS) instrument, and a lap-top computer. While transects of the lake are run, pairs of depth and position readings will be automatically taken and stored in the computer. Later, the data will be downloaded into specialized software that produces contour maps. The discussion below refers to instruments of the recording type that were common in the 1970s; however, the same basic concepts still apply.]

Echo sounders measure the interval of time required for a sound wave emitted by a transducer to strike the bottom of a lake and return to the transducer as an echo. Length of time depends on the depth of the water and the speed of sound through water, which is about 4,800 feet per second.

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Briefly, the chain of events in depth sounding are as follows. The electronic unit of the sounding instrument produces electrical impulses that are converted into sound waves by the transducer. These waves are projected downward from the surface of the water. Upon striking the bottom, the sound waves are reflected back to the transducer as echoes. The echo triggers an electronic signal that is displayed or recorded. A rapid succession of echoes results in a continuous line of recordings.

Echo sounders are of two general types: one type momentarily flashes the readings on a dial or screen; a second type records readings graphically on a paper chart. The latter instrument is the more practical for mapping lakes. Two distinct advantages of the chart recorder are that (1) it produces permanent recordings that can be easily checked for accuracy, and (2) depth recordings can be transcribed at a convenient time by virtue of their permanent character.

10.1 Equipment

The structure of graph-type echo sounders described here is based on the Bendix D R-10 Depth Recorder and the Raytheon Fathometer, Model D E-119. The recording unit is composed of an electronic section and a mechanical section. The components of the electronic section produce the electrical impulses and amplify the returning echoes to a voltage sufficient to mark the recording paper. A converter changes electrical current from a 6-volt storage battery to suitable voltages.

The recording unit of the sounder may be mounted on a board clamped to the gunnels near mid-ship. In mounting the transducer, it is important to avoid wakes and turbulence which create air bubbles that reflect sound waves and interfere with echo reception. To reduce turbulence, the transducer may have to be mounted in a small, streamlined wooden hull ("fish"). (Some newer model transducers are sufficiently streamlined.) The transducer can be installed several different ways. It may be mounted on the side of the boat, externally on the bottom of the boat, or internally inside the hull. Mounting on the side is recommended for mapping. Presently, the transducer unit is mounted on the side of the boat by means of a wood lever with spring tension.

Other equipment for mapping includes: boat; motor; battery charger; tracing of the shore outline of the lake prepared from an aerial photo; mounting board for the tracing; notebook for sounding-run records and other data; compass; cable for horizontal measurements; sounding cable equipped with a bottom sampler; pole (preferably bamboo) for shallow-water soundings; and either a dumpy level and stadia rod, or a chalk line and line level, for establishment of bench marks. A hammer and spikes are needed for setting up bench mark monuments.

10.2 Mapping procedure

The field crew consists of two people – one to navigate the boat and another to operate the sounder. In selecting sites for sounding transects, distinctive landmarks should be chosen which are recognizable both on the lake and on the work chart (i.e., an outline map of the lake prepared in advance from an aerial photo). These landmarks will be used to define the ends of transects. The procedure for starting a run depends on the type of sounder used. With an instrument of the Bendix D R-10 type, runs are started and ended at the 5-foot contour because this instrument does not give discernible readings in shallower depths. (The graph paper used with this instrument is calibrated in fathoms.) The starting point for each run on the 5-foot contour is located with the sounding pole, and the distance from shore is measured and recorded. Then the outboard motor and the echo sounder are started and a ***straight*** transect run is made at ***uniform speed*** toward the landmark on the opposite shore. At the opposite shore, the 5-foot contour is located again and its distance from shore is recorded. It is essential that boat speed be kept uniform so that, later, water depths can be transcribed accurately from sounder graph recordings to the work chart. This uniformity is required to make the length of the graph recording proportional to the actual distance of the run, and also to the distance on the work chart (the graph revolves at a uniform speed, therefore boat speed must also be uniform). Note that although boat speed during a transect run must be uniform, different (but uniform) speeds for other transect runs are permissible.

With a sounder of the Raytheon Fathometer D E-119 type, sounding may be done in depths as shallow as 2 or 3 feet. (The graph paper used with this instrument is calibrated in feet.) Distances to shore from the beginning and from the end of a run with the sounder are measured and recorded as with the Bendix D R-10.

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Numerous transects are run from shore to shore and each is numbered on the base map as well as on the sounder graph paper. Many runs may be recorded successively on one sheet of graph paper. If the curvature of the shoreline is fairly uniform, most (if not all) of the transects may be made parallel to each other. Changes in direction of transects may be necessary if the shoreline is marked with bays or other distinctive irregularities. The number of transect runs required for a given lake must be determined largely by the operator's judgment; basins that have numerous depressions or irregular bottoms require more soundings than basins with uniform declivity. Ordinarily, lakes with a surface area of approximately 100 acres require 20 to 30 transects. The operator should be sure to identify the lake by name and location on the graph paper. When the recordings for a given lake have been completed, remove that section of graph paper from the roll. Now and then it may be necessary to sound with a hand line to verify echo sounder readings. Take hand soundings when recordings are fuzzy due to dense vegetation or equipment malfunction.

Another use of the hand line is to determine bottom soil types. A sample of the bottom is retained in a cup at the base of the sounder weight. The number of samples required depends on extent of variation of soil types.

If corrections need to be made on the work outline (because changes have occurred in lake shape since the aerial photo was taken), make them while at the lake. At that time add shore features such as slopes, wooded areas, marsh, prominent buildings, etc. Establishment of a bench mark completes the field work.

Later, at a work table, transcribe depths from sounder graph recordings to the work chart. Simple proportion is used for locating sounding stations and plotting corresponding depths. Equal divisions are marked off on both the sounder chart recordings and the transect lines of the work chart. The depth at each division mark on the recording is determined and then transcribed to the corresponding mark on the transect line. The number of equal divisions may range from three to seven or more – the number depending on length of the transect and amount of depth data required for accurate contours.

After a sufficient number of depths have been recorded on all transect lines, depth contours can be drawn by eye.

10.2.1 Sounder operation instructions

Refer to the instrument's manual for detailed instructions on operation. The following comments are merely precautions and hints that will aid in operation, and apply specifically to the Bendix D R-10 Depth Recorder and the Raytheon D E-119 Fathometer. These suggestions may or may not apply to other sounders.

Adjustment of the power output regulates the uniformity and density of the recording trace. A strong vibration is required to register the surface of flocculent bottom in deep water. However, excess volume (sensitivity) may result in secondary reflections that are recorded on the graph at twice the actual depth. Also, excess power will burn the stylus point. The sensitivity (volume) control is adjusted at various depths so that there will be adequate power to produce a legible recording. If the stylus point has been burned, the stylus will need to be readjusted. A spare stylus, an additional vibrator, and a complete extra set of tubes should be carried in the spare parts kit.

A fully charged storage battery will supply sufficient power to operate the sounder for about 8 hours. It is advisable to carry an extra battery for use while the other one is being recharged.

Dense vegetation is apt to cause false readings. When such difficulty occurs, hand line or sounding pole will have to be employed. Where extensive areas are involved, mapping of the lake may need to be postponed until late fall or early spring when density of aquatic vegetation is minimal.

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10.3 Preparation of the work chart and tracing

Prior to taking soundings at the lake, the work chart is prepared from an aerial photo that shows the outline of the lake. Scales of aerial photos presently available are too small for lake mapping work; consequently, the work chart consists of an enlargement of the photo, made with plastic grid cards and map paper.

Grid cards are clear plastic sheets on which squares have been scratched. Commonly used grid cards have 2, 3, 4, 5, 6, 8, or 10 lines per linear inch (4, 9, 16, 25, 36, 64, or 100 sections per square inch). Outside dimensions of the grid cards range from 3 inches to 12 inches square. The size to be employed depends on the size of the photographic outline of the lake. The grid cards are subject to shrinkage and should be checked from time to time for accuracy. Usually, they need to be replaced every few months.

For example, suppose we wish to enlarge the aerial photographic outline of a lake by 5-fold for a work chart. First, tape a grid card with 5 divisions per inch over the aerial outline. Then, transcribe (by inspection) a section of shoreline that extends between successive division lines on the grid card onto a sheet of grid map paper. The ends of the transcribed section will be 1/5-inch apart under the grid card and 1-inch apart on the work chart. If the aerial photo has a true scale of 1 inch equals 1,760 feet, and the lake outline is being enlarged 5 times, the scale of the enlarged work chart becomes 1 inch equals 352 feet (1,760 ÷ 5).

After transcription of the shore outline, islands, roads, trails, and any other prominent lake-related features that appear on the photo are added to the work chart. If shoal areas are evident on the photo, their outlines should be shown on the work chart (with broken lines, for example) to provide orientation during field work.

Nearly always the given scale for the aerial photo needs to be corrected because of primary error or photo paper shrinkage. In such cases, the correct scale must be determined before the work chart can be prepared. Correction is made by comparing measured distance between landmarks on the aerial photo to their known distance (e.g., township lines). The points of dividers (or calipers) are placed on two landmarks on the photo whose distance apart is known, then divider spread is measured with an engineer's ruler. This measurement is then multiplied by the scale given on the aerial photo and compared to the known distance. A measurement span of about 3 inches should be used for comparison. Corrections are computed on the basis of 40 parts to the inch.

If the photo lacks landmarks for checking scale accuracy and computing a correction factor, then at the lake make on-the-spot measurements between landmarks that appear on the photo and compute a correction later.

Example 10.1- The scale given on an aerial photo is 1 inch equals 1,666 feet. One mile represented on the photo is found to contain 120 1/40-inch units.

$120 \div 40 = 3$ inches
$5{,}280 \div 3 = 1{,}760$ feet

Therefore, 1 inch on the photo now actually represents 1,760 feet rather than 1,666 feet.
If the lake shown on the photo is enlarged 4x on the work chart:

$1{,}760 \div 4 = 440$

The scale on the work chart is 1 inch = 440 feet.

Before the lake is sounded, the accuracy of the shoreline drawn on the work chart should be checked. This may be done while circling the lake in a boat. This precaution is advised because the shoreline may have changed since the aerial photo was taken, or it may have been misinterpreted from the aerial photo. If corrections are necessary, make them before sounding commences. Shoreline corrections can be made with a common alidade, compass, and measuring cable. Positions of roads, trails, streams, etc., should be checked also. Important features not apparent from the photograph should be added to the work chart while on-site.

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Final touches to the map are made later, in the laboratory. First, carefully examine the work chart for all required information. The agency (if different from the one preparing the new map) responsible for the aerial photo is given a credit line and the date of the photo is recorded. Then the map is prepared for photographic blow-up to a standard scale. Over the past 40 years (of lake mapping and drafting) most maps have been drawn on a chart paper with dimensions of 22 inches x 34 inches. For the final blow-up, select a scale that permits maximum enlargement of the lake outline ***and*** uses one of following scales (feet of lake dimension to inch of final map): 25, 50, 75, 100, 150, 200, 300, 400, 600, 800, 1000, or 1200. At the time of the 1976 revision of these instructions, lake maps were being drafted by the Engineering Division of the MDNR.

Written 2/1957 by B. V. Hughes and C. M. Taube
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Chapter 11: Instructions for Winter Lake Mapping

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Chapter 11: Instructions for Winter Lake Mapping

Clarence M. Taube

[Editor's note: This chapter records methods used by the Institute for Fisheries Research from approximately 1940 to 1970, when many public lakes in Michigan were mapped.]

This memo outlines the standards for lake maps and is intended to help the less experienced technician. It will bypass those techniques with which the crew leader should already be familiar.

Because the Fisheries Division does most mapping by the baseline-grid system on frozen lakes, the discussion will point toward this method, but comments generally apply to other methods.

11.1 Equipment

A check list of equipment and supplies is given in the following table. Although this list applies specifically to winter work, most of the items are also used in other methods.

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11.1.1 Check list of lake mapping equipment and supplies

Car	Shovel	Leveling rod
Sled and riggings	Ice creepers	Level, line
Ice drill	Yard stick (or 6-foot steel tape)	Chalk line
Augers (2, for drill)	Ruler (12-inch plain)	Spikes (8-in, for bench marks)
Oil can	Ruler (12-inch engineer 's triangular)	Hammer, heavy
Batteries, storage (2)	Stationery and postage	Cold chisel
Battery charger	Clipboard	Wrench, Allen
Battery cables (2 extra)	Map paper	Pliers
Battery strap	Gridded work sheets (8 1/2- x 11-in)	Axe
Hydrometer	Lake Mapping Record forms	Pencils, #3 or #4 lead
Ice spud	Road map (state)	Pencils, #2 lead
Plane table and tripod	Map book (county)	Erasers
Compass	Directory (Department personnel)	Paper clips
Alidade	Personnel forms (Time & Attendance, etc.)	Rubber bands
Alidade, right-angle, with tripod	Diaries	Thumb tacks
Cables, 100-ft. measuring, with reels (2)	Note books	Masking tape
Cables, 100-ft. sounding, with reels (2)	Scratch paper	Instructions memo
Sounding weights (2)	Mailing tubes	
Level, surveyor's, with tripod	Parcel post labels	

Below are precautions that apply to the care and use of the battery-powered ice drill:

1. Keep the bit or auger covered with the protective block when the drill is not in actual use.
2. Two sets of small set screws on the shaft of the drill must be kept tight with an Allen wrench to guard against loss of the auger.
3. Drilling should be done with the drill perpendicular to the ice; the auger may be bent while drilling at an angle.
4. Do not use the drill in very shallow water where the auger can be ruined by stones or frozen earth; use a spud over very shallow places.

For lake sounding, the advantage of the drill is the time it saves on thick ice. Spudding is more efficient on relatively thin ice (to about 4-6 inches thick).

Mapping data should be recorded on standard map paper, 22 inches x 34 inches, which is gridded with either 1/3-inch or 1/2-inch square divisions to assist with measurements. Sometimes the paper has shrunk so that the divisions are reduced in size. In this case, allowances must be made for the shrinkage when using the grid for measurements. With regard to soundings, there are two alternatives: (1) the recorder measures distances between sounding locations on the map, rather than determining them with the printed grid, or (2) the actual distances between soundings are reduced to match the grid on the shrunken paper (e.g., if the map shrinkage amounts to 2% and if soundings were to be made at 200-foot intervals, the interval to be measured on the ice should be reduced to 196 feet).

Gridded 8 1/2-inch x 11-inch work sheets are provided for convenience in plotting the shoreline, especially on large lakes. Sections of shoreline may be sketched on these sheets then transferred to the larger field map, eliminating repeated transport of the larger map between baseline and shore.

11.2 Mapping Procedure

11.2.1 Access to lakes

Lakes are classed as follows based on ownership and access:

- **Public lakes**.–Some publicly owned frontage, such as county park, public fishing site, state or federal land, etc.
- **Semi-public lakes**.–Either: (a) shores are entirely owned by private interests, but the public is allowed to fish without charge; (b) have boat liveries; or (c) have navigable inlets or outlets that lead to public access sites.
- **Private lakes**.–The public is excluded or charged a fee for access.

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Any public lake may be mapped. Semi-public lakes usually are mapped, but should not be mapped if there are clear indications that public fishing is likely to be prohibited in the near future. Private lakes should not be mapped, except in special instances, or on a consulting basis at private expense.

11.2.2 Lake outline

The map should be planned so the north direction will be located somewhere within the top half of the sheet. Symbols, legend, sounding data, etc., are to be entered parallel with the top border. Choose a scale which will allow the lake outline to fill a large part of the sheet, but which will also allow ample room for shore features, the heading, and legend. One of the following scales (feet to 1 inch) should be used: 25, 50, 75, 100, 150, 200, 300, 400, 600, 800, 1000, or 1200. A feature sometimes overlooked is that of encroaching shore. This type of shoreline borders wetland areas where the lake's edge is not clearly defined. Indication of encroaching shore on lake maps can be very helpful to fisheries workers and people who are buying frontage.

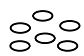
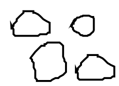
11.2.3 Soundings

The spacing of soundings has an important bearing on both mapping accuracy and speed. Insufficiency of depth records may result in an inaccurate map, or one that does not give adequate information for management. On the other hand, over-intensive sounding wastes time and effort. It is difficult to prescribe a definite pattern for spacing depth measurements because of the variability of lake basins. Good decisions on how frequently soundings should be made increases with experience. The following is a general guide relating lake acreage to sounding interval when mapping is done on ice: 5-acre lakes – 50-foot intervals; 10-25 acres – 100 foot; 50-300 acres – 200 foot; larger lakes – 300- to 400-foot intervals. Additional soundings are often necessary between shore and the drop-off, in and around shoal areas that occur well out from shore in some fairly deep lakes, and throughout the basins of lakes in which depths are highly variable. Incompleteness of depth data may become evident as a set pattern of sounding is in progress; in such cases additional measurements should be made in the questionable area.

11.2.4 Substrate

Soft bottom can cause significant errors in depth measurements. The bottom may be so soft that the sounding weight passes through it almost as freely as water. In such areas sounding must be done with extreme care, and the cup which collects bottom materials should be inspected often to determine the top level of the deposits. After some experience, one acquires a "feel" for the difference in descent of the weight through water and through very soft bottom, which helps greatly in locating the boundary between the two strata.

A cup is attached to the lower end of the sounding weight to retain a sample of the bottom deposit when a depth is measured. The type of deposit present at each measuring site is determined, and is recorded on the map with the depth figure (e.g., 4-S, 10-M, etc). If goodly quantities of two soils occur together in a sample, indicate the presence of both, listing the key letter of the predominant type first. Below is the classification of bottom deposits currently in use for lake maps, including key letters and symbols used on completed maps to show the distribution of each material:

Organic	-	O	Gravel	-	
Marl	-	M	Rocks	-	
Sand	-	S	Bed Rock	-	BR

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The physical characteristics and usual locations of these materials are:

Organic.–Consists of decomposed or partially decomposed parts of plants. It may have any of a variety of colors, and generally has a smooth texture but often contains plant fibers. This is the most prevalent deposit of deep areas, but organic materials may also occur in shallow locations.

Marl.–Gray in color, often gritty, pieces of snail or clam shells frequently included. This deposit may sometimes be mistaken for clay, especially if smoothly textured. When hydrochloric acid is dropped on a questionable sample, boiling action will ensue if it is marl, but not if it is clay. This is a fairly common lake soil, which may be found in either shallow or deep places.

Sand, gravel, rocks, bed rock.–Classification is based on particle size, with rock defined as having a diameter greater than 3 inches. These materials are largely confined to wind-swept shoals of inland lakes. If present in deeper waters, they are usually deeply covered with finer sediments and will not be detected. Superficial gravel and rock deposits will not be sampled by the cup, but noises or vibrations during depth sounding may indicate their presence.

11.2.5 Shore features

The sample legend on the next page illustrates features and symbols used on our lake maps.

Legend

Bottom

O	Organic
M	Marl
S	Sand
	Gravel
	Rocks
BR	Bed rock
	Deadheads (or snags)
	Stumps
	Brush shelter
	Trash

Outline and Contours

	Shoreline
	Encroaching shore
	Breakwater
5'	Contours

Shore features

	Improved road (appling to gravel or pavement)
	Unimproved road
	Trail (foot trail, not passable for cars)
	Railroad
	Bridge
Culvert	(no symbol; use word "culvert" with arrow to show location)
	Building (if public or semi-public, also designated as "Hotel," "Store," etc.)
	Boathouse
	Dock
	Steep slope (use in series, showing course of formation)
W	Wooded
PW	Partly wooded
P	Pasture (or cleared land)
C	Cultivated land
	Brush
	Marsh
	Spring
	Inlet
	Intermittent inlet
	Outlet
	Intermittent outlet
	Dam
	Beaver dam
	Beaver house
	Bench mark

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11.2.6 Legend

Formerly, it was customary to show on maps all buildings present on lake shores. This practice was discontinued because it was often impractical to show all homes or cottages, and on some lakes continuous building activity causes those map features to become quickly outdated. However, for the sake of orientation, prominent structures (hotels, isolated homes, etc.) should be included. Leave out boat docks unless they are substantially constructed, but include boat houses.

Public fishing sites are to be shown (with boundaries, if conveniently possible), as are the locations of other public frontage and semi-public establishments (boat liveries, Boy Scout camps, etc.). Buildings associated with such developments need not be plotted.

Roads and trails near the lake should be included. Their widths are not drawn to scale, but their distance from the shoreline should be to scale, and their compass directions true. Record the names or numbers of designated roadways.

11.2.7 Bench marks

Bench marks are established for measuring lake level fluctuations. They can be very useful. Trees, bridge or dam abutments, and concrete foundations are among the objects that may serve as bench mark monuments. Spikes serve as reference points in trees, and a cold chisel is used to etch concrete or steel objects. Measurements of water elevations are made with either a surveyor's level and leveling rod, or a line level, chalk line, and leveling rod. Plainly record elevation, location, and establishment date for each bench mark on the field map. Bench marks should be established at the time the lake is mapped so that those data can be included on the finished map.

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Our system of presenting water level data assigns the figure 100 as the level of the bench mark. The lake level reading appears as the difference between this figure and the distance in feet that the lake surface lies below the bench mark. For example, if the water surface is 3. 8 feet lower than the bench mark at the time of mapping the lake surface is 96.2, which is simply 100 minus 3.8.

The vertical measurements for level determinations should be recorded on the field map. Following is a sample computation from measurements made with a surveyor's level and leveling rod:

Rod reading above water level	6.78 feet
Rod reading above bench mark	–2.64 feet
Bench mark above water level	4.14 feet

100.00 - 4.14 = 95.86 = water surface elevation
(rounded off to 95.9 on the drafted map)

The computation is simpler if a line level is used: subtract from 100 the height above the lake surface that the leveled chalk line meets the measuring rod. This equipment is adequate if the bench mark is near the edge of the lake (within 50 feet or so). Surveyor's equipment is better when the bench mark is some distance from the lake, and it may be used in all situations.

Occasionally, a bench mark may be higher above the lake than the maximum height of the leveling rod. In such situations, it is necessary to make the level determination in successive steps from the bench mark to the lake, resetting the rod and adding the successive heights.

Below are cautions and guidelines for bench mark procedures:

1. Be sure you are thoroughly familiar with level determination methods. The data are of no value if inaccurate. If a line level is used, place it on the chalk line approximately midway between the bench mark and the rod or pole at the other end.

2. Place the bench mark higher than the estimated maximum level of the lake. When a tree is chosen as a monument, drive the spike in near the base of the trunk, leaving at least 3 inches of the spike exposed.
3. Try to establish three bench marks at each lake that is mapped. Formerly, establishment of one monument was standard procedure, but the loss of the bench mark at some lakes has pointed up the need for more than one.
4. Try to space bench marks widely apart to insure against loss of all of them.
5. If public frontage is available, locate at least one of the bench marks there. Avoid yards of homes as locations.
6. If possible, do not place bench marks in willows, poplars, or birches because these trees are short-lived and deteriorate rapidly after death. Elms should be bypassed because of the prevalence of Dutch elm disease. At some lakes, however, scarcity of suitable objects for monuments permits little choice.

Agencies other than the Fisheries Division have established bench marks at some lakes. In some instances, you will be informed if a bench mark exists for lakes on your mapping schedule. If a bench mark has already been provided for a lake that is to be mapped, its location, a new level determination made from it, and its original level data are to be included on your map. New level readings obtained from these previously established references should be expressed in the terms of the original data, which are usually based on sea level.

Mapping crews may be asked to set up additional bench marks for lakes that have been mapped and which have a Fish Division bench mark. In such instances, it is always necessary to obtain a water level reading from the original bench mark the same day the new reference points are installed.

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11.3 Completing the map

11.3.1 Depth contours

Contours are drawn after depth sounding has been completed. It is advisable to draw contours while the crew is still in the vicinity of the lake in case additional soundings are needed.

Ordinarily, contours are drawn at 5-foot intervals to depths of 20 feet, and at 10-foot intervals beyond 20 feet. Exceptions are: (1) situations in which all or most of a lake is less than 5 feet deep (either 2-foot contour intervals or no contours may be appropriate), and (2) lakes in which the declivity is too abrupt to permit drawing contours with intervals of less than 10 feet (but plot the 5-foot contour if at all possible).

Contours should be drawn with smoothed curves. Where a recorded depth is identical to a contour interval, carry the line a little *to the deeper side* of the sounding location rather than through it. Where several equal depths occur successively in a shore-to-deepwater direction, draw the contour near the middle of the series.

Contours naturally tend to parallel each other. Therefore, be suspicious of depth data if contours deviate markedly from this tendency.

Too few soundings or erroneous records can cause marked variation in contour placement. Verify suspicious data and take additional soundings, as needed, while still on the lake.

11.3.2 Bottom soils

Indicate bottom soil types by symbol, as listed previously. If only one kind of soil was found over the whole lake, a note on this fact is sufficient (e.g., “The entire bottom is organic”). If one or more types are associated with another type that strongly predominates, indicate the predominant type by symbol and the subordinate types by notation.

11.3.3 Miscellaneous data

Other data that need to be recorded on the field map are: name(s) of the lake; location as to township, range, and section (to quarter section if there is a chance the lake can be confused with another in the same section); names of the persons who did the mapping; dates spent on the job; and scale. *Be sure to record the scale which actually applies to the lake*, and not one you had intended to use but discarded later, or one (not applicable to this map) unintentionally carried over from another map.

Printed forms (the Lake Mapping Record) are provided for entry of certain kinds of information about lakes. This record is to be prepared for each lake that is mapped, and should also be filled out (as completely as available information will allow) for a lake that was visited but not mapped.

Send field maps to the drafting office periodically rather than submitting all of them at one time at the end of the work season. This practice will permit more orderly final drafting, and should clarification of work be required, it usually can be done best soon after a map has been drawn.

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Written 12/1960 by C. M. Taube
Revised 5/1969 by A. W. DeClaire
Revised 3/1976 by G. P. Cooper
Extensively revised 1/2000 by J. C. Schneider

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Manual of Fisheries Survey Methods II: with periodic updates

Chapter 12: Three Methods for Computing the Volume of a Lake

Clarence M. Taube

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Chapter 12: Three Methods for Computing the Volume of a Lake

Clarence M. Taube

[Editor's note: Area of lakes, a basic requirement for volume calculations, has traditionally been estimated with a mechanical planimeter. In recent years, computer programs can compute area (such as Arcview™) and volume (such as Tecplot®).]

12.1 Method No. 1

The formula in solid geometry for calculating the volume of a frustum of a circular cone has been applied by limnologists and fisheries biologists to compute the volume of a lake. This formula is:

$$V = \tfrac{1}{3}H\left(A_1 + A_2 + \sqrt{A_1 \times A_2}\right)$$

Where: V = volume of water;

H = difference in depth between two successive depth contours;

A_1 = area of the lake within the outer depth contour being considered;

A_2 = area of the lake within the inner contour line under consideration.

The procedure consists of determining the volumes of successive layers of water (frustums), and then summing these volumes to obtain the total volume of the lake.

12.2 Method No. 2

Another formula has occasionally been used for computing lake volume. This method is employed by engineers for computing reservoir volumes, and is derived from the "end-area formula" sometimes applied to find the volume of prismoidal forms. The formula is:

$$V = \tfrac{1}{2}H\left(A_1 + A_2\right)$$

Variables and general procedures are the same as in Method No. 1.

12.3 Method No. 3

A third method for estimating lake volume is to determine average lake depth and multiply it by lake area. Average depth is obtained by averaging depth soundings. For a reliable average, the soundings should be spaced in a uniform grid pattern. The accuracy of this method depends on frequent soundings at regular intervals and the recording of all soundings. The omission of depth soundings for very shallow water (e.g., close to shore) is a common source of error in the application of this method.

12.4 Procedures

The first two methods require an accurate depth contour map and a planimeter. The third method requires a field map showing actual depths (on a grid pattern) and a planimeter.

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When working with either Method No. 1 or No. 2, first determine area within each contour by tracing around map contour lines with a planimeter. Start with the shoreline contour and continue to the innermost contour line. The resultant readings will be in square inches (the unit of measure of the planimeter). Then, based on the scale of the field map, convert planimeter readings to values of lake area, either in acres or square feet. For very small ponds it may be desirable to compute areas in square feet, but lake area is commonly expressed in acres.

As an example of calculating lake area, and then areas within consecutive contours, assume that a lake map was drawn on the scale of 1 inch equals 100 feet. Then, 1-square inch of map area (planimeter reading) equals 10,000 square feet (100×100) of lake area, or 0.22957 acres (10,000/43,560). Further assume for this example that the lake has a maximum depth of 23 feet, depth contours were drawn for each 5-foot interval, and planimeter readings for the area within the contours were as in the following table:

Depth contour (feet)	Planimeter reading (square inches)	Calculated area	
		Square feet	Acres
(Shoreline contour) 0	210.0	2,100,000	48.2
5	150.0	1,500,000	34.4
10	110.0	1,100,000	25.3
15	83.5	835,000	19.2
20	21.7	217,000	5.0
(Maximum depth) 23			

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Those calculated areas were obtained by conversion factors of 10,000 for square feet and 0.22957 for acres. Area in acres could have been calculated by dividing area in square feet by 43,560 (number of square feet per acre). Note that 48.2 acres is the calculated total area of the lake.

As an illustration of computing water volumes, we continue to use the sample data given above. By Method No. 1, calculations of volume (in acre-feet) are as follows:

Depth strata	Equation	Acre feet
0 - 5 ft :	$\frac{1}{3} * 5\left(48.2 + 34.4 + \sqrt{48.2 * 34.4}\right)$	= 205.5
5 - 10 ft :	$\frac{1}{3} * 5\left(34.4 + 25.3 + \sqrt{34.4 * 25.3}\right)$	= 148.7
10 - 15 ft :	$\frac{1}{3} * 5\left(25.3 + 19.2 + \sqrt{25.3 * 19.2}\right)$	= 110.8
15 - 20 ft :	$\frac{1}{3} * 5\left(19.2 + 5.0 + \sqrt{19.2 * 5.0}\right)$	= 56.7
20 - 23 ft :	$\frac{1}{3} * 3\left(5.0\right)$	= 5.0
	Total volume	= 526.7

Note that the volume calculation for the lowermost layer (20-23 ft) uses the cone formula: volume = 1/3(HA). By applying the formula here we assume that the maximum depth of 23 feet occurred only in a small area. If the maximum depth of 23 feet prevailed over an extensive area, then encircle this area with a contour line, determine its area with a planimeter, and use the frustum formula to calculate volume of the 20-23-foot zone.

By Method No. 2, example calculations of volume (in acre-feet) are as follows:

Depth strata	Equation		Acre feet
0 - 5 ft :	$\frac{1}{2} * 5(48.2 + 34.4)$	=	206.5
5 - 10 ft :	$\frac{1}{2} * 5(34.4 + 25.3)$	=	149.3
10 - 15 ft :	$\frac{1}{2} * 5(25.3 + 19.2)$	=	111.3
15 - 20 ft :	$\frac{1}{2} * 5(19.2 + 5.0)$	=	60.5
20 - 23 ft :	$\frac{1}{2} * 3(5.0)$	=	7.5
	Total volume	=	535.1

When using acres for area values and feet for depth values, volume will be in acre-feet. An acre-foot of water is 1 acre of water 1 foot deep, i.e., 43,560 cubic feet.

In Method No. 3, all soundings of the lake are summed, then divided by the number of soundings to obtain average depth. Lake volume equals average depth times lake area. Lake area is determined by planimeter measurements on the field map, as described above.

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12.5 Comparison of the three methods

The three methods give approximate rather than exact volumes of lakes, but these approximations are close enough to the true values for fisheries work. These methods usually give quite similar results, as demonstrated by the three example lakes below:

			Computed volumes (acre-feet)		
Name of lake	Area (acres)	Location	Method No.1	Method No.2	Method No.3
Frost	60.0	Ogemaw Co.	1,949	1,963	1,977
Robinson	20.3	Oakland Co.	64	63	58
Eagle	19.9	Oakland Co.	137	142	138

However, based on years of experience, Methods 2 and 3 often give slightly higher values than Method 1 (the Frost Lake example is one of the exceptions). The slight difference appears to be related to lake basin shape, but has no practical significance to fisheries work. Methods Nos. 2 and 3 are preferable to Method No. 1 from the standpoint of simplicity. Assuming that the lake in question is shaped like a series of frustums, the formula of Method No. 1 is mathematically correct.

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Chapter 13: The Coefficient of Condition of Fish

J. E. Williams

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Chapter 13: The Coefficient of Condition of Fish

J. E. Williams

The relative robustness, or degree of well-being, of a fish is expressed by "coefficient of condition" (also known as condition factor, or length-weight factor). Variations in a fish's coefficient of condition primarily reflect state of sexual maturity and degree of nourishment. Condition values may also vary with fish age, and in some species, with sex.

The coefficient of condition has usually been represented by the letter K when the fish is measured and weighed in the metric system. The formula most often used is:

$$K = \frac{100{,}000\,W}{L^3}$$

where: W = the weight of the fish in grams;

L = the standard length of the fish in millimeters.

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In the English system, coefficient of condition is expressed as C, and the formula is:

$$C = \frac{100{,}000\,W}{L^3}$$

where: W = the weight of the fish in pounds;

L = the total length (maximum) of the fish in inches

To best compare the coefficient of condition of fish from different waters, data should be from fish of the same species, length, age, and sex; and should have been collected on the same date (or at least in the same season). If comparison is made between individuals from the same water, the fish must have been collected on the same date. For any comparison, be aware that gear selectivity may also be a confounding factor.

The metric coefficient of condition K may be converted into the English C by the following formula (devised by Hile and published by Beckman 1949):

$$C = 36.1\, r^3 K$$

where: r = the standard length divided by the total length;

K = the coefficient of condition in the metric system.

Klak (1941) devised conversion factors for changing from K to C and from C to K. His factor is 0.02768 and is used as follows:

$$C = \frac{K}{0.02768}$$

$$K = 0.02768\,C$$

Klak's factor has been found to be applicable to trouts and ciscoes, but not to species that are of other shapes.

Carlander (1977) summarized information from nearly all published works on condition factor of American fishes. It has very helpful alignment charts from which both *K* and *C* can be read with the use of a ruler.

As an alternative to calculating *C* or *K*, when ample data on lengths and weights are available, the relative robustness of a population of fish can be detected from a length-weight regression. Simply plot the length-weight regression for the population on graph paper and compare it to a similar plot for the Michigan average (see Chapter 17). Relatively robust fish will exceed the Michigan average weight at a given length, and relatively skinny fish will weigh less than average.

In recent years, relative weight indices (Wr) were developed for many species (Murphy et al. 1991). These indices are based on samples from populations across the United States. For most uses, Wr should be used in lieu of the traditional coefficients of condition described above.

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Manual of Fisheries Survey Methods II: with periodic updates

Chapter 14: Conducting Roving and Access Site Angler Surveys

Roger N. Lockwood

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Chapter 14: Conducting Roving and Access Site Angler Surveys

Roger N. Lockwood

Surveys of anglers are completed annually on various Michigan waters by the Fisheries Division to estimate angling effort and catch by species. Estimated angling effort is measured in angler hours, angler trips or angler days, and estimated angler catch is measured in numbers of fish harvested and/or caught and released. These surveys are conducted on inland lakes and rivers, and selected waters of the Great Lakes.

This chapter describes roving and access site angler surveys and discusses general methods for conducting these surveys. Equations for estimating angling effort and catch, and additional descriptions of survey methods, are given in Lockwood et al. (1999). Other reference sources are given at the end of this chapter.

14.1 Description

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Two separate sampling components are used to estimate fishing activity and success over a given period of time at a specified location – counts of angler activity and interviews of anglers or angler parties. Numerous methods exist for collecting data on both components. For example, angling effort (anglers or angler units which represent one or more anglers) may be counted from an airplane while a survey clerk interviews anglers at an access site as they complete their fishing trip. This type of complemented survey is referred to as an aerial-access angler survey. When anglers are counted from an airplane and a survey clerk interviews anglers while they are actively fishing (before they complete their fishing trip) the survey is called aerial-roving. Similarly, when anglers at a single location are both counted and interviewed by the survey clerk, the surveys are designated as either roving-access (complete-trip interviews) or roving-roving (incomplete-trip interviews). When angling effort is estimated by mail survey and catch by access interviews, the survey is a mail-access angler survey. Other complemented angler survey types may be used, but Michigan currently uses roving-access, roving-roving, aerial-access, and aerial-roving methods.

Counts provide estimates of angling effort (pressure) while interviews provide estimates of catch rate by species. The product of estimated effort and estimated catch rate is estimated catch. Counts and interviews each sample only a portion of the entire angling population and are assumed to accurately (without bias) represent that population. Routine information collected on count forms for each count are: location, date, type of count, duration of count (where applicable), mode of count, time of count, and counted numbers of units (anglers, boats etc.). Routine information collected on interview forms for each angler or angler party are: location, date, angling mode, whether fishing trip is complete or incomplete, number of anglers, start time of fishing trip, time of interview, and number of fish caught by species (catch-and-release and harvest information are recorded separately).

Catch and effort estimates may be calculated by day or multiple days within a time period (e.g., week days within a month). Angling modes (boat, shore, pier etc.) are calculated separately. These estimates may be summed to estimate catch and effort for longer time periods. Likewise, estimates from more than one location are summed to estimate catch and effort for a larger area. When anglers report the species or group of species they are targeting, targeted catch and effort may be estimated.

In addition to angling effort and catch, the angler interviewing process may be used to collect tag information from fish, angler residency, and bait type used. Anglers may also be queried regarding current or proposed fishing regulations and other issues.

14.2 Methods

Angler surveys consist of four basic elements: sampling schedule, survey clerk, angler counts and angler interviews.

14.2.1 Sampling Schedule

Sampling schedules are constructed to randomly sample anglers on various days and at various times within these days. Since survey estimates are based on mean values, both active and less active days and time periods are sampled. Stratification, such as by weekday or weekend day, tends to congregate similar activity levels and reduce variability in estimates. Supervisors must ensure that survey clerks follow sampling schedules. When a sampling schedule is not followed, data is not representative of angling population effort and catch, and resulting estimates will not accurately portray angling statistics during a given time period and location.

14.2.2 Survey Clerk

Survey clerks are an integral component in any angler survey and their importance cannot be stressed enough. Clerks must be able to perform in all weather conditions and in periods of both high and low fishing activity. The quality of a clerk's performance is determined by the quality of their supervision. Weekly contact by a supervisor promotes reliability and demonstrates to the clerk the importance of the job.

Just as the supervisor must not take the clerk for granted, neither should the clerk become complacent or indifferent. Changes may occur during an angler survey that directly influence the results of that survey. For example, concentrations of anglers may shift to a new area (such as a new boat access site). Clerks should recognize the importance of this change and notifying the supervisor so that modifications in the sampling scheme can be implemented. Training prepares a clerk for most, but not all situations, so a good survey clerk must be prepared to ask questions. For example, a species of fish may appear in the angler's catch that was not anticipated during training. Clerks should contact the supervisor so that additional training in identification can be implemented. The last thing any supervisor wants is to learn of problems after all data have been collected. When meeting the public, survey clerks represent the entire Department of Natural Resources. A survey clerk's mannerism and professionalism, and the way in which they treat equipment entrusted to them, are all important and reflect upon the Division.

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14.2.3 Counts

Single or multiple counts may be made at a given location and day. Counts are made of individual anglers or of angler units, which may represent more than one angler (such as boats, trailers, ice shanties etc.). Two types of counts are made, instantaneous and over time interval. Instantaneous counts are suitable for access or aerial surveys, while interval counts are only suitable for access surveys.

14.2.3.1 Instantaneous.–When all angling activity may be observed from a single vantage point, the instantaneous method is appropriate. Angling activity may be enumerated from the ground or from an airplane. In some situations a ground-based clerk must drive to more than one vantage point to count an area, however the count is still considered instantaneous. Spatial stratification is often used to ensure that counts are as instantaneous as possible. For example, a lake may be divided into several areas and each counted from a unique vantage point; or a clerk may drive along a river and count vehicles at access locations. From the air, angling activity is enumerated as the plane flies over each area. When more than one count location is used, direction and order of count are randomized to avoid potential biases. Care must also be taken to prevent double counting of anglers or angler units, especially if they may move from one area to another while the count is being made.

When instantaneous counts are made of ice shanties, either only occupied shanties are counted or all shanties (occupied and unoccupied) are counted. In the later alternative, the ratio of occupied to unoccupied shanties must be obtained during representative time periods to adjust the total shanty counts.

In some situations, fishing boats on a lake may be difficult to distinguish from non-fishing boats. In such situations, all boats (fishing and non-fishing) are counted and all parties (fishing and non-fishing) using the site are interviewed. Counts are then adjusted by the proportion of angling parties in the interview data set. This same technique may be applied to other counting units, such as boat trailers or vehicles at an access site.

14.2.3.2 Interval.–When anglers enter a fishery and disappear from the clerk's view, interval counts are appropriate. Typically, this situation occurs on the Great Lakes where boats leave a port and travel some distance out onto the lake to fish. Boats may be present in the fishery, but are not visible to the clerk for instantaneous enumeration. In this situation, all fishing boats leaving a port during a randomly selected time interval (duration) are counted. Interval counts are generally 15 minutes or longer in duration. As above, when fishing boats are difficult to distinguish from non-fishing boats, all boats are counted and all boating parties interviewed, then boat counts are adjusted to reflect only fishing boats. While counting units other than boats are entirely possible, appropriate conditions are rare. As previously noted, interval counts are made by ground based clerks (access count).

14.2.4 Interviews

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Since catch rates of complete-trip interviews and incomplete-trip interviews are calculated differently, care should be taken to collect only one type of interview (complete- or incomplete-trip) within a strata.

14.2.4.1 Complete-Trip Interviews.–When anglers or angler parties are interviewed by the clerk upon completing their fishing trip, the interview is referred to as a complete trip. Complete-trip interview information may be collected either from individual anglers or collectively from angling parties. Often the counting technique employed will dictate whether angler or angler party information is collected. In situations where instantaneous counts of anglers are made, either individual angler or angler party information may be collected. When angler units which may represent more than one angler are counted, angler party size information is collected.

14.2.4.2 Incomplete-Trip Interviews.–When anglers are interviewed by the survey clerk while actively fishing, prior to completion of their fishing trip, interviews are of incomplete trips. To avoid angler party size bias, only individual angler catch information is recorded, not angler party catch information (Lockwood 1997). Incomplete-trip interviews are advantageous when instantaneous angler counts are made and the clerk has easy access to anglers. For example, anglers at a pier or open ice fishery are readily accessible for interviewing. In the case of an open ice fishery where anglers may gain access to the lake at many points, incomplete-trip interviews provide a very efficient sampling method. When this method is appropriate, a clerk is usually able to collect more incomplete-trip interviews than complete-trip interviews, thus sampling a greater proportion of the angling activity. Minimum fishing time for incomplete-trip interviews is 0.5 h (Pollock et al. 1997).

The situation and type of count may dictate whether complete- or incomplete-trip interviews are required. For example if interval boat counts are made, angler party trip length information is required to convert boats per interval to boat angler hours. This information can only be obtained from complete-trip interviews. In addition, anglers are not available for interviewing prior to completion of their trip.

14.2.4.3 Voluntary Interviews.–Catch records voluntarily submitted by individuals not randomly selected are called voluntary interviews. Such records may be submitted by fishing guides, boat livery or resort operators, lake association members, or cooperating anglers. Interview forms may be distributed prior to the starting date of the angler survey, or made available from boxes on site or be distributed after the trip (e.g., post cards left on vehicle windshields). These records are especially valuable for fishing localities or anglers inaccessible to survey clerks. This situation occurs when anglers enter a fishery from resorts or cottages on a lake. The survey clerk may easily interview anglers using public launch sites, but anglers accessing the fishery from private dwellings may be difficult or impossible to interview. Voluntary interviews will be of complete trips and catch rates are calculated as for complete-trip interviews collected by a survey clerk.

There are disadvantages to voluntary interviews. Of primary concern is the uncertainty as to their representation of an angling population. For example, avid anglers may report their fishing trips more often than less avid anglers, anglers may exaggerate their catch, anglers may report successful trips more often than less successful trips, and species of fish may be more likely to be misidentified. When using voluntary interviews in conjunction with interviews collected by a survey clerk, catch rates of all sampled anglers and percentages of successful anglers should be compared before combining these two types of interviews. Differences or similarities in rates of catch and success should be viewed objectively.

14.3 Implementation

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Implementation of an angler survey begins with planning and includes: determining purpose of survey, site evaluation, designing count and interview forms, determining number of clerks needed, special equipment needs, and survey clerk hiring and training. Assistance in planning and conducting a Great Lakes survey is available through the Charlevoix Great Lakes station (study 427) and for inland surveys through the Institute for Fisheries Research in Ann Arbor (study 646). Surveys categorized as Great Lakes are those surveys done on the Michigan waters of the Great Lakes, connecting waters, and river sections with fisheries for runs of Great Lakes species. Inland surveys are those done on any of the remaining lakes or rivers, including river sections directly connected to the Great Lakes where migrations of Great Lakes species are not present.

Often, the survey purpose and site evaluation will greatly influence number of survey clerks required. In some situations, subsampling prior to the actual survey will determine potential precision of estimates and number of survey clerks needed. When a survey is designed to extend over an entire season (summer months for example), a seasonal vehicle from Motor Transport Division may be required for the duration of the survey. In the case of river surveys or ice fishing surveys, a canoe or snowmobile, may be needed.

Training is a joint effort between Research personnel and the biologist requesting the angler survey. Orientation should include a general overview of angler surveys and the purpose for the current survey. Training should include correct completion of count and interview forms, clerk behavior (public relations), operation of equipment and fish identification.

The biologist (supervisor) initiating the angler survey is responsible for procurement of vehicle(s), special equipment and survey clerk(s), and daily supervision. Regular contact (weekly) with the survey clerk is essential for quality survey results. The supervisor should check count and interview forms submitted by the clerk for completeness and correctness; additional proof reading will be done by Research personnel. Data processing and timely calculation of estimates are the responsibility of Research personnel.

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Chapter 15: Weighted Average Length and Weighted Age Composition

James C. Schneider

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Chapter 15: Weighted Average Length and Weighted Age Composition

James C. Schneider

Simple averages computed from subsamples stratified by size of fish usually give biased estimates of growth and age composition of fish populations. This bias can be eliminated by computing weighted averages with the aid of a length-frequency distribution representative of the population.

In the example below, a large number of bluegills were captured by electrofishing. A length frequency was tabulated for the first 200 fish, and scale samples were taken from 20 of each inch group.

The calculations show that simple averages tend to overestimate the average length of older, rarer, fish (e.g., 6.2 inches versus 5.8 inches for age 4), and to greatly distort the relative frequency of the various age groups (e.g., as much as 22%).

Note that a bias may still exist in weighted averages due to gear size selectivity. Among young fish, the larger individuals are often more vulnerable to capture. In this example, both the length-frequency and the age-frequency information indicate that either the small age-1 fish were not fully vulnerable to the gear, or that the age-1 cohort was relatively weak and the age-2 cohort was relatively strong.

When recording average lengths on the FISH GROWTH form, indicate (on the appropriate blank) if a weighted method was used.

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		Sample aged				Relative
Length group (inches)	Length-frequency sample number (A)	Ages present	Number	Percent (B)	Average length (C)	number (A × B)
2.0 - 2.9	40	1	15	100.0	2.4	4,000
3.0 - 3.9	80	1	5	33.3	3.2	2,664
		2	10	66.7	3.5	5,336
4.0 - 4.9	50	2	7	46.7	4.3	2,335
		3	8	53.3	4.7	2,665
5.0 - 5.9	28	2	2	13.3	5.1	373
		3	5	33.3	5.4	932
		4	8	53.4	5.7	1,495
6.0 - 6.9	2	4	2	100.0	6.5	200

Weighted average length for an age group = sum of A × B × C ÷ A × B for relevant size groups:

For age 1: $\dfrac{4000 \times 2.4 + 2664 \times 3.2}{4000 + 2664} = 2.7$ (Simple average = 2.6)

For age 2: $\dfrac{5336 \times 3.6 + 2335 \times 4.3 + 373 \times 5.1}{5336 + 2335 + 373} = 3.9$ (Simple average = 4.0)

For age 3: $\dfrac{2665 \times 4.7 + 932 \times 5.4}{2665 + 932} = 4.9$ (Simple average = 5.0)

For age 4: $\dfrac{1495 \times 5.7 + 200 \times 6.5}{1495 + 200} = 5.8$ (Simple average = 6.2)

Weighted age-frequency for an age group = Sum of A × B for all relevant size groups:

For age 1:	4000 + 2664	=	6,664	(33.3%)	(Simple average = 26.7%)
For age 2:	5336 + 2335 + 373	=	8,044	(40.2%)	(Simple average = 25.3%)
For age 3:	2665 + 932	=	3,597	(18.0%)	(Simple average = 17.3%)
For age 4:	1495 + 200	=	1,695	(8.5%)	(Simple average = 30.7%)
Total:		=	20,000	(100%)	

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Chapter 16: Endangered and Threatened Fishes in Michigan

William C. Latta

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Chapter 16: Endangered and Threatened Fishes in Michigan

William C. Latta

Michigan legislation of 1974 requires the listing of endangered and threatened fishes every two years. A committee of six experts recommends species for the lists. The Natural Heritage Program, Wildlife Division, Michigan Department of Natural Resources compiles and administers the list. The species of fishes thought to be extirpated in Michigan will automatically be listed as threatened if rediscovered. The finding of any of these species should be reported to the National Heritage Program. The Natural Heritage Program will also answer specific questions on the listings. The species of fishes considered endangered, threatened or extirpated in Michigan in 1998 are listed below. The list is frequently updated and can be found at <http://www.dnr.state.mi.us/Wildlife/Heritage/Thr_End/default.htm>.

16.1 Endangered fishes

Redside dace	*Clinostomus elongatus* (Kirtland)
Creek chubsucker	*Erimyzon oblongus* (Mitchill)
Silver shiner	*Notropis photogenis* (Cope)
Northern madtom	*Noturus stigmosus* Taylor
Pugnose minnow	*Opsopoeodus emiliae* Hay
River darter	*Percina shumardi* (Girard)
Channel darter	*Percina copelandi* (Jordan)
Southern redbelly dace	*Phoxinus erythrogaster* (Rafinesque)

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16.2 Threatened fishes

Lake sturgeon	*Acipenser fulvescens* Rafinesque
Eastern sand darter	*Ammocrypta pellucida* (Putnam)
Lake herring	*Coregonus artedi* Lesueur
Shortjaw cisco	*Coregonus zenithicus* (Jordan and Evermann)
Mooneye	*Hiodon tergisus* Lesueur
Sauger	*Stizostedion canadense* (Smith)

16.3 Extirpated fishes

Deepwater cisco	*Coregonus johannae* (Wagner)
Blackfin cisco	*Coregonus nigripinnis* (Gill)
Shortnose cisco	*Coregonus reighardi* (Koelz)
Bigeye chub	*Notropis amblops* (Rafinesque)
Ironcolor shiner	*Notropis chalybaeus* (Cope)
Weed shiner	*Notropis texanus* (Girard)
Paddlefish	*Polyodon spathula* (Walbaum)
Blue pike	*Stizostedion vitreum glaucum* Hubbs
Arctic grayling	*Thymallus arcticus* (Pallas)

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Chapter 17: Length-Weight Relationships

James C. Schneider, Percy W. Laarman, and Howard Gowing

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Chapter 17: Length-Weight Relationships

James C. Schneider, Percy W. Laarman, and Howard Gowing

The relationship between total length (L) and total weight (W) for nearly all species of fish is expressed by the equation:

$$W = aL^b$$

Values of W usually have been calculated from the logarithmic (base 10) equivalent:

$$\log W = \log a + b \cdot \log L$$

A graph of log W against log L forms a straight line with a slope of b and a Y-axis (log W) intercept of log a. Invariably, b is close to 3.0 for all species.[a]

The exact relationship between length and weight differs among species of fish according to their inherited body shape, and within a species according to the condition (robustness) of individual fish. Condition sometimes reflects food availability and growth within the weeks prior to sampling. But, condition is variable and dynamic. Individual fish within the same sample vary considerably, and the average condition of each population varies seasonally and yearly. Sex and gonad development are other important variables in some species, especially percids. Surprisingly, type of habitat – stream, inland lake, Great Lake – is not a reliable predictor of fish condition. Chapter 13 discusses traditional coefficients of condition which may be derived from length-weight data. A more direct approach is, for a given length, to calculate a weight from the regression and compare it to a reference weight such as a state average weight.

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Even for routine population surveys it is both practical and worthwhile to collect length-weight data on individual fish. Fish of all sizes can be accurately and easily weighed on portable electronic balances in a sheltered location. Number of fish sampled need not be high, 5-10 fish per inch group over a wide size range are enough to establish a regression line for each important species. Weight data for species which are scale-sampled can be conveniently recorded on the same envelopes. The resulting length-weight regressions are useful for (a) calculating total weight of fish caught from length-frequency data (thereby eliminating the need for bulk weighing of groups of fish while at the lake or stream), (b) measuring changes in robustness/health of this population (relative to past or future samples at the same place and season), (c) determining the relative condition of small fish compared to large fish (from the slope of the regression), and (d) comparing condition of this population to the state-wide standards discussed below.

State average length-weight relationships (analogous to state average growth rates) have been compiled for 16 species of fish. For two of these species, brook and brown trout, there is one set of regressions for stream dwellers and another set for lake dwellers (which tend to be significantly plumper at larger sizes). These data were obtained mainly from wild fish in inland lakes and streams, of both sexes, in all seasons. Included for each species were several to many populations and a variety of growth rates.

A recent compilation of data indicates Great Lakes fish populations are not consistently heavier at the same length than populations in inland waters and it is not practical to present separate regressions by habitat. Across all habitats, deviations from the accepted standards rarely exceeded 15%. Sources of

[a] In previous versions of this appendix, and in much fisheries literature, the regression constant is represented by "c" rather than "a", and the regression slope is represented by "n" rather than "b". Equations in the form of natural logarithms (base e) and power functions are commonly used instead of log10.

these data were publications, reports, and the Great Lakes Sport Fishing Survey (Rakoczy 1996). For example, for yellow perch the average length-weight regression based on seven Great Lakes samples was identical to that long-used as the State average (inland). Likewise, lake trout and rainbow trout (including stream residents and steelhead) seem to be adequately represented by single equations developed earlier. Brown trout in streams, inland lakes, and the Great Lakes seem to vary the most; consequently, both stream and lake equations are offered. Very large brown trout in the Great Lakes may exceed predictions derived from the lake equation by 20%. Smallmouth bass condition may also vary with habitat, but additional sampling is needed to confirm its consistency and importance. Fish in Lake Superior are often relatively thin, but do not warrant separate equations at this time.

For 61 other species (or species groups) for which no Michigan average has been determined, length-weight data or regressions were assembled from various sources. These will be the standard until more data are available. Preference was given to Michigan or Midwestern sources when possible. Sources included: (1) median values, or the best data, compiled in Carlander's Handbooks (1969 and 1977); (2) data or regressions in the original literature; and (3) unpublished data, kindly supplied by Peter Bayley (formerly Illinois National History Survey, Urbana), Mike Wiley (The University of Michigan, Ann Arbor), and Jerry Rakoczy (Michigan Department of Natural Resources, Charlevoix).

Table 17.1 lists the coefficients for the regression equations and sources of the data. For all but two fishes, splake and Atlantic salmon, the regressions cover the size range likely to be collected in routine fisheries surveys. The regressions may not be as accurate for relatively small fish (less than 2 inches) or for very large fish that tend to have high variability.

For example, to calculate weight in pounds of a 20-inch largemouth bass, the equation would be:

$$\begin{aligned} \log_{10} \text{Lb} &= -3.43162 + 3.12735 \cdot \log_{10}(20) \\ &= 0.63716 \\ \text{Lb} &= 4.34 \end{aligned}$$

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Tables 17.2-17.8 contain some commonly used lengths and weights calculated from these equations.

Tables 17.9-17.11 contain average lengths and weights typical of some hatchery-reared fish.

The length-weight relationships in these tables may be used for computing biomass estimates from length-frequency distributions when weight data specific to the time and site are not available. The FISH COLLECTION form provides columns for biomass, and if empirical weights were not taken during a survey, the standards may be used to calculate biomass estimates. Be sure to note on the form if the standards were used in lieu of empirical weights. A computerized version of the FISH COLLECTION form has been developed with these equations built in as defaults. It automatically calculates biomass estimates and performs other required computations.

State average length-weight regressions may also be used to evaluate the relative condition of populations. If a population has a length-weight curve which is below the average curve, then its fish are relatively skinny. Conversely, if a population's curve is above the average curve, then its fish are relatively plump. The curves may cross, possibly indicating a change in condition caused by a change in diet as fish grow. For many species, a nationwide system of relative weight indices has been developed (Murphy et al. 1991). However, it advocates the use of the 75th percentile rather than the 50th percentile (the average) as a standard for condition.

Table 17.1.–Length-weight regression coefficients for Michigan fishes. Values for the intercept (a) are given in both English (E) and metric (M) systems; the value for the slope (b) is the same in both systems. English equations are in lb and in; metric equations are in g and mm. The standard equation is: $\log_{10}$ Weight = a + b·($\log_{10}$ Length).

Species[a]	slope (b)	Intercept (a) E	Intercept (a) M	Notes[b]
Alewife	3.06370	-3.64198	-5.28911	VA (Boaze and Lackey 1974)[c]
Bass, Largemouth	3.12735	-3.43162	-5.16885	
Smallmouth	3.02635	-3.31934	-4.91466	
Rock	3.05438	-3.17738	-4.81208	
White	3.0342	-3.41794	-5.0233	IL (Bayley and Austen 1987)[c]
Bloater	3.1110	-3.71552	-5.429045	L. MI (Carlander 1969)[d]
Bluegill	3.17266	-3.30288	-5.10377	
Bowfin	2.96004	-3.39775	-4.89906	MI+(Carlander 1969)[e]
Bullhead, all	2.88495	-3.20930	-4.60512	Brown, yellow, black (Carlander 1969)[d]
Buffalo, Bigmouth & all	3.09298	-3.36229	-5.05036	(Carlander 1969)[d]
Burbot	3.03888	-3.60272	-5.21478	(Carlander 1969)[d]
Carp, Common	2.83840	-3.11203	-4.44245	(Carlander 1969)[d]
Catfish, Channel	3.2764	-3.8665	-5.8116	IL (Bayley and Austen 1987)[c]
Flathead	3.16495	-3.60167	-5.39084	MI+(Carlander 1969)[d]
Chub, all				Use hornyhead
Creek	2.92494	-3.39611	-4.84812	(Carlander 1969)[d]
Hornyhead	3.170	-3.4740	-5.2702	IL (Bayley unpublished)[c]
River				Use hornyhead chub
Chubsucker, all	3.18937	-3.41781	-5.24128	Blueberry Lake + Carlander (1969)[d]
Cisco, all				Use lake herring
Crappie, Black	3.17980	-3.43238	-5.24330	
White	3.3835	-3.7282	-5.8236	IL (Bayley and Austen 1987)[c]
Dace, all				Use fathead minnow
Darter, all				Use blackside
Blackside	3.236	-3.6003	-5.4899	IL(Bayley unpublished)[c]
Johnny	3.198	-3.5686	-5.4040	IL (Bayley unpublished)[c]
Rainbow	3.403	-3.5391	-5.6619	IL (Bayley unpublished)[c]
Drum, Freshwater	3.1973	-3.6007	-5.4353	IL (Bayley and Austen 1987)[c]
Eel, American	3.47	-4.722	-6.94	(Carlander 1969)[d]
Gar, Longnose	3.5070	-4.7973	-7.067	MO (Carlander 1969)[c]
Shortnose	2.9811	-3.8730	-5.4039	SD (Carlander 1969)[d]
Herring, Lake	2.85755	-3.45588	-4.81321	(Carlander 1969; except tullibee)[d]
Killifish, all				Use topminnow
Lamprey, ammocete spp	2.65465	-4.09370	-5.16569	W. brook (Carlander 1969)[d]
Brook	2.8355	-4.0634	-5.3917	W. brook (Carlander 1969)[d]
Chestnut	3.21468	-4.38861	-6.23605	MI (Hall 1963)[c]
Sea	2.63133	-3.66299	-4.70251	Ocqueoc R. (Applegate 1950)[e]
Logperch				Use blackside darter
Madtom, all				Use tadpole madtom
Tadpole	3.102	-3.3401	-5.0396	IL (Bayley unpublished)[c]
Minnow, all				Use bluntnose
Bluntnose	3.390	-3.6038	-5.7089	IL (Bayley unpublished)[c]
Fathead	3.07650	-3.36851	-5.03343	(Carlander 1969)[e]
Mooneye	3.12105	-3.6165	-5.3459	L. Erie (Carlander 1969)[d]
Mudminnow				Use creek chub
Musky, Northern	3.44346	-4.25593	-6.43636	MI+WI (Hanson 1986)[d]
Tiger	3.07273	-3.82649	-5.48612	Limited sites
Perch, Pirate	3.102	-3.2306	-4.9310	IL (Bayley unpublished)[c]
White	3.21747	-3.51718	-5.38013	NE (Thoits 1958 and Reid 1972)[e]
Yellow	3.17285	-3.53359	-5.33475	
Pickerel, Grass	3.00982	-3.72313	-5.29438	WI (Kleinert and Mraz 1966; pooled)
Pike, Northern	3.14178	-3.85333	-5.61083	

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Table 17.1.–Continued.

Species[f]	slope (b)	Intercept (a) E	Intercept (a) M	Notes[g]
Pumpkinseed	3.21060	-3.25719	-5.11138	
Quillback	3.09633	-3.46781	-5.16059	(Carlander 1969)[d]
Redhorse, all				Use golden
Golden	2.908	-3.3410	-4.7690	(Bayley unpublished)[c]
Shorthead	2.94414	-3.33201	-4.81098	(Carlander 1969)[d]
Silver	2.778	-3.2034	-4.4489	IL (Bayley unpublished)[c]
Salmon, Atlantic	2.78090	-3.22020	-4.47028	To 25" (Dexter 1991)[c]
Chinook	3.113913	-3.594065	-5.31348	L. MI 1983-93 (Wesley 1996)[c]
Coho	3.42700	-4.01200	-6.16900	G. L. 1992-94 (Rakoczy)[e]
Pink	2.877	-3.344	-4.737	MI (Wagner 1985)[c]
Sculpin, all	3.25202	-3.38754	-5.29903	MI (Wiley unpublished)[c]
Shad, Gizzard	3.03707	-3.46799	-5.07752	(Carlander 1969)[d]
Shiner, all				Use spottail shiner
Common	3.320	-3.6055	-5.6124	Assume same as striped shiner
Emerald	2.730	-3.5320	-4.7100	IL (Bayley unpublished)[c]
Golden	3.08217	-3.57486	-5.24775	(Carlander 1969)[d]
Spottail	2.98913	-3.49145	-5.03363	MN (Smith and Kramer 1964)[c]
Striped	3.320	-3.6055	-5.6124	IL (Bayley unpublished)[c]
Smelt, Rainbow	2.96408	-3.63360	-5.12117	Lake Superior (Bailey 1964)[e]
Stonecat	2.862	-3.3759	-4.7390	IL (Bayley unpublished)[c]
Stoneroller				Use horneyhead chub
Sturgeon, Lake	3.13960	-3.86356	-5.61713	MI (Baker 1980)[c]
Sucker, all				Use white
Hog	3.16433	-3.57116	-5.35946	(Carlander 1969)[e]
Longnose	3.05946	-3.41194	-5.05295	(Carlander 1969)[d]
Spotted				Use golden redhorse
White	3.00004	-3.40672	-4.96508	
Sunfish, all				Use longear
Green	3.1644	-3.2813	-5.0697	IL (Bayley and Austen 1987)[c]
Longear	3.16	-3.26	-5.04	IL (Lewis and Elder 1952)[c]
Redear	3.33276	-3.43879	-5.46370	(Carlander 1977)[d]
Topminnow, Blackstripe	3.326	-3.5513	-5.5659	IL (Bayley unpublished)[c]
Trout, Brook (lakes)	3.14041	-3.57650	-5.33120	
(streams)	2.98634	-3.43599	-4.97427	
Brown (lakes)	3.00809	-3.37430	-4.94311	
(streams)	3.01000	-3.46113	-5.03265	
Lake	3.17882	-3.71034	-5.51900	
Rainbow (all)	3.05253	-3.51688	-5.14777	
Splake	3.37517	-3.91829	-6.00279	to 21". Higgins L. + WI (Brynildson & Kempinger 1970)[e]
Trout-perch				Use white sucker
Walleye	3.03606	-3.53280	-5.14176	
Warmouth	3.20625	-3.27670	-5.12390	MI (Schneider unpublished)[e]
Whitefish, Lake	3.29176	-3.82670	-5.79403	Carlander 1969)[d]
Round	3.18825	-3.76016	-5.58208	(Carlander 1969)[e]

[a] Under the species heading, the lines ending in "all" (e.g., Bullhead, all) are to be used for either: fish not identified to species, any species not listed separately, or each species in the group.
[b] Restrictions because of size range or source are noted. Otherwise, regression is based on an average of several to many Michigan populations.
[c] A regression equation from the source was used to calculate English and metric equivalents.
[d] Regressions were fit to the means, mean of means, or medians provided by Carlander (1969; 1977).
[e] Regressions were fit to raw or pooled data provided by the source.
[f] Under the species heading, the lines ending in "all" (e.g., Bullhead, all) are to be used for either: fish not identified to species, any species not listed separately, or each species in the group.
[g] Restrictions because of size range or source are noted. Otherwise, regression is based on an average of several to many Michigan populations.

Table 17.2.–Length-weight relationships (inches-pounds) for wild panfish.

Length (inches)	Bluegill	Pumpkin-seed	Redear sunfish	Warmouth	Green sunfish	Longear sunfish	Rainbow smelt
1.5	.0018	.0020	.0014	.0019	.0019	.0020	.0008
2.5	.0091	.0105	.0077	.0100	.0095	.0099	.0035
3.5	.0265	.0309	.0237	.0294	.0276	.0288	.0095
4.5	.0588	.0692	.0547	.0657	.0611	.0637	.0201
5.5	.1112	.1318	.1068	.1251	.1152	.1201	.0364
6.5	.189	.225	.186	.214	.195	.204	.060
7.5	.297	.357	.300	.338	.301	.320	.091
8.5	.442	.533	.456	.505	.457	.475	.132
9.5	.630	.762	.660	.721	.650	.676	.184
10.5	.865	1.051	.922	.994	.892	.927	.247
11.5	1.15	1.41	1.25	1.33	1.19	1.24	.32
12.5	1.50	1.84	1.65	1.74	1.54	1.61	.41

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Table 17.2.–Continued

Length	Perch		Rock	Crappie		White	Bull-
(inches)	Yellow	White	bass	Black	White	bass	head[a]
1.5	.0011	.0011	.0023	.0013	.0007	.0013	.0020
2.5	.0054	.0058	.0109	.0068	.0042	.0062	.0087
3.5	.0156	.0171	.0305	.0198	.0130	.0171	.0229
4.5	.0346	.0384	.0657	.0441	.0303	.0366	.0473
5.5	.0654	.0733	.1213	.0835	.0598	.0674	.0845
6.5	.111	.125	.202	.142	.105	.112	.137
7.5	.175	.199	.313	.224	.171	.173	.207
8.5	.260	.297	.459	.333	.261	.252	.297
9.5	.370	.425	.644	.475	.380	.354	.409
10.5	.509	.587	.874	.653	.533	.479	.545
11.5	.68	.79	1.15	.87	.73	.63	.71
12.5	.88	1.03	1.49	1.14	.96	.81	.90
13.5	1.13	1.32	1.88	1.45	1.25	1.03	1.13
14.5	1.42	1.66	2.34	1.82	1.59	1.28	1.38
15.5	1.75	2.05	2.87	2.25	1.99	1.56	1.68

[a] Weights for brown, yellow, and black bullheads are similar.

Table 17.3.–Length-weight relationships (inches-pounds) for large wild sport fish.

Length (inches)	Large-mouth Bass	Small-mouth Bass	Walleye	Northern pike	Muskel-lunge	Lake sturgeon	Channel Catfish	Flathead Catfish	Lake whitefish
1.5	.0013	.0016	.0010	.0005	.0002	.0005	.0005	.0009	.0006
2.5	.0065	.0077	.0047	.0025	.0013	.0024	.0027	.0045	.0030
3.5	.0186	.0212	.0132	.0072	.0041	.0070	.0082	.0132	.0092
4.5	.0409	.0454	.0282	.0158	.0098	.0154	.0188	.0292	.0211
5.5	.0765	.0834	.0519	.0297	.0197	.0289	.0362	.0551	.0408
6.5	.129	.138	.086	.050	.035	.049	.063	.094	.071
7.5	.202	.213	.133	.079	.057	.077	.100	.147	.113
8.5	.299	.311	.195	.117	.088	.113	.151	.219	.171
9.5	.423	.436	.273	.165	.129	.161	.217	.311	.246
10.5	.578	.590	.369	.226	.182	.220	.302	.427	.343
11.5	.77	.78	.49	.30	.25	.29	.41	.57	.46
12.5	1.00	1.00	.63	.39	.33	.38	.53	.74	.61
13.5	1.27	1.26	.79	.50	.43	.48	.69	.95	.78
14.5	1.59	1.57	.98	.62	.55	.61	.87	1.19	.99
15.5	1.95	1.92	1.21	.77	.70	.75	1.08	1.46	1.23
16.5	2.38	2.32	1.46	.94	.86	.91	1.33	1.78	1.52
17.5	2.86	2.77	1.74	1.13	1.06	1.09	1.61	2.15	1.84
18.5	3.40	3.28	2.06	1.34	1.28	1.30	1.93	2.56	2.21
19.5	4.01	3.84	2.42	1.58	1.54	1.54	2.29	3.03	2.63
20.5	4.68	4.47	2.82	1.85	1.82	1.80	2.70	3.55	3.10
21.5	5.44	5.17	3.26	2.15	2.15	2.09	3.16	4.13	3.63
22.5	6.27	5.93	3.74	2.48	2.51	2.41	3.66	4.76	4.21
23.5	7.18	6.76	4.26	2.85	2.92	2.76	4.22	5.47	4.86
24.5	8.18	7.67	4.84	3.24	3.37	3.15	4.84	6.24	5.57
25.5	9.27	8.66	5.46	3.68	3.87	3.57	5.52	7.08	6.36
26.5			6.14	4.15	4.42	4.03	6.26	8.00	7.22
27.5			6.87	4.66	5.02	4.52	7.07	8.99	8.15
28.5			7.66	5.22	5.67	5.06	7.95	10.07	9.17
29.5			8.50	5.81	6.39	5.64	8.90	11.23	10.27
30.5			9.41	6.46	7.16	6.26	9.92	12.48	11.46
31.5			10.4	7.1	8.0	6.9	11.0	13.8	
32.5			11.4	7.9	8.9	7.6	12.2	15.3	
33.5			12.5	8.7	9.9	8.4	13.5	16.8	
34.5			13.7	9.5	11.0	9.2	14.9	18.4	
35.5			14.9	10.4	12.1	10.1	16.3	20.2	
36.5				11.4	13.3	11.0	17.9	22.0	
37.5				12.4	14.6	12.0	19.5	24.0	
38.5				13.4	16.0	13.0	21.3	26.1	
39.5				14.5	17.5	14.1	23.2	28.3	

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Table 17.4.–Length-weight relationships (inches-pounds) for salmonids in streams and inland lakes.

Length (inches)	Stream trout[b]	Trout in lakes[a] Lake	Splake	Brown	Brook	Atlantic salmon
1.5	.0012	.0007	.0005	.0014	.0009	.0019
2.5	.0056	.0036	.0027	.0066	.0047	.0077
3.5	.0150	.0105	.0083	.0183	.0136	.0196
4.5	.0320	.0232	.0193	.0390	.0298	.0395
5.5	.0590	.0440	.0381	.0712	.0560	.0690
6.5	.097	.075	.067	.118	.095	.163
7.5	.148	.118	.108	.181	.148	.231
8.5	.220	.175	.165	.264	.220	.315
9.5	.306	.250	.241	.369	.312	.417
10.5	.411	.343	.338	.498	.427	.417
11.5	.54	.46	.46	.66	.57	.54
12.5	.70	.60	.61	.84	.74	.68
13.5	.87	.76	.79	1.06	.94	.84
14.5	1.08	.96	1.00	1.32	1.18	1.02
15.5	1.33	1.18	1.26	1.61	1.45	1.23
16.5	1.60	1.44	1.55	1.94	1.77	1.46
17.5	1.90	1.74	1.89	2.32	2.12	1.72
18.5	2.26	2.08	2.28	2.74	2.53	2.01
19.5	2.64	2.46	2.73	3.21	2.98	2.33
20.5	3.08	2.88	3.23	3.73	3.49	2.68
21.5	3.54	3.35	3.79	4.30	4.05	3.06
22.5	4.05	3.87	4.42	4.93	4.68	3.47
23.5	4.63	4.45	5.12	5.62	5.36	3.91
24.5	5.25	5.08	5.89	6.37	6.11	4.39
25.5	5.92	5.76	6.75	7.19	6.93	4.91
26.5	6.65	6.51	7.68	8.07		5.47
27.5	7.44	7.33	8.70	9.02		6.06
28.5	8.28	8.21	9.82	10.05		6.69
29.5	9.18	9.16	11.03	11.14		7.37
30.5	10.15	10.19	12.34	12.32		8.08
31.5		11.3	13.8	13.6		8.8
32.5		12.5	15.3	14.9		9.6
33.5		13.7	16.9	16.3		10.5
34.5		15.1	18.7	17.8		11.4
35.5		16.5	20.6	19.5		12.3
36.5		18.0	22.6			13.3
37.5		19.6	24.8			14.4
38.5		21.4	27.1			15.4
39.5		23.2	29.5			16.6

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[a] Rainbow trout in lakes are similar to stream trout.
[b] Brook, brown, and rainbow trout in streams are similar in weight.

Table 17.5.–Length-weight relationships (inches-pounds) for other large wild fish.

Length (inches)	Lake herring	Burbot	Bowfin	Common carp	Freshwater drum	Longnose gar
1.5	.0011	.0009	.0013	.0024	.0009	.0001
2.5	.0048	.0040	.0060	.0104	.0047	.0004
3.5	.0126	.0112	.0163	.0271	.0138	.0013
4.5	.0257	.0241	.0343	.0552	.0307	.0031
5.5	.0457	.0444	.0622	.0976	.0584	.0063
6.5	.073	.074	.102	.157	.100	.011
7.5	.111	.114	.156	.235	.157	.019
8.5	.158	.167	.226	.336	.235	.029
9.5	.218	.234	.314	.460	.335	.043
10.5	.290	.317	.422	.612	.462	.061
11.5	.38	.42	.55	.79	.62	.08
12.5	.48	.54	.71	1.00	.81	.11
13.5	.59	.68	.89	1.25	1.03	.15
14.5	.73	.84	1.10	1.53	1.30	.19
15.5	.88	1.03	1.34	1.85	1.60	.24
16.5	1.05	1.25	1.61	2.21	1.96	.30
17.5	1.24	1.50	1.91	2.61	2.36	.36
18.5	1.46	1.77	2.25	3.05	2.82	.44
19.5	1.70	2.08	2.64	3.54	3.34	.53
20.5	1.96	2.42	3.06	4.09	3.92	.64
21.5		2.80	3.52	4.68	4.56	.75
22.5		3.21	4.02	5.32	5.28	.88
23.5		3.66	4.58	6.02	6.06	1.03
24.5		4.16	5.18	6.78	6.93	1.19
25.5		4.69	5.83	7.59	7.88	1.37
26.5		5.28	6.53	8.47		1.56
27.5		5.91	7.29	9.41		1.78
28.5		6.58	8.10	10.41		2.02
29.5		7.31	8.97	11.48		2.28
30.5		8.09	9.90	12.62		2.56
31.5		8.9	10.9	13.8		2.9
32.5		9.8	12.0	15.1		3.2
33.5		10.8	13.1	16.5		3.6
34.5		11.8	14.3	17.9		3.9
35.5		12.8	15.5	19.4		4.4
36.5		14.0		21.0		4.8
37.5		15.2		22.7		5.3
38.5		16.4		24.4		5.8
39.5		17.7		26.3		6.3

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Table 17.6.–Length-weight relationships (inches-pounds) for suckers and redhorses.

Length	Sucker			Redhorse		
(inches)	White	Hog	Longnose	Shorthead	Golden	Silver
1.5	.0013	.0010	.0013	.0015	.0015	.0019
2.5	.0061	.0049	.0064	.0069	.0065	.0080
3.5	.0168	.0141	.0179	.0186	.0174	.0203
4.5	.0357	.0313	.0386	.0390	.0362	.0409
5.5	.0652	.0591	.0713	.0704	.0649	.0713
6.5	.108	.100	.119	.115	.105	.114
7.5	.165	.158	.184	.176	.160	.169
8.5	.241	.234	.270	.254	.230	.239
9.5	.336	.333	.380	.352	.318	.326
10.5	.454	.457	.516	.473	.425	.430
11.5	.60	.61	.68	.62	.55	.55
12.5	.77	.79	.88	.79	.71	.70
13.5	.96	1.01	1.11	.99	.88	.86
14.5	1.20	1.27	1.38	1.22	1.09	1.05
15.5	1.46	1.57	1.70	1.49	1.32	1.27
16.5	1.76	1.91	2.06	1.79	1.58	1.51
17.5	2.10	2.30	2.46	2.13	1.89	1.78
18.5	2.48	2.75	2.92	2.50	2.21	2.07
19.5	2.91	3.24	3.43	2.92	2.57	2.40
20.5	3.38	3.80	3.99	3.39	2.98	2.76
21.5	3.90		4.62	3.90	3.42	3.15
22.5	4.47		5.31	4.46	3.90	3.57
23.5	5.09		6.06	5.07	4.43	4.03
24.5	5.77		6.89	5.73	5.00	4.52
25.5	6.50		7.79	6.44	5.61	5.06

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Table 17.7.–Length-weight relationships (inches-pounds) for some non-sport fish.

Length (inches)	Gizzard shad	Alewife	Chubsucker spp.	Chub Creek	Chub Hornyhead	Grass pickerel	Stonecat
1.5	.0012	.0008	.0014	.0013	.0012	.0006	.0013
2.5	.0055	.0038	.0071	.0059	.0061	.0030	.0058
3.5	.0153	.0106	.0208	.0157	.0178	.0082	.0152
4.5	.0328	.0229	.0463	.0327	.0395	.0175	.0312
5.5	.0603	.0423	.0878	.0588	.0746	.0320	.0554
6.5	.100	.071	.150	.096	.127	.053	.089
7.5	.155	.109	.236	.146	.200	.081	.135
8.5	.226	.161	.352	.210	.297	.119	.192
9.5	.317	.226	.502	.291	.422	.166	.265
10.5	.430	.307	.690	.390	.580	.224	.352
11.5	.567	.405	.923	.509		.295	.457
12.5	.730	.523	1.204	.649		.379	.580
13.5	.922	.662	1.539	.813		.478	.723
14.5	1.146	.824	1.933	1.002		.592	.887
15.5	1.403	1.011	2.391	1.218		.724	1.074
16.5	1.70						
17.5	2.03						
18.5	2.40						
19.5	2.82						
20.5	3.28						

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Table 17.7.–Continued.

Length (inches)	Pirate perch	Tadpole madtom	Sculpin spp.	Darter Blackside	Darter Johnny	Darter Rainbow
1.5	.0021	.0016	.0015	.0049	.0010	.0011
2.5	.0101	.0078	.0081	.0145	.0051	.0065
3.5	.0286	.0223	.0241	.0326	.0148	.0205
4.5	.0625	.0485	.0545	.0624	.0331	.0483
5.5	.1164	.0905	.1047	.1072	.0630	.0956

Table 17.8.–Length-weight relationships (inches-pounds) for shiners and minnows.

	Shiner				Minnow		
Length (inches)	Golden	Spottail	Emerald	Common/ striped	Fathead	Bluntnose	Blackstripe topminnow
1.5	.0009	.0011	.0009	.0010	.0015	.0010	.0011
2.5	.0045	.0050	.0036	.0052	.0072	.0056	.0181
3.5	.0126	.0136	.0090	.0159	.0202	.0174	.0418
4.5	.0274	.0289	.0178	.0366	.0438	.0408	.0815
5.5	.0509	.0527	.0308	.0722	.0811	.0805	.1421
6.5	.085		.049	.124			
7.5	.133		.072	.199			
8.5	.195		.101	.302			
9.5	.275		.137	.437			
10.5	.374		.180	.609			
11.5	.495			.824			
12.5	.640			1.087			
13.5	.811			1.404			
14.5	1.011			1.779			
15.5	1.241			2.220			

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Table 17.9.–Length-weight relationships for hatchery-reared muskellunge, if pounds = 0.0001600 L^3.

Total length		Weight		Total length		Weight	
inches	mm	pounds	grams	inches	mm	pounds	grams
0.3	8	.0000043	0.00196	4.2	107	.0118	5.38
0.4	10	.0000102	0.00464	4.3	109	.0127	5.77
0.5	13	.0000200	0.00907	4.4	112	.0136	6.18
0.6	15	.0000346	0.0157	4.5	114	.0146	6.61
0.7	18	.0000549	0.0249	4.6	117	.0156	7.06
0.8	20	.0000819	0.0372	4.7	119	.0166	7.54
0.9	23	.000117	0.0529	4.8	122	.0177	8.03
1.0	25	.000160	0.0725	4.9	124	.0188	8.54
1.1	28	.000213	0.0966	5.0	127	.0200	9.07
1.2	30	.000276	0.0125	5.1	130	.0212	9.63
1.3	33	.000352	0.159	5.2	132	.0225	10.2
1.4	36	.000439	0.199	5.3	135	.0238	10.8
1.5	38	.000540	0.245	5.4	137	.0252	11.4
1.6	41	.000655	0.297	5.5	140	.0266	12.1
1.7	43	.000786	0.357	5.6	142	.0281	12.6
1.8	46	.000933	0.423	5.7	145	.0296	13.4
1.9	48	.00110	0.498	5.8	147	.0312	14.2
2.0	51	.00128	0.581	5.9	150	.0329	14.9
2.1	53	.00148	0.672	6.0	152	.0346	15.7
2.2	56	.00170	0.773	6.1	155	.0363	16.5
2.3	58	.00195	0.883	6.2	158	.0381	17.3
2.4	61	.00221	1.00	6.3	160	.0400	18.2
2.5	64	.00250	1.13	6.4	163	.0419	19.0
2.6	66	.00281	1.28	6.5	165	.0439	19.9
2.7	69	.00315	1.43	6.6	168	.0460	20.9
2.8	71	.00351	1.59	6.7	170	.0481	21.8
2.9	74	.00390	1.77	6.8	173	.0503	22.8
3.0	76	.00432	1.96	6.9	175	.0525	23.8
3.1	79	.00477	2.16	7.0	178	.0549	24.9
3.2	81	.00524	2.38	7.1	180	.0573	26.0
3.3	84	.00575	2.61	7.2	183	.0597	27.1
3.4	86	.00629	2.85	7.3	185	.0622	28.2
3.5	89	.00686	3.11	7.4	188	.0648	29.4
3.6	91	.00746	3.39	7.5	190	.0675	30.6
3.7	94	.00810	3.68	7.6	193	.0702	31.9
3.8	96	.00878	3.98	7.7	196	.0730	33.1
3.9	99	.00949	4.31	7.8	198	.0759	34.4
4.0	102	.0102	4.64	7.9	201	.0789	35.8
4.1	104	.0110	5.00	8.0	203	.0819	37.2

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Table 17.10.–Length-weight relationships for hatchery-reared walleye, if pounds = 0.000300 L^3.

Total length		Weight		Total length		Weight	
inches	mm	pounds	grams	inches	mm	pounds	grams
0.3	8	.0000081	0.00367	4.2	107	.02223	10.1
0.4	10	.0000192	0.00871	4.3	109	.02385	10.8
0.5	13	.0000375	0.0170	4.4	112	.02556	11.6
0.6	15	.000065	0.0294	4.5	114	.02734	12.4
0.7	18	.000103	0.0467	4.6	117	.02920	13.2
0.8	20	.000154	0.0697	4.7	119	.03115	14.1
0.9	23	.000219	0.0992	4.8	122	.03318	15.0
1.0	25	.000300	0.136	4.9	124	.03529	16.0
1.1	28	.000399	0.181	5.0	127	.03750	17.0
1.2	30	.000518	0.235	5.1	130	.03980	18.0
1.3	33	.000659	0.299	5.2	132	.04218	19.1
1.4	36	.000823	0.373	5.3	135	.04466	20.3
1.5	38	.001013	0.459	5.4	137	.04724	21.4
1.6	41	.001229	0.557	5.5	140	.04991	22.6
1.7	43	.001474	0.669	5.6	142	.05268	23.9
1.8	46	.001750	0.794	5.7	145	.05556	25.2
1.9	48	.002058	0.933	5.8	147	.05853	26.6
2.0	51	.002400	1.09	5.9	150	.06161	28.0
2.1	53	.002778	1.26	6.0	152	.06480	29.4
2.2	56	.003194	1.45	6.1	155	.06809	30.9
2.3	58	.003650	1.66	6.2	158	.07150	32.4
2.4	61	.004147	1.88	6.3	160	.07501	34.0
2.5	64	.004687	2.13	6.4	163	.07864	35.7
2.6	66	.005273	2.39	6.5	165	.08239	37.4
2.7	69	.005905	2.68	6.6	168	.08625	39.1
2.8	71	.006586	2.99	6.7	170	.09023	40.9
2.9	74	.007317	3.32	6.8	173	.09433	42.8
3.0	76	.008100	3.67	6.9	175	.09855	44.7
3.1	79	.008937	4.05	7.0	178	.10290	46.7
3.2	81	.009830	4.46	7.1	180	.10737	48.7
3.3	84	.01078	4.89	7.2	183	.1120	50.8
3.4	86	.01179	5.35	7.3	185	.1167	52.9
3.5	89	.01286	5.83	7.4	188	.1216	55.1
3.6	91	.01400	6.35	7.5	190	.1266	57.4
3.7	94	.01520	6.89	7.6	193	.1317	59.7
3.8	96	.01646	7.47	7.7	196	.1370	62.1
3.9	99	.01780	8.07	7.8	198	.1424	64.6
4.0	102	.01920	8.71	7.9	201	.1479	67.1
4.1	104	.02068	9.38	8.0	203	.1536	69.7

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Table 17.11.–Length-weight relationships for hatchery-reared brook, brown, and rainbow trout.

Length (inches)	Weight (pounds)	Length (inches)	Weight (pounds)	Length (inches)	Weight (pounds)
1.0	.0004	5.3	.0565	9.6	.352
1.1	.0006	5.4	.0600	9.7	.364
1.2	.0007	5.5	.0645	9.8	.376
1.3	.0009	5.6	.0685	9.9	.388
1.4	.0011	5.7	.0730	10.0	.399
1.5	.0013	5.8	.0775	10.1	.410
1.6	.0015	5.9	.0835	10.2	.422
1.7	.0018	6.0	.0900	10.3	.435
1.8	.0021	6.1	.0950	10.4	.447
1.9	.0025	6.2	.1000	10.5	.461
2.0	.0029	6.3	.105	10.6	.475
2.1	.0033	6.4	.110	10.7	.489
2.2	.0037	6.5	.115	10.8	.503
2.3	.0042	6.6	.120	10.9	.518
2.4	.0046	6.7	.126	11.0	.532
2.5	.0050	6.8	.132	11.1	.545
2.6	.0058	6.9	.138	11.2	.560
2.7	.0069	7.0	.144	11.3	.575
2.8	.0080	7.1	.151	11.4	.590
2.9	.0095	7.2	.158	11.5	.605
3.0	.0109	7.3	.165	11.6	.621
3.1	.0122	7.4	.172	11.7	.639
3.2	.0138	7.5	.179	11.8	.655
3.3	.0152	7.6	.186	11.9	.672
3.4	.0165	7.7	.193	12.0	.690
3.5	.0180	7.8	.199	12.1	.706
3.6	.0195	7.9	.205	12.2	.723
3.7	.0210	8.0	.211	12.3	.740
3.8	.0225	8.1	.219	12.4	.758
3.9	.0245	8.2	.227	12.5	.777
4.0	.0265	8.3	.235	12.6	.798
4.1	.0287	8.4	.244	12.7	.819
4.2	.0308	8.5	.251	12.8	.839
4.3	.0329	8.6	.259	12.9	.860
4.4	.0350	8.7	.267	13.0	.880
4.5	.0370	8.8	.274	13.1	.904
4.6	.0390	8.9	.282	13.2	.928
4.7	.0410	9.0	.290	13.3	.952
4.8	.0434	9.1	.300	13.4	.975
4.9	.0459	9.2	.310	13.5	1.00
5.0	.0482	9.3	.320	13.6	1.02
5.1	.0509	9.4	.330	13.7	1.05
5.2	.0535	9.5	.340	13.8	1.07

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Chapter 18: Sampling Zooplankton in Lakes

Merle G. Galbraith, Jr. and James C. Schneider

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Chapter 18: Sampling Zooplankton in Lakes

Merle G. Galbraith, Jr. and James C. Schneider

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This chapter describes methods for sampling zooplankton in lakes, laboratory procedures for determining the number of large (≥1.4 mm) zooplankters, and applications of results.

18.1 Equipment

- A portable fathometer for locating the sampling sites.
- Equipment for determining dissolved oxygen.
- A Wisconsin-style plankton net with straining bucket. Net 30-inches long with mesh size of 153- or 160-µm nytex netting and mouth opening of 4.5-5 inches. May use larger mouth diameters if numbers caught are adjusted to an area of 16 square inches.
- Three 125-ml plastic wash bottles with fine-tipped spouts.
- Widemouth bottles, 3- or 4-ounce, to preserve samples.
- Formalin.
- A homemade filter funnel of No. 30 mesh brass screening (0.006-inch openings), made with a pouring spout.
- A pipet for removing subsamples.
- A petri dish (grid counting) or other type of counting chamber.
- Binocular microscope, at least 20× magnification, with an ocular micrometer which covers as a wide field as possible.

Suggested sources of equipment:

Wildco Instruments, 301 Cass Street, Saginaw, MI 48602 (catalog no. 40-A65)

Phoenix Wire Works, Inc., 585 Stephenson Hwy, Troy, MI 48084

18.2 Sample sites

Most lakes have one large basin with a zone of deoxygenated water in summer. This lake type should be sampled as follows. Determine the depth at which dissolved oxygen is *less* than 0.5 ppm. This depth will hereafter be referred to as the "critical depth" because zooplankton will not occur below it. Retrieval of the plankton net should begin at that depth. To locate sampling stations, divide the lake into four quadrants centered over the deepest basin (Figure 18.1). One axis of the quadrants should be in line with the direction of the wind. Choose a site on each axis as far out from the center as possible and near where critical depth intersects the lake bottom. Allow enough room below the critical depth so that the plankton net will not stir up bottom sediments.

Some lakes, with greater depth or lower productivity (oligotrophic), retain some dissolved oxygen in bottom waters during summer. The oxygen may be confined to a very small basin and, if one uses the critical depth previously defined, the sampling stations will be too close together. Therefore, the critical depth is redefined as the lower limit of zooplankton. To find that critical depth, take water samples with a Kemmerer bottle (or similar device) from the deepest part of the lake at 2-foot intervals, progressing upward from the bottom. Draw at least three-fourths of the water from the

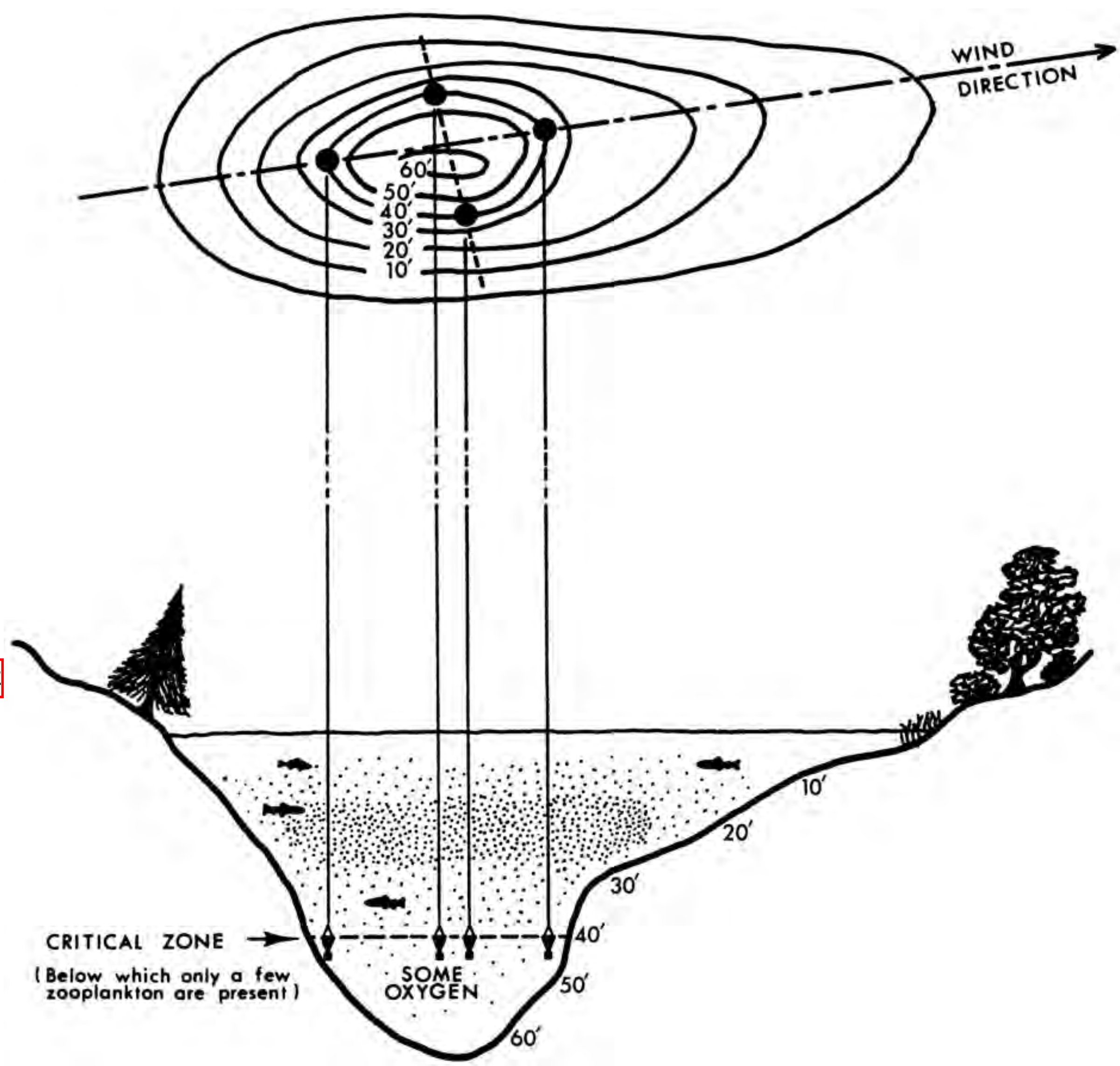

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Fig 18.1–Location of stations for sampling zooplankton in a deep lake with little or no oxygen depletion.

sampler into a standard 250-ml water bottle, stopper it, and examine the contents for zooplankton. Holding the bottle toward a light background will aid visual inspection. If several zooplankters are observed, take another sample 1 foot deeper. The critical depth will either be at that depth or deeper.

Other lakes are so shallow that dissolved oxygen occurs throughout the water column and there is no critical depth. Instead, select station locations, with equal depth, that are approximately equidistant from the center of the lake and the shoreline. This lake type also should be divided into quadrants, as described above.

If a lake has more than one basin, one or both criteria for determining critical depths may have to be used to locate sampling sites. In some of these lakes, the zone of deoxygenated water may be similar in every basin, so there is no need to intensively sample each one. However, if the oxygen profiles of the basins differ, then each should be sampled separately. At least two stations should be sampled in each "different" basin at locations 180° from each other, and all counts from the lake should be averaged for computing average plankton density.

Note that one sample collected from each lake quadrant is barely adequate for estimating plankton populations. An additional sample from the center of the quadrants, and the same critical depth, will probably improve the estimate. If even more samples are deemed necessary, select station locations in pairs 180° apart. Be cognizant of wind direction (both current and preceding) because strong continuous winds tend to "pile up" zooplankton on the lee side of a lake.

18.3 Taking samples

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As a precaution, tie net, bucket, and brass stopper together with a safety string to prevent loss of parts. To minimize agitation of the bottom, always lower the net very slowly and carefully for the last 3 feet. Upon reaching the proper depth, pause for at least 30 seconds, then raise the net at a rate of approximately 4 feet per second. A hand reel with revolving handles on both sides will greatly facilitate smooth, uninterrupted retrieval. Raise the net out of the water in one motion until the plankton bucket is just above the surface. While hanging on to the net with one hand, splash lake water on the *outside* of the net to dislodge plankton that may still adhere to the inside of the net. After washing all plankton into the bucket, detach the bucket and wash down its sides with a 125-ml wash bottle. Remove stopper, and allow sample to drain into a preservation bottle while washing the inside of the bucket with a squeeze bottle. Add enough formalin to make approximately a 5% solution.

18.4 Lab procedures

If interested only in the larger zooplankton (≥1.4 mm), pour the contents of a sample through a 30-mesh screen to get rid of the smaller organisms. Thoroughly wash the contents through the screen using either a wash bottle, or a 5-mm (inside diameter) tap hose to which a small tapered eyedropper is attached. When using the hose, be sure to regulate water pressure carefully beforehand so that organisms are not accidentally splattered off the screen or forced through it. Pour screen contents into a counting dish containing 70% alcohol.

Examine the washed sample under magnification and count zooplankters ≥1.4 mm. An ocular micrometer should be installed in the microscope eyepiece to make measurements. Measure daphnids from the crest of the head to the base of the spine and copepods from the head to the last segment on the tail which bear the long hairs. After measuring organisms in a few samples it will become easy to judge size of most zooplankters.

If there are too many zooplankters in a sample to easily count (i.e., over 200 individuals of each of several species), then a sample may be properly diluted to a known volume and subsampled. The proper dilution is when at least 30 organisms of each of the common species, or of a particular species, will be in a l-ml aliquot subsample. To remove an aliquot from a sample, use a Wildco-Hensen-Stemple pipet, with plunger spring, designed for this purpose. Alternatively, use an automatic pipet with a tip constructed from a burette tip (2-3 inches long, inside diameter ≥5 mm).

While removing each aliquot, gently agitate the sample so that plankton is uniformly dispersed. Take five l-ml aliquots subsamples, make counts of organisms in each, and average them. The total count for a sample is calculated by multiplying this average by the original total volume of liquid in the sample. After counting organisms in an aliquot, they must all be returned to the sample before removing the next aliquot.

As a final step, volume and relative size of large zooplankton (mostly daphnids) may be determined. First, pour the sample containing large zooplankton into a centrifuge tube and spin it until the zooplankton stops settling. Next, read their volume (in cc) from the graduated marks on the tube. Finally, compute "volumetric index" (another measure of zooplankter size) by dividing volume by number of large daphnids per sample, then multiplying by 1000.

18.5 Computations and applications

The density of each important species in a lake may be calculated from average counts per sample, per quadrant, and per lake. Ultimately, density can be expressed either in number of organisms per net haul, per lake surface area, or per volume of water strained through the plankton net. The later two require that area of the mouth of the plankton net be known; the volume calculation additionally requires that distance (depth) the net was raised be factored in. A complication with this seemingly simple calculation is that volume of water actually strained will be less than so computed because water "piles up" in front of the net's mouth, especially if the net is pulled too fast. (Volume of water actually strained is most accurately measured by a flow meter mounted on the net.) That is why it is important to maintain the recommended pulling speed (see above), so that a consistent estimate of *relative* density will be obtained across samples.

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Large *Daphnia* ($\geq$ 1.4 mm) are useful indicators of habitat and food conditions for both bluegill and rainbow trout. Lakes with larger *Daphnia* tend to have faster growing bluegills (Theiling 1990) and, therefore, are more likely to have larger bluegills (Schneider 1981 and 1990). Galbraith (1975) related zooplankton to rainbow trout stocking success (i.e., growth and survival). He found that poor trout lakes had less than 100 large daphnids per net haul (and the volumetric index was <0.65) and good trout lakes had more than 150 large daphnids per net haul (and the volumetric index was > 0.80). Galbraith's guidelines should be applied to the management of small trout lakes.

Zooplankter mean length is also an indicator of overall fishing quality (Mills et al. 1987). In the State of New York, zooplankton sampling during spring and midsummer is a standard element of routine lake surveys. The information is used to evaluate relative year class strength of young fish, relative abundance of older planktivors, and predator-prey ratios.

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Chapter 19: Measurement of Stream Velocity and Discharge

Frank F. Hooper and Steven L. Kohler

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Chapter 19: Measurement of Stream Velocity and Discharge

Frank F. Hooper and Steven L. Kohler

There can be a number of reasons to measure stream flow characteristics:

- To describe the habitat of fish and benthic invertebrates in relation to current preferences;
- To determine the amounts (weight) of materials being transported in the stream (sediment load, nutrient mass);
- To estimate land runoff rates (discharge per unit of watershed area) for agriculture and flood predictions;
- For river basin development in terms of (a) flood control, (b) industrial and domestic water supply potential, and (c) irrigation projects.

The pattern of stream flow is based on several hydrologic features inherent to natural stream channels. Stream velocities are not uniform in all parts of a traverse section but are reduced near the surface due to friction with the surface tension and along the bottom or sides of the channel due to friction with a solid surface (Figure 19.1). For this reason, in studies of organisms that reside on the bottom, one may find velocities at the bottom interface are more important than the average velocity of the stream. Methods for current measurements very close to a surface are not well established and are often considered imprecise. However, for biological studies in streams such measurements may be critical. Hynes (1970) cites a number of such methods.

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The maximum velocity in streams is usually found in the upper one-third of the water column (Figure 19.2). However, in shallow streams the region of maximum velocity is near the surface and in deep rivers the maximum is usually at the one-third point. The mean velocity at any point across a stream is ordinarily at 0.55 to 0.65 of the depth. The velocity at 0.6 of the depth is usually within 5% of the mean velocity.

The exact distribution of velocities in natural streams is governed by several factors operating simultaneously. These are:

- Shape of the channel;
- Roughness of the channel;
- Size of the channel;
- Slope of the channel.

Details of how these factors interact to determine the velocity of water are discussed in Hynes (1970) and Whitton (1975).

Velocity measurements with mechanical current meters (e. g., Price-Gurley meters) are usually taken at 0.4 of the depth for shallow streams and at both 0.4 and 0.6 of the depth (then averaged) for rivers or streams having bottom obstructions. Ice cover reduces surface velocity more than air. Therefore, under ice conditions, mean velocity is taken as the average of velocities at the 0.2 and 0.8 points of depth.

Stream discharge (units of volume/time) is dependent upon the product of two somewhat independent measurements: velocity (units of distance/time) and cross-sectional area (an area measure). Current velocity and discharge may be estimated in a variety of ways.

19.1 Methods for Current Measurement

Current velocity may be measured using various types of meters and devices. Apparatus and procedures are described in more detail in Welch (1948) and Buchanan and Sommers (1973). A brief discussion of these methods follows.

19.1.1 Embody Float Method

One of the simplest ways of measuring velocity and discharge in a stream is to use a floating object (Davis 1938). The best objects float just beneath the surface and avoid wind effects. Oranges serve as good floats because they have the right buoyancy and are quite visible. By measuring the time such a float takes to travel downstream over a known distance, one obtains an estimate of the surface velocity. Repeating the float measurement over the same stretch of stream but at various distances from shore will give, when averaged, a rough estimate of the average surface velocity. To obtain an estimate of discharge, measure the average time (t, usually in seconds) for the float to travel the known distance (l) of stream, and measure average depth (d) and average width (w) (preferably made at two or more stream transects). With these data, discharge (Q) is given by:

$$Q = \frac{w\,d\,l\,a}{t}$$

The constant "a" of this formula is a correction factor that relates surface velocity to overall stream mean velocity. This constant varies with the degree of roughness of the stream bottom from 0.9 for sand or mud to 0.8 for coarse gravel or loose rock.

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19.1.2 Current Meters (Price-Gurley)

The best known and most dependable mechanical current meter for measuring stream flow is the Price pattern Gurley meter manufactured by the W. and E. Gurley Company. The original Gurley current meter was designed in 1882; the latest model is called Type AA. Stream velocities are measured with a carefully balanced bucket wheel mounted on a pivot. Upon each rotation of the bucket wheel, or every fifth turn depending on the contact setting, an electrical impulse is produced. The impulse may be heard as a click over headphones or recorded on a counter. By noting the number of impulses per unit time, velocity may be determined by consulting the special rating chart prepared for each instrument. The Type AA is capable of accurately measuring velocities from 0.1 to 10 ft/sec. A smaller version of this meter, called the Pygmy Gurley current meter, allows closer measurements to the stream bottom and operates at somewhat slower velocities.

The Type AA Gurley current meter or the Pygmy Gurley may be suspended from either a wading rod assembly or a flexible cable assembly employing a 15-pound torpedo-shaped lead weight.

Use of these current meters with a headphone apparatus requires the operator to count the number of clicks produced by the instrument over a known length of time. Thus, a stopwatch or watch with a second hand is needed. One should select a location in the stream where there is a minimum of turbulence (no eddy currents). When using the current meter for the most accurate work, attach the directional fins available with the unit. These fins allow one to determine both current rate and current direction. This is important because flow does not always move straight downstream, parallel to the banks, so a correction is required. With the fins attached, the angle of deviation from parallel can be measured and looked up in a table of correction coefficients ("K"). The K coefficient multiplied by velocity gives an exact measure of current moving directly downstream at the sampled site. Details of this procedure are best left for the instructions included with each meter.

Alternatively, one can obtain a more approximate estimate of discharge with the current meter by ignoring directional variability of flow. In this simpler method, omit the fins and measure the current at 0.6 of the depth at selected intervals along a transect line. The arithmetic average of these values gives an overall mean velocity across that transect. If one also records, along the same transect, water depth at selected intervals and total stream width, these results can be plotted on graph paper. This width-depth plot can be used to estimate the stream's cross-sectional area by simply counting squares on the graph and applying an appropriate weighting factor for each square. Multiplying cross-sectional area by mean velocity produces an estimate of discharge at that transect. One should measure discharge at two or more transects in close proximity to estimate the average discharge of the river in a particular reach.

19.1.3 Cone and Rubber Bag Method

A simple, inexpensive device for measuring current velocity has been described by Hynes (1970). The device consists of a truncated cone with a small opening (less than 10 mm diameter) which has a rubber bag attached to its base. It is helpful if the bag is surrounded by a clear, open-ended plastic cylinder (Figure 19.3). A suitable cone is a small, plastic garden hose attachment. Balloons are suitable rubber bags; they should be long and relatively large. A balloon is easily attached to the garden hose cone using the rubber washer that is supplied with the cone.

19.1.3.1 Operation.–Close the cone opening with a finger and place the device, facing into the current, at the point where a measurement is to be made. (This should be a measured distance from the bottom for precision and replication). Remove the finger for a few seconds (precisely timed—usually 5 seconds or less, depending upon the size of the cone opening, the size of the bag, and the current velocity) and then replace it. Measure the volume of water collected with a graduated cylinder. The measurement should be repeated several times at each sampling point. An average of four or five measurements should always be used; use more for precise work.

Sampling time should be chosen so that the bag does not become full. In relatively fast currents (more than 50 cm/s), this necessitates the use of either short sampling times or fairly large bags. The latter is preferable because more error is associated with measuring short time intervals. Be sure the bag is empty between measurements. Air should be expelled by squeezing the bag before placing a finger over the opening.

19.1.3.2 Calculations.–Current velocity is determined using the discharge relationship:

$$V = \frac{Q}{A} ,$$

where: V = velocity (cm/s);

$$Q = \frac{\text{volume of water sampled in milliliters (ml)}}{\text{time for sample in seconds (s)}} ,$$

$$A = \pi\left(\frac{D}{2}\right)^2 ,$$ with D the diameter of the cone opening in centimeters (cm).

This gives V in units of cm/s (30.5 cm/s = 1 ft/s). D should be measured as precisely as possible. Since Q is a linear function of V (with slope A), a plot of Q versus V can be prepared and used to provide a quick estimate of V in the field.

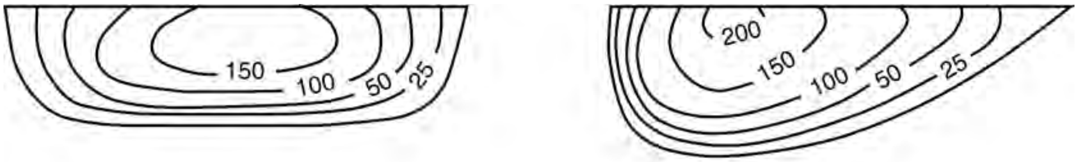

Figure 19.1–Idealized diagrams of the patterns of flow in cross-section of open channels: left shows the pattern on a straight reach, right shows the pattern on a bend. The units on the lines of equal flow-rate could be centimeters per second. (modified from Hynes 1970)

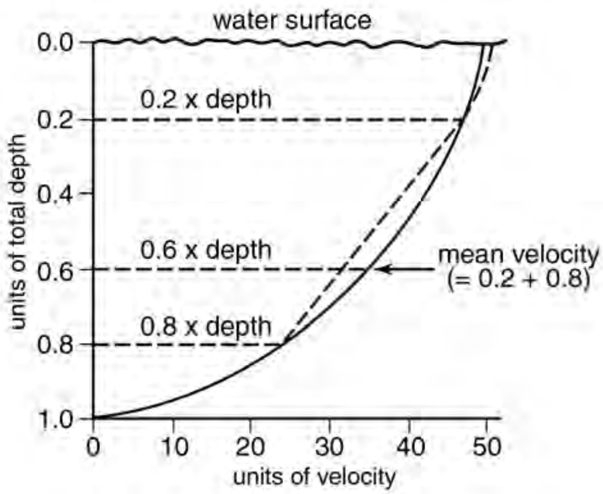

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Figure 19.2–The rate of flow of water at different depths in an open channels, and depths at which the mean flow can be measured. (modified from Hynes 1970)

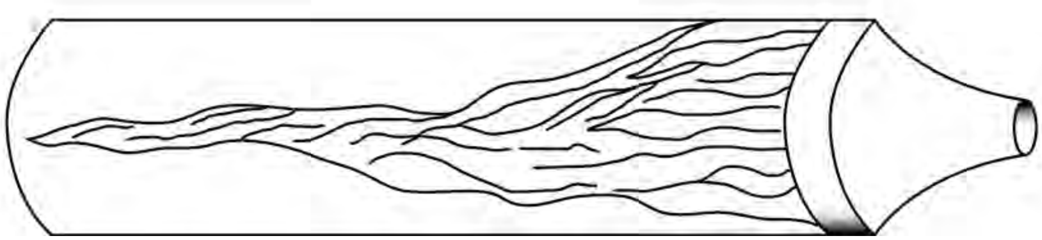

Figure 19.3–A rubber-bag current meter. (from Hynes 1970)

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Chapter 20: Michigan Stream Classification: 1967 System

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Chapter 20: Michigan Stream Classification: 1967 System

Anonymous

[Editor's note: The 1967 classification served as the basis for the subsequent "Director's list of Designated Trout Streams". Very recently (see 2000 Michigan Fishing Guide) Michigan streams (and lakes) were classified on the basis of the most appropriate trout and salmon fishing regulations. A landscape-based ecological classification of rivers is currently in progress (see Seelbach et al. 1997, Research Report 2036).]

Michigan's 36,000 miles of streams occur in all degrees of size, quality, and development. A classification system is prerequisite to orderly and effective fish and recreation management programs.

A previous classification of trout streams proved valuable in adopting trout management policy and providing a basis for habitat protection. The new classification will involve a revision of the existing trout stream classification and an extension to include warmwater streams. It will serve as the means for identification of legally defined trout streams. The new system will also include additional inventories to provide a more comprehensive basis for establishing policy and action programs for the management of fisheries, streams, and related lands. Streams will be classified by: I-Type and quality, II-Size, and III-Extent of building development. The inventory will be applicable in the following situations: establishment of water quality standards; determination of recreation values; "wild" or "scenic" river designations; stream and stream frontage improvement and preservation; dam and impoundment problems; fishing and boating access programs; fishing regulations; research planning; fish planning and management; and stream land acquisition.

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20.1 Part I–Stream type and quality

20.1.1 Non-anadromous

Top quality trout mainstream.–Contain good self-sustaining trout or salmon populations and are readily fishable; typically over 15 feet wide.

Top quality trout feeder stream.–Contain good self-sustaining trout or salmon populations but difficult to fish due to small size; typically less than 15 feet wide.

Second quality trout mainstream.–Contain significant trout or salmon populations but these populations are appreciably limited by such factors as inadequate natural reproduction, competition, siltation, or pollution. Readily fishable; typically 15 feet wide.

Second quality trout feeder stream.–Contain significant trout or salmon populations, but these populations are appreciably limited by such factors as inadequate natural reproduction, competition, siltation, or pollution. Difficult to fish because of small size; typically less than 15 feet wide.

Top quality warmwater mainstream.–Contain good self-sustaining populations of warmwater game fish and are readily fishable; typically over 15 feet wide.

Top quality warmwater feeder stream.–Contain good self-sustaining populations of warmwater game fish, but are difficult to fish because of small size; typically less than 15 feet wide.

Second quality warmwater mainstream.–Contain significant populations of warmwater fish, but game fish populations are appreciably limited by such factors as pollution, competition, or inadequate natural reproduction. Readily fishable; typically over 15 feet wide.

Second quality warmwater feeder stream.–Contain significant populations of warmwater fish, but game fish populations are appreciably limited by such factors as pollution, competition, or inadequate natural reproduction. Difficult to fish because of small size; typically less than 15 feet wide.

20.1.2 Designation of existing runs of anadromous trout and salmon, Director's designated trout streams

Streams, or stream sections, that currently receive significant runs of anadromous trout or salmon are also to be designated as trout streams, regardless of whether they are "trout" or "warmwater" according to the above classification. These streams, together with the additional streams classified as trout in Part I, will constitute our legally designated trout streams. This meets our obligation to designate those streams that, in the opinion of the Director of the Natural Resources Department, contain significant populations of trout or salmon.

In outline form this stream type and quality classification can be presented as follows:

I. Trout stream
- A. Top quality
  1. Mainstream
  2. Feeder stream
- B. Second quality
  1. Mainstream
  2. Feeder stream

II. Warmwater stream
- A. Top quality
  1. Mainstream
  2. Feeder stream
- B. Second quality
  1. Mainstream
  2. Feeder stream

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Anadromous designation: Additive to each of the above, when applicable.

20.1.3 Discussion

Usually, top quality trout streams will not require stocking as a management procedure. However, it will not be necessary to designate a stream second quality to justify stocking. All streams should be classified as your judgment dictates, and if for some reason you deem it advisable to stock a top quality trout stream, the matter will be resolved on its own merits, not entirely on the basis of this classification.

A value judgment will have to be made for streams that contain warmwater game fish populations year-round as well as anadromous runs of trout and salmon during certain parts of the year. If, in your opinion, the runs of anadromous fish are significant enough to warrant the protection provided by legal classification as a trout stream, the stream should be classified as anadromous. If, however, the warmwater fishery that would be made unavailable by trout stream classification outweighs in value expected losses of trout or salmon, then the stream should not be classified as anadromous.

In this classification system the term "feeder" can, on the basis of size, be applied to a stream that flows directly into one of the Great Lakes. Similarly, the term "mainstream" can be applied to a stream that does, in fact, feed another larger stream.

Two criteria—fishability and 15-foot width—are provided for differentiating between "mainstream" and "feeder stream." Usually, the two criteria will be complementary, but when this is not the case, fishability is to be the dominant criterion, with the 15-foot criterion used to help resolve difficult cases, or to handle abnormal situations such as recently ditched or extraordinarily brushy streams.

20.1.4 Mapping

Part I of the inventory will be recorded on one map; parts II and III on a second map. One-inch-to-the-mile maps showing public ownership are to be utilized. This will permit the subsequent measurement of stream classes by ownership category.

The classification will be indicated on maps by coloring the thread of the stream by color code and pattern. Trout streams will be indicated by a cold color, blue, and warmwater streams will be indicated by a warm color, red. Top quality waters will be indicated by the primary colors, blue or red, and second quality waters by the respective yellow modification, green or orange. Mainstreams will be indicated by a solid line, approximately 1/8 inch wide, and tributaries will be indicated by a broken or dashed line of the same width.

To signify runs of anadromous trout or salmon, superimpose upon the classifications in Part IA a series of arrows pointing upstream. The arrows should proceed upstream in each drainage to the point where the runs stop or become insignificant.

The following is a list of the categories and their proper colors and color patterns:

Top quality trout mainstream	
	BLUE
Top quality trout tributary	
Second quality trout mainstream	
	GREEN
Second quality trout tributary	
Top quality warmwater mainstream	
	RED
Top quality warmwater tributary	
Second quality warmwater mainstream	
	ORANGE
Second quality warmwater tributary	

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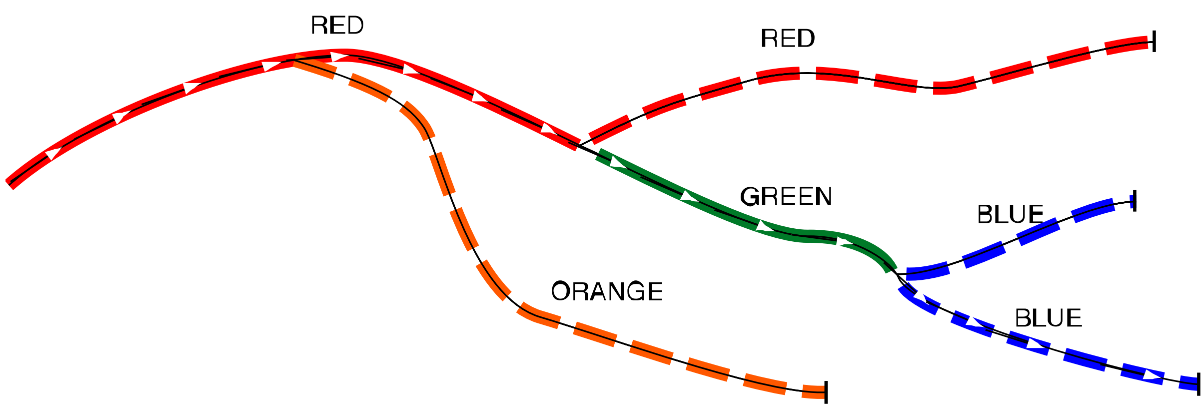
Application of system, illustrating use of anadromous symbol**:**



20.2 Part II–Stream size

Stream size category definitions and criteria below are based on boatability. This classification provides information which will be useful not only to boating, but also for the following factors: Capacity of stream to provide fish and fishing; capacity to handle waste effluents; scenic attraction; scale of problems involved in impoundment and bridge construction; capacity of stream to attract development and to withstand impact of development; etc. It is realized that a size classification based only on boatability is less than ideal, but it has been selected as being the most feasible of the several alternative systems considered. (It is not intended that this size classification be based on "navigability" in its legal sense. The treatment of legal navigability and public status of waters is not within the purpose or scope of this inventory.)

20.2.1 Stream size categories

Very small stream.–With perennial flow (except that streams not flowing during infrequent short periods during dry summers are to be included), but too small for canoe travel. Temporary barriers to canoe travel, such as windfalls or fences, will not serve as criteria for applying this category.

Small stream.–Canoeable, with difficulty. Limitations imposed by amount of wading or lift-overs required, extended low water periods, rockiness, etc. Streams with removable windfall barriers can be considered as canoeable if volume, etc., is otherwise adequate.

Medium stream.–Readily canoeable, with not more than a limited number of lift-overs or portages; or requiring only occasional and short-stretch wading.

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Large stream.–Of a size that will permit the use of small to medium-sized outboard motorboats, but too small to permit the use of large outboard or inboard motorboats.

Very large stream.–Of a size that will permit use of large outboard and inboard motorboats.

20.2.2 Fluctuating stream subclass

Streams having an extended high-flow period, during which its rating would be one size class larger than during the major part of the dominant fishing-recreation season, can be placed in a subclass.

Stream class should be based on size of the stream during the season of dominant fishing and recreation use, or the major part of the total fishing-recreation year. In most cases, the fact that a stream typically has a high flow during spring runoff and lower flow during some weeks in the summer can be ignored, since this is fairly typical for Michigan streams.

However, the pattern of flow fluctuation in some streams is of such character as to establish significantly different use patterns and use potential in different seasons. Therefore, *a seasonal high flow* subclass can be applied if the following criteria apply: (a) the flow is sufficiently high as to raise the class by *at least* one level; (b) the season is sufficiently protracted, sufficiently dependable, and desirably timed as to weather characteristics; and (c) all in all, the high flow period presents a distinct recreational or fishing use opportunity, present or potential. This subtype should be applied conservatively.

20.2.3 Part II–Mapping (Stream size)

Stream size will be indicated by coloring the thread of the stream one of five colors, progressing from largest to smallest: brown, violet (purple), red, orange, and yellow. The color line should be about 1/8 inch wide.

The purpose of the survey does not include the identification of individual riffles and pools. Therefore, you are not asked to indicate change in size class unless, usually, a stretch of at least 2 miles is involved.

Seasonal high flow subclass streams will be indicated by entering a narrow black line adjacent to the basic stream size symbol. (Basic color will refer to size during the major part of the fishing-recreation season.) This line should be entered on the left side, looking upstream.

These are the stream size symbols:

		Standard Symbol	Seasonal high flow Subclass symbol
Very small stream	Yellow		
Small stream	Orange		
Medium stream	Red		
Large stream	Violet		
Very large stream	Brown		

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20.3 Part III–Stream zone development

A development is a building or set of buildings, of whatever kind, sufficiently close to the stream to influence the character or aesthetics of the stream setting; its use for fishing, boating or other recreational purposes; and its management or value. Ordinarily, buildings within view of those who are fishing or boating on the stream would be classed as developments, but this would not necessarily apply to distant farm buildings lying across open fields. Also, those developments should be counted which, though not readily evident from the stream, yet have definite influence on character of the streamside zone. The general objective of this classification is to establish the degree of presence or absence of human occupancy which influences the character of the stream and land within the streamside zone.

20.3.1 Classes

The following classes are established:

***Undeveloped*.**–From 0 development, up to 1 development per 3 miles of stream.

Very light development.–From more than 1 development per 3 miles of stream, up to 3 developments per mile.

Light development.–From more than 3, up to 12 developments per mile.

Medium development.–From more than 12, up to 20 developments per mile.

Heavy development.–More than 20 developments per mile.

20.3.2 Mapping (Development)

Streambank development will be indicated on the size-development map by a circled Roman numeral in black appearing above (north) of stream sections occurring on an east-west axis, and to the right (east) of stream sections occurring on a north-south axis. The point of change from one classification to the next will be indicated by a black line drawn perpendicular to the stream.

(This line need not be placed at the downstream terminus of a tributary unless the mainstream has a different class.)

Use Roman numerals in accordance with the following system:

Numeral	Class	Degree of development	Usual minimum length to be mapped
I	Undeveloped	None up to 1 in 3 miles	2 ½ - 3 miles
II	Very light development	More than 1 in 3 miles, to 3 per mile	1 mile
III	Light development	More than 3, up to 12 per mile	¾ - 1 mile
IV	Medium development	More than 12, up to 20 per mile	½ - 1 mile
V	Heavy development	More than 21 per mile	¼ - 1 mile

20.4 General instructions and discussion–all parts

1. ***Streams to be included***: All streams are to be included that have perennial flow, regardless of existence of public access or ditching. Stream type and stream size classifications should be based on flows and other conditions existing during the major fishing-recreation season.
2. ***Base map correction***: Where the base map is in error, showing incorrect locations or courses for the streams, or showing incorrect upstream limits of perennial flow, the errors should be corrected by a thin black line and applicable color.
3. A short, prominent black line perpendicular to the stream should be placed at the point on each stream where it ceases to be identified as perennial, and upstream from which this inventory does not apply. This will assist in assuring there are no errors of omission in classifying or copying, and will also serve to "correct" the base map when the stream appears on that map as extending beyond the termination of its perennial flow.
4. ***Dams and impoundments***: Locations of dams should be indicated by a solid black isosceles triangle with the baseline at the dam site and the apex pointing downstream. Impoundments over 5 acres in size should be outlined by a thin black line. The type quality of the impounded waters should be indicated by a line through the thread of the impoundment of the same color as used to indicate comparable stream type quality. Parts II and III, size and development, should not be entered on large impoundments which distinctly have the nature of lakes, such as the Fletcher Pond, Michigamme Reservoir, or Thornapple Lake. However, impoundments which retain significant riverine character in shape, size, use or development should be classified under Parts II and III.
5. When entered in color, erroneous entries will be difficult to remove. Therefore, simply cancel out by running a wavy black line through the erroneous entry, with adjacent entry of the correct color.
6. In estimating distances for Part III, make realistic generalizations as needed. For instance, see the example diagrams on the following page.

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20.5 Procedure

It is recommended that field data be collected on two sets of 14-inch x 18-inch maps, one set for type quality and one set for size development.

In instances where streams cross District boundaries, the District Fish Biologist from the neighboring District should be consulted to insure uniformity.

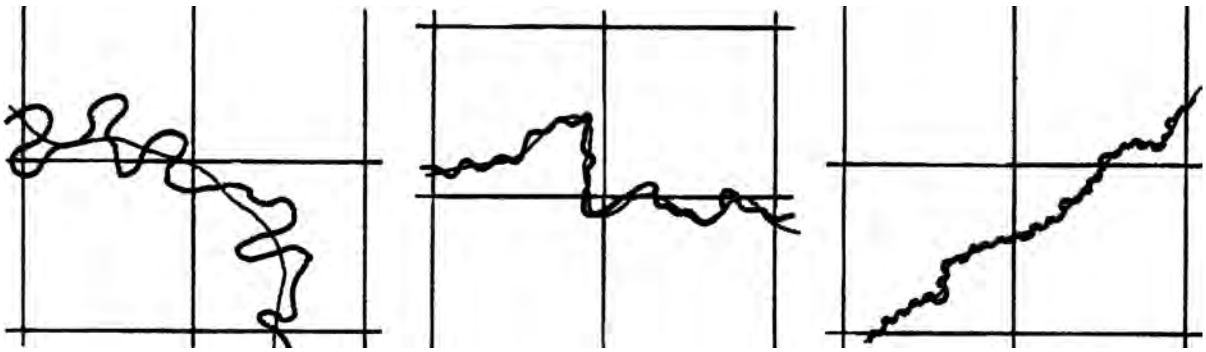
After the field data have been collected, the information should be transferred to l-inch-per 1-mile county maps for both the type quality and size development classifications. These maps should be made in triplicate so that District, Region and Lansing all have identical copies of both classifications. After completion of the set for each county, they should be forwarded to Region where they will be reviewed to insure completion and uniformity of approach. After satisfactory review at Region, maps should be forwarded to Lansing for review and tabulation. After review at Lansing, the Regional and District copies will be returned.

The necessary 1-inch-per-1-mile maps and the colored felt pens will be provided by Lansing Fish and Recreational Resources Planning divisions.

Pens being supplied have felt tip about 3/16-inch wide. Trim to not over 1/8-inch with vertical razor blade cut.

To approach the task systematically and to avoid error of omission, it is suggested that classification work commence at the downstream end of the stream system and proceed upstream, completing each tributary in turn. All copies should be checked in this manner to assure there are no omissions.

Examples of generalizing distances for Part III:



Actual	5.5	Actual, about	3.6	Actual, about	3.7
Generalized	2.5	Generalized	2.9	Generalized	2.6
(ratio 1:2.2)		(ratio 1:1.24)		(ratio 1:1.24)	
<u>Use</u> the actual		<u>Use</u> the Generalized		<u>Use</u> the Generalized	

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Revised 3/1981 by J. W. Merna.
Slightly edited 1/2000 by J. C. Schneider

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Manual of Fisheries Survey Methods II: with periodic updates

Chapter 21: Interpreting Fish Population and Community Indices

James C. Schneider

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Chapter 21: Interpreting Fish Population and Community Indices

James C. Schneider

A variety of statistics about fish populations and communities are collected during surveys (Chapter 2). Some guidelines for their interpretation will be reviewed here to complement the professional judgement of fisheries biologists.

There are three major questions in the interpretation of survey statistics:

- Is the sample representative of the species and sizes present;
- What biological attributes and processes are revealed by the statistics; and
- Exactly how do the statistical values relate to average expectations and to the quality of populations, communities, and fishing?

The first assumes that a representative ("fair") sample has been obtained or that biases caused by gear or season are recognized; the second that we can agree on the interpretation of population and community characteristics; and the third that within the continuous array of possible statistics, groups can be recognized that we can agree represent poor, average, or good conditions.

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These questions are partially addressed in Table 21.1. This table summarizes some important population and community indicators, associated sampling concerns, and biological interpretations. Further elaboration follows.

Population indices reflect many important characteristics of a species population. Length-frequency distribution, length-biomass distribution, and average length and weight of the sample reflect population size structure. Age and growth analysis reflects recruitment, mortality, and longevity patterns as well as growth rate. Length-weight relationships also indicate growth rate and food conditions. Recruitment surveys focus on reproductive success within the last year or two. Catch-per-effort (CPE) statistics are a rough index of population abundance. Growth, length-weight relationships, and recruitment are discussed in Chapters 2, 9, 13, 15, 17, and 23 so will not be discussed further here.

Community indices are based on species composition of the catch sample. Species ratios and predator-prey ratios are statistics that may be derived. Community composition on a weight basis is a less variable and more useful statistic than community composition on a numbers basis (Schneider 1981). While the catch of one large fish can skew the proportion by weight in a small sample, erratic catches of small fish can more often have an even greater effect on the proportion by number.

21.1 Population indices

21.1.1 Size and age structure

Size structure and age structure of fish populations result from interactions among additions (recruitment), growth, and losses (natural plus fishing mortality). True size and age distributions of populations, by both numbers and weight, can be mathematically simulated if the many possible combinations of the variables are known. Figure 21.1 is an example based on recruitment, growth, and natural mortality patterns observed at Blueberry Pond (data in Schneider 1993). This lake is a best case example because virtually no fishing mortality occurs, growth is very good up to 8 inches, standing crop is high, and size structure is excellent. Figure 21.1

demonstrates that numbers of fish rapidly decline with age so that old and large fish are quite rare. On the other hand, standing crop biomass reaches a peak at an intermediate age (4) and size (6 1/2”).

Our perception of true population structure is clouded by the size selectivity of our sampling gear. Figure 21.2 demonstrates the selectivity of three types of gear for bluegill in Mill Lake. Generally, angling, gill net, trap net and large-mesh fyke nets are biased towards large fishes, whereas seine, electrofishing, and small-mesh fyke nets are biased toward small or medium-sizes (Laarman and Ryckman 1980; Schneider 1990, 1997). Table 21.2 summarizes an analysis of trap net and electrofishing selectivity based on comparison of catches to “true” population size structure, as derived from intensive mark-and-recapture studies at a small number of lakes (Schneider 1997).

21.1.1.1 Size structure.–Standards for interpretation of fish population size structure in Michigan are partially developed. Possible approaches to standardization are to adopt proposed national systems or to develop systems tailored to Michigan conditions. The latter could be based either on empirical data from large data sets, recognition of “type” waters, or mathematical models computed from average statistics.

The national systems (see Gabelhouse 1984) begin with defining a “stock” size, which is the minimum size of fish to be included in the analysis (“the stock”). Proportions of larger fish in the stock may then be computed and are given such terms as PSDs, RSDs, quality size, etc. It is presumed that the sampling gear gives an unbiased picture of size distribution above this stock size. Stock (minimum) sizes have been defined as 3” for bluegill and pumpkinseed, 8” for largemouth bass, 5” for black crappie and yellow perch, and 10” for walleye. Comparison of these sizes to the gear selectivity data in Table 21.2 indicates electrofishing data can meet the minimum criteria for all species, so those systems potentially could be used. However, electrofishing may not catch representative samples of large fish when they inhabit deep water (Table 2.2). Trap nets do not catch small stock size well (Table 21.2), and small-mesh fyke nets may catch small enough sizes but still be biased towards larger panfish (Schneider 1997).

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For Michigan bluegill, Schneider (1990) devised an empirical scoring system based on length-frequency statistics of bluegill sampled with several types of gear used in Michigan. The length-frequency indices incorporated were average length and proportions of the catch larger than 6”, 7”, and 8”. The scoring system has been reproduced here as Table 21.3. Resulting scores of 3 to 4 indicate average population size structures, scores of 1 to 2 indicate populations lacking large fish (and usually slow-growing, but possibly short-lived), and scores of 5 to 7 indicate unusually high proportions of relatively large bluegill (which are fast-growing or long-lived). Application of the system to 303 lakes in 1990, and more lakes since then (Schneider and Lockwood 1997), indicated it is useful for classifying bluegill populations and lakes. The score for any lake can be converted to a percentile relative to the 303 lakes.

21.1.1.2 Age structure.–Information about large and old fish is especially valuable. It reflects the important interaction between growth and mortality, which determines potential angling quality (abundance of large fish) and longevity (maximum age). Mortality rate is best determined from intensive sampling of population age structure, however, it can be inferred from our conventional low-intensity sampling for age and growth as follows.

Table 21.4 shows state average length at ages 3 and 4 (in spring) for some important sport fish. Very generally, trap and fyke nets with conventional 1.5” mesh pots will sample quite well black crappie, largemouth and smallmouth bass, and northern pike of sizes equivalent to age 3 and older. The same gear catches bluegill, pumpkinseed, and yellow perch of sizes equivalent to age 4 and older. If we assume age 3 and older fish of all species typically have a combined natural and angling mortality rate of 60% per year, which is reasonable based on cumulative information, then we can calculate the probabilities of finding old fish in our samples as shown in Table 21.4.

For example, for all species in the top group (age 3 base), for every 100 fish age 3 and older *randomly* sampled, about 1 (0.6) should be age 8. For species in the lower group, the ratio of age 8 to all age 4 and older fish is also about 1 (1.5). The same age distribution could apply to other rates of growth if the distributions of mortality rate and gear age selectivity are adjusted appropriately.

I propose as a rule of thumb for all these species: if the maximum age taken in a good random sample (approximately 100 fish) is about age 8, that indicates a typical mortality rate probably exists within the population. If fish age 10 or older are found, that suggests mortality is relatively low. If the maximum age is less 7 or less, mortality rate is probably relatively high (or we can't age the fish reliably). If old fish are found in smaller samples, that likewise indicates mortality must be low. Walleye have a growth pattern which places them in the top group, however on average they have a lower mortality rate than the other species so usually reach at least age 10 in good samples.

Note that to determine maximum age, scale samples need not be taken on a strictly random basis. Our usual technique of sampling only 10-15 fish per inch group (stratified sampling) has two advantages: (1) it is highly likely that the oldest fish in the sample will be discovered; and (2) we don't have to age so many age 3 and 4 fish to obtain the statistical power of a larger random sample. For example, for bluegills 5- to 8-inches long, aging 10 fish per inch group (40 fish) will give approximately the same information about longevity as randomly aging 100 fish.

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Difficulties with the longevity method above are that old fish are rare (and may be missed by sampling) and they usually are slow growing (and may be hard to age from scales). The ratio of age 3 or age 4 fish to all older ages (age 4 or age 5 plus) is a potentially more reliable statistic because it is a larger number. However, it must be based on a random sample or a de-stratified sample (Chapter 15). In the 60% annual mortality example (Table 21.4), 60% of the age 3+ fish were age 3 and maximum age was about 7-8. If annual mortality were only 40%, 40% of the age 3+ fish would be age 3 and maximum age would be 10-11. If annual mortality were 80%, 80% of the age 3+ fish would be age 3 and maximum age would be 5-6.

21.1.2 Abundance

Densities of fish can be only inferred from catch data. Clearly, the presence of a species or size group is confirmed when at least one representative is caught. However, failure to catch any of a species or size does not assure absence from the lake or stream. Catch per effort (CPE) is only a rough indicator of relative abundance. Relatively large catches imply large populations, but catch rate is influenced by many factors other than population density.

Table 21.5 shows average catch rates (CPEs), by species, for several types of fishing gear used for lake surveys in Michigan. These CPEs can be used as a rough standard – analogous to state average growth rates (Chapter 9) – for evaluating, interpreting, and comparing results of future surveys. Excluded from the average CPE for a species were surveys with zero catches. Also, surveys during spring spawning runs were excluded to make the averages representative of general surveys. The CPE averages are based on representative survey data present in the electronic Fish Collection System as of mid September 1999; they should be revised periodically and stratified by region or lake type after more data accumulate in the system. Note that differences among catch rates in Table 21.5 reflect both that small mesh nets retain more smaller fish (but perhaps fewer larger fish) and that there are regional differences in net usage. Generally, fyke nets have been the preferred net in the Upper Peninsula and the northern Lower Peninsula, and trap nets have been favored in the southern Lower Peninsula. Since there are corresponding regional differences in fish communities and densities, the CPEs may reflect that also.

It appears CPE is much more reliable for reflecting changes in population density within a lake (Schneider 1998b) than differences in density between lakes. My (1998) preliminary analyses suggest some useful relationships between CPE and population density eventually may be developed for bluegill, pumpkinseed, yellow perch, and walleye. For walleye 13 inches and larger, it appears that a non-proportional relationship exists between trap net CPE and mark-and-recapture population estimates. Very roughly, a catch of two walleye per net lift implies a population density of about four walleye per acre and a catch of six walleye per lift implies a population of about seven per acre. Extensive data from Wisconsin lakes indicates walleye population per acre multiplied by 0.019 will estimate walleye catch per angler hour (Beard et al. 1997).

Densities of larger-sized sport fish have been estimated by mark-and-recapture methods at many Michigan lakes to date. Density estimates for largemouth bass, northern pike, and bluegill were compiled in recent reports and are duplicated here as Tables 21.6, 21.7, and 21.8. Generally, largemouth bass over 10 inches long number less than 10/acre, northern pike over 14 inches number less than 5/acre, and bluegill over 6 inches long usually number less than 100/acre but vary widely.

21.2 Community indices

21.2.1 Coldwater Lakes

Status of trout in these lakes is the primary management concern. In small lakes intensively managed for rainbow and brook trout, it is generally accepted that even small numbers of other species (especially predators) detracts from trout production and fishing. The more piscivorous trouts – lake, splake, and brown – often benefit from modest numbers of soft-rayed forage fish. In larger lakes with both cold, cool, and warmwater habitats and natural mixtures of species, northern pike in more than token amounts are detrimental to trout. Presence of cisco indicates potential trout habitat exists and there is an excellent forage base for lake trout.

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In coldwater lakes trout population characteristics themselves are the best indicators of conditions. Growth can be compared to state averages for trout in lakes (Chapter 9). Survival is generally satisfactory if any trout carry over from one year to the next. Rainbow trout success is linked to the abundance of large *Daphnia* (Chapter 18).

21.2.2 Coolwater Lakes

In these lakes the typical coolwater species – yellow perch, smallmouth bass, walleye, rock bass, northern pike, and white sucker – predominate on a weight basis. Some habitat may also be available for trout and warmwater species. Characteristics of good and poor coolwater communities have been partially evaluated. White suckers should not comprise more than 50% of standing crop biomass and predators should probably comprise between 20 and 50% of the total biomass (Schneider and Crowe 1980; Schneider 1981). Relative growth and longevity of the species populations should serve as indicators of both population quality and community balance.

21.2.3 Warmwater Lakes

In these lakes typical warmwater species – bluegill, largemouth bass, crappie, carp, and bowfin – predominate. In Michigan's range of climate, some habitat will also be available for coolwater species, especially the ubiquitous yellow perch. Stocked walleye can thrive in most of these lakes if forage and predators are favorable.

Indicators of undesirable lake communities, and usually poor overall fishing quality, are these percentages on a weight basis (Schneider 1981):

- Common carp or white sucker >50%;
- Bluegill + pumpkinseed >78%;
- Minnows + chubsucker + warmouth >15%;
- Predators <20% and >50% (tentative).

The bluegill is a key species in the management of warmwater lakes. Generally, satisfactory or good bluegill characteristics will be reflected in satisfactory to good overall fishing quality (Schneider 1981). An important exception is that lakes with stunted bluegill often produce exceptionally large bass. These bluegill population indices have been recommended (Schneider 1981):

- Presence of any 8-inch bluegill indicates a relatively good population;
- Absence of 8-inch bluegill coupled with a bluegill growth index greater than 1 inch below state average indicate unsatisfactory conditions.

21.2.4 Average warmwater and coolwater lake communities

Information on average lake fish communities comes primarily from large seining operations and mark-and-recapture population studies. Large seines (over 800 feet long) were used to sample 229 lakes (Schneider 1981). This gear missed the smallest fish and underestimated total number and weight per acre. Also, poor fishing lakes may have been over-represented in the data set. However, the seine was probably relatively unbiased as to community composition on a weight basis, and this data set is the largest and most representative the Fisheries Division has systematically collected. A table from that report showing average values for northern Lower Peninsula (region II) and southern Lower Peninsula (region III) is reproduced here as Table 21.9.

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Mark-and-recapture population estimates have been conducted at numerous lakes by research personnel. Most studies targeted the larger sizes of a few species, but for some lakes, gear was sufficiently diverse and sampling effort was intensive enough to obtain acceptable estimates for every important species and size. In Table 21.10 are fish community composition estimates which are believed to be typical of small, shallow, Lower Peninsula lakes. In Table 21.11 are similar but less reliable data for small lakes in the Upper Peninsula containing typical mixtures of warmwater species. In Table 21.12 are additional estimates from northern lakes with simple but acceptable fish communities.

The estimates based on seining (Table 21.9) indicated, on average, bluegill comprise 36% and largemouth bass 18% of the fish community standing crop biomass in northern Lower Peninsula lakes. For southern Lower Peninsula lakes sampled by seining, bluegills comprised 41% and largemouth bass 16% of the community standing crop biomass. The best mark-and-recapture data for Lower Peninsula lakes (Table 21.10) indicate more bluegill, 50%, and fewer largemouth bass, 11%. Small Upper Peninsula lakes with diverse species (Table 21.11) contained 56% bluegill, 2% largemouth bass, and none of those warmwater species which have a more southerly distribution pattern (e.g., chubsucker, bowfin, grass pickerel, warmouth). Schneider (1973a) provided estimates of community composition for many other lakes with unusual or unbalanced fish assemblages.

Other types of sampling provide imperfect snapshots of the composition of warmwater fish communities. Trap nets tend to underestimate the proportion on a weight basis of bluegill, yellow perch, and minnows, and over-sample black crappie, northern pike, and bowfin (Table 21.13). Daytime electrofishing under-samples bluegill, northern pike, and bullheads, and over-samples pumpkinseed, bowfin, grass pickerel, and chubsucker on a weight basis (Table 21.14).

Relative to trap net biases, fyke nets with the same mesh give about the same picture of populations and communities (Schneider 1999). Compared to trap and fyke nets, gill nets are the best sampling tool for pelagic and cold-water species, but tend to over-sample northern pike, walleye, yellow perch, white sucker, and the predator-prey ratio. Gill nets tend to under-sample bluegill, rock bass, and other centrachids. Night electrofishing can be very effective for adult largemouth bass and smallmouth bass as well as the small sizes of most species.

21.2.5 Standing Crops

Our best estimates of total standing crops of fish in typical lake communities are included in Tables 21.10 and 21.11. The estimates based on seine catches per acre (Table 21.9) are clearly too low to be realistic. Earlier summaries (Schneider 1973a and 1978) listed estimates from a wide variety of Michigan sources, including estimates for lakes with unbalanced populations (such as those completely dominated by severely stunted bluegill, bass, or yellow perch). Lakes with fewer species of fish generally have lower total standing crops because fewer niches are completely filled. However, stunted bluegill by themselves can develop surprisingly high standing crops because they feed low on the food chain (Schneider 1995).

The average total standing crop for the Lower Peninsula lakes included in Table 21.10 is 147 lb/acre. This figure is probably higher than the true average of all lakes because most of these lakes were relatively productive (mesotrophic) and lightly exploited. Mill Lake, for example, had an estimated standing crop of 109 lb/acre in unfished years (Table 21.10) compared to 94 lb/acre in a fished year (Schneider 1971). Standing crop estimates for small, fairly productive Upper Peninsula lakes with diverse communities (Table 21.11) were on the same order of magnitude, an average of 121 lb/acre, but this number is inflated by two suspiciously high estimates. In general, it appears that productive shallow lakes in which bluegill predominate often contain 100-150 lb/acre of all fish.

Total standing crop (lb/acre) of fish in any lake can be roughly estimated from the equation below (Schneider 1978, equation 3):

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$$\begin{aligned}\log_{10}(Lb/acre) = {} & 0.9840 + 0.3632(panfish\ \ index) + 0.00030(climate\ \ index) + 0.1990(1/(\log_{10} Secchi)) + \\ & 0.4342(\log_{10}(vegetation\ \ index)) - 0.1065(\log_{10} area) + 0.5204(rough\ \ fish\ \ index)\end{aligned}$$

Where:

panfish index is approximate fraction of total weight as bluegill, pumpkinseed, and crappie combined;

climate index is average growing-degree days above a base of 55^0F (Figure 21.3);

Secchi is typical Secchi disk transparency in feet;

vegetation index is macrophyte abundance ranked 1-5, where 1 = sparse … 5 = very abundant;

area is lake area in acres;

rough fish index is estimated fraction of total weight as bullheads, carp, and suckers combined.

An example calculation for Mill Lake is as follows. Panfish and rough fish indices can be estimated from Table 21.10: *panfish index* = 0.41+0.11+0.05=0.57; *rough fish index* = 0.03 + 0.01 + tr = 0.04. (Note: for most lakes only typical survey data are available, so use ratios in trap or fyke net catches to approximate the indices). *Climate index* for western Washtenaw County is 2000 (Figure 21.3). *Secchi* disk ranges from 8 to 12 feet, so 10 feet is typical. Macrophytes, quite abundant, are ranked as 4. *Area* is 136 acres. The calculated standing crop is 111 lb/acre (antilog of 2.045), which agrees with field measurements of 94 to 109 lb/acre.

21.2.6 Angling yield

Annual catches of fish from Michigan lakes by anglers may be similarly estimated (Schneider 1975). Equation 1 from Table V of that publication is the most appropriate:

$$\log_{10}(Lb/acre) = -0.3322 + 0.9928(panfish\ index) + 0.00022(climate\ index) + 0.2829(1/(\log_{10} Secchi)) + 0.6151(\log_{10}(vegetation\ index)).$$

Terms are as defined above. Note that lake area and rough fish index are not used here.

Mill Lake can be used again as an example and required values were given above. The calculated sport catch was 21 lb/acre/year. Actual yearly catch from Mill Lake has never been estimated, but extensive creel census data from nearby and similar Sugarloaf Lake averaged 29 lb/acre/year.

21.2.7 Angling statistics

On-site census of angling effort and catch has been conducted at many Michigan lakes. Data collected from 1934 to 1982 is compiled or referenced in reports by Schneider and Lockwood (1979) and Ryckman and Lockwood (1985). It is difficult to generalize the statistics because extensive variation is caused by season, year, lake characteristics (e.g., region, area, productivity, fish species present, fish species targeted), and other factors. Estimates of fishing pressure ranged from 3 to over 200 hours/acre, estimates of total number of fish caught ranged from 1 to over 1000 fish/acre, and catch rates ranged from 0.1 to over 2.0 fish/angler-hour. Corresponding yearly averages for 22 typical Lower Peninsula lakes in a 1946-65 data set were 90 hours/acre, 106 fish/acre, and 1.0 fish/angler-hour (Schneider and Lockwood 1979).

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Table 21.1.–Possible indicators of important characteristics of fish populations and communities and their interpretation.

A. Population level:

1. **Individual size range** – Can be detected with high bias gear and small sample size.

    Big fish present – Fishable; growth not poor and total mortality not high.

    Medium fish present – Recruits for fishery; reproduction several years ago.

    Small fish present – Recent reproduction.

    In combination, all three indicate uniformity of reproduction and recruitment.

2. **Size frequency** – Requires large sample and unbiased or corrected distribution, or standard gear plus expectations. A better measure of recruitment and potential fishing quality than size range.

    Large predominate – Potential fishing quality is high.

    Small predominate – Possible stunting, over-fishing, community imbalance, food limitation.

3. **CPE** – Requires standard effort, index sites, and season. Indicates both abundance and catchability.

4. **Age frequency and longevity** – Require unbiased or corrected age distribution. Indicate recruitment and mortality patterns.

5. **Growth** – Requires relatively unbiased sampling by age and size or weighting procedure. Growth rate, and to a lesser extent mortality, determine size frequency. Populations with average or better growth will have large fish unless mortality is unusually high.

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B. Community level:

1. **Presence or absence** – Requires targeted gear suitable for all species likely to be present.

2. **Species** –

    Types available to fishery.

    Suggests food chains.

    Indicates habitat types present (temperature, oxygen, pH, etc.).

3. **Rare species** – need protection.

4. **Diversity** –

    Complex interactions are likely.

    Variety of habitats are available.

    Stability implied.

    Total productivity relatively high.

5. **Relative composition** – Requires unbiased or corrected gear, or standard gear plus expectation. Measures are percent by number or weight.

    a. Predator-prey ratio.
    b. % panfish.
    c. % sucker and carp.
    d. % chubsucker and golden shiner.
    e. Winterkill indicators (over-abundance of bullhead, perch, pumpkinseed, bowfin).

Table 21.2.–General patterns of gear size selectivity (Schneider 1997).

Species and gear	Number of lakes[a]	Minimum length (in)[b]	Peak[c]	Shape[d]
Bluegill				
1.5" trap nets[e]	6	4-5	7+	increasing
Electroshocking[f]	5	1-2	4-6	dome
Pumpkinseed				
1.5" trap nets	5	4-5	7+	increasing
Electroshocking	5	2	3-7	dome
Yellow perch				
1.5" trap nets	6	5-7	7+	increasing
Electroshocking	6	2	5-7	flat
Black crappie				
1.5" trap nets	3	3	6+	increasing
Electroshocking	2	5	7-9	flat
Largemouth bass				
1.5" trap nets	5	7-10	10+	sl increasing
Electroshocking	5	2	2-11	flat?
Northern pike				
1.5" trap nets	2	13-15	16-24+	flat?
Electroshocking	3	6-19	20-24+	increasing?
Walleye				
1.5" trap nets	1	8-9	18+	increasing
Electroshocking	1	10-11	16+	increasing

[a] Number of lakes for which size distributions by gear were compared to size distributions by mark-and-recapture estimates to determine catchability curves.

[b] Range in minimum length of fish caught by the gear in various study lakes.

[c] The inch groups where the highest proportion of sizes present are caught by the gear. For example, "4-6" indicates that 4-6 inch fish were the most catchable sizes in the population, and "7+" indicates that catchability was high at 7 inches and even increased through larger sizes.

[d] Indicates shape of the catchability curve. "Increasing" indicates larger fish are increasingly catchable (as a proportion of sizes available); "dome" indicates both large and small fish are less catchable than an intermediate size; "flat" indicates no size selectivity above the minimum size caught.

[e] Trap nets with pots of 1.5-inch stretched mesh. Fyke nets with similar mesh probably have similar selectivity.

[f] Electroshocking. Data for day and night analysis is pooled, but often larger fish are caught at night. Selectivity can be caused by netters not seeing or ignoring small sizes in addition to fish behavior and distribution patterns.

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Table 21.3.–Scores (1 - 7) for five indices of bluegill population characteristics obtained during lake surveys. The four length indices are given for two basic gear types; growth index is independent of gear type. Also given are ranks (very poor to superior) corresponding to the scores. (Reproduced from Schneider 1990).

		Trap net or fyke net[a]				Shocker or large seine[b]				Growth
Rank	Score	Avg L[c]	% >6" [d]	% >7"[e]	% >8" [f]	Avg L	% >6"	% >7"	% >8"	index[g]
Very poor	1	<5.0	0-9	0-1.9	<0.1	<3.8	0-3	0-0.7	<0.1	<-1.0
Poor	2	5.0-5.4	10-24	2-4	<0.1	3.8-4.2	4-8	0.8-1.7	<0.1	-1.0 to -0.6
Acceptable	3	5.5-5.9	25-49	5-9	<0.1	4.3-4.7	9-17	1.8-33	<0.1	-0.5 to -0.1
Satisfactory	4	6.0-6.4	50-74	10-29	0.1-0.9	4.8-5.2	18-29	3.3-9.9	0.1-0.9	0 to 0.4
Good	5	6.5-6.9	75-85	30-49	1-9	5.3-5.7	30-39	10-24	1.0-2.9	0.5 to 0.9
Excellent	6	7.0-7.5	86-95	50-79	10-39	5.8-6.2	40-49	25-39	3-19	1.0 to 1.4
Superior	7	≥7.6	≥96	≥80	≥40	≥6.3	≥50	≥40	≥20	≥1.5

[a] Impounding nets with 1.5-inch stretched mesh in pots; also gill nets.
[b] Boom shockers or large seines; also fyke or trap nets with small mesh.
[c] Average length of catch in inches.
[d-f] Percent of catch greater than 6.0, 7.0, and 8.0 inches in length, respectively.
[g] Average deviation (inches) from the seasonal state average length at age (GI).

Directions for use: Determine a score of 1 to 7 for each of the four size indices. (If the percent of the catch greater than 8 inches is <0.1, then its score = 2). Then compute "size score (SS) by averaging the scores for average length (Avg L), percent over 6 inches (% >6"), percent over 7 inches (% >7"), and percent over 8 inches (% >8"). If one or two of the length scores is unknown because of missing data, compute SS by averaging the known scores.

Example: Sugarloaf Lake, Washtenaw County, was sampled by electrofishing in 1977 (Table 2). Indices were: Avg L = 5.2", % >6" = 48, % >7 = 15, % >8" = ? (not required on old form). Corresponding scores derived from Table 21.3 are: Avg L = 4, % >6" = 6, % >7" = 5, % >8" = ?. The SS = (4 + 6 + 5) / 3 = 5.0.

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Table 21.4.–Approximate age distribution of fish populations based on an assumed total mortality rate of 60% per year and state average growth. Species are grouped by growth rate (size) so as to have good catchability in trap or fyke nets. Some species are well sampled beginning at age 3, others beginning at age 4.

Group	Length at age		Percent of sample in age group							
and Species	Age 3	Age 4	3	4	5	6	7	8	9	10
Age 3 base:			60	24	10	3.8	1.5	0.6	0.2	0.1
Northern pike	20.8	23.4								
Black crappie	7.5	8.6								
Largemouth bass	11.6	13.2								
Smallmouth bass	10.8	12.6								
Age 4 base:			…	60	24	10	3.8	1.5	0.6	0.2
Bluegill	5.0	5.9								
Pumpkinseed	4.9	5.6								
Yellow perch	6.5	7.5								

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Table 21.5.–Average catch per unit of effort (CPE) during inland lake surveys for 12 species of fish and 8 types of fishing gear.[a] Mesh size (stretched measure) in experimental gill nets and in pots of fyke and trap nets are indicted. Averages were derived from data in the computerized Fish Collection System as of mid-September 1999, include only surveys in which at least one fish of the species was caught, and exclude inflated samples taken during spawning runs of walleye, northern pike, and white sucker. Blank indicates insufficient number of surveys (<10) to compute an average; italics indicates sample size of 10 to 29; normal type indicates 30 to 151 surveys in average.

	Fyke nets				Trap net	Gill net	Shocker
Species	0.7”	1”	1.5”	2”	1.5”	1.5-4”	DC
Largemouth bass	*1.7*	*1.0*	*5.2*	3.4	3.5	2.3	50.0
Smallmouth bass		*1.6*	*2.6*	*1.1*	1.6	*0.8*	14.0
Walleye		*2.2*	*1.5*	*1.0*	1.0	2.1	41.7[b]
Northern pike		1.4	0.8	*1.1*	0.8	2.3	7.4
Bluegill	14.1	*14.5*	*14.0*	10.6	56.6	4.5	165.2
Pumpkinseed	*2.7*	14.1	6.2	*1.8*	8.1	1.1	30.7
Yellow perch	*32.3*	*22.9*	14.7	*1.6*	1.0	9.5	33.0
Black crappie		*2.2*	*3.3*	*2.2*	23.3	5.3	15.8
Rock bass	*9.5*	*5.1*	7.7	*5.3*	4.0	1.3	8.5
Bullhead spp.	*7.1*	*10.2*	*13.7*	*1.8*	7.7	2.7	6.6
White sucker	*3.7*	2.9	3.3	*2.9*	2.7	3.1	*4.2*
Bowfin				*1.3*	1.7	*0.8*	*3.7*

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[a] Fyke nets have rigid frames 4 feet high, and the same mesh is used throughout the pot, heart, and lead. Trap nets have collapsible frames, and pots 8 feet long x 5 feet wide x 3 feet high with 1.5-inch stretched mesh; mesh in hearts, wings, and leads is generally larger. Experimental inland gill nets are 125 feet long x 6 feet deep and have panels of 1.5, 2.0, 2.5, 3.0, and 4.0-inch stretched mesh (usually multifilament nylon); they are fished on bottom. Boom shockers are primarily 220-V DC with various amperages and configurations. See Chapter 3 for more details.

[b] Nearly all walleye surveys targeted recruitment of small fish in fall or spring.

Table 21.6.–Comparative densities of largemouth bass in unexploited and exploited Michigan lakes exceeding indicated minimum sizes as estimated by mark-recapture methods. Arranged by latitude. Table reproduced from Schneider (1998a).

Lake	County	Minimum length (in)	Number per acre	Reference
		Unexploited		
Blueberry	Livingston	≥10	27	Schneider 1993
		≥14	1.6	"
Third Sister	Washtenaw	≥10	12	Schneider 1971
Mill	Washtenaw	≥10	9.4	
		≥15	1.0 - 1.4	"
Dead	Washtenaw	≥10	6.6	Schneider 1993
		≥14	1.9	"
Wakeley	Crawford	≥10	2.7-7.6	Schneider 1998
		≥15	0.3-3.8	"
Cub	Gogebic	≥10	25	Clady 1975
		≥15	0	"
		Exploited		
Whitmore	Washtenaw	≥10	3.1 - 8.1	Latta 1959; Goudy 1981
Sugarloaf	Washtenaw	≥10	2.0 - 9.5	Laarman and Schneider 1979
Pontiac	Oakland	≥10	4.9	Goudy 1981
Kent	Oakland	≥10	1.5	"
Fife	Grand Traverse	≥10	3.0 - 5.5	Schneider 1971
Lodge	Ogemaw	≥10	1	"
Jewett	Ogemaw	≥10	10.5	Schneider 1995
		≥14	2.3	
Stager	Iron	≥12	0.4	Wagner 1988
Tepee	Iron	≥12	0.8	"
Chicago	Delta	≥12	0.2	"
East	Schoolcraft	≥12	1.1	"
Anderson	Marquette	≥12	0.6	"
Big Shag	Marquette	≥12	0.6	"

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Table 21.7.–Comparative densities of northern pike in unexploited and exploited Michigan lakes exceeding indicated minimum sizes as estimated by mark-recapture methods. Table reproduced from Schneider (2000).

Lake	County	Minimum length (in)	Number per acre	Reference
		Unexploited		
Mill	Washtenaw	≥20	1.2	Schneider 1971
Dead	Washtenaw	≥20	2.6	Schneider 1993
Wakeley	Crawford	≥17	1.7 - 10.3	Schneider 1998
		Exploited		
Sugarloaf	Washtenaw	≥14	0.4 - 5.1	Laarman and Schneider 1979
Whitmore	Washtenaw	≥14	0.8	Schneider 1971
Big Portage	Jackson	≥14	0.6	“
Fife	Grand Traverse	≥14	6.4	“
Grebe	Ogemaw	≥14	10	“
		≥20	5	“
Manistee	Kalkaska	≥20	0.4 - 2.2	Laarman and Schneider 1986

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Table 21.8.–Comparison of bluegill population characteristics for Michigan lakes. Ranges indicate multiple years.

Lake and county	Growth index	Number per acre >6"	Number per acre >8"	Adult mortality rate Total (A)	Adult mortality rate Fishing (u)	Adult mortality rate Natural (v)
Blueberry[a] Livingston	+0.3	215–507	124–333	0.37	low	…
Dead[a] Washtenaw	+0.2	208–237	16-44	0.41	low	…
Mill[b] Washtenaw	-1.0	44–209	0.3–22	0.54	0	0.54
Cassidy[c] Washtenaw	+0.0	125–126	0.3–0.6	0.55-0.62	…	…
Third Sister[d] Washtenaw	+0.2	156	68	…	low	…
Sugarloaf[ef] Washtenaw	-0. 1 to -0.4	35–80	3	0.68	0.25–0.30	0.40–0.42
Whitmore[e] Livingston	+0.6	42	4.0	0.68[g]	…	…
Manistee[h] Kalkaska	+1.0	5–47	0.9–4.4	0.64	0.10–0.31	…
Fife[i] Kalkaska	+0.1 to +1.5	4–90	1.5	0.55[j]	…	…
Jewett[k] Ogemaw	-0.1 to -1.0	42–127	1–4.6	0.86	0.23	0.63
Lodge[k] Ogemaw	-1.6	35–72	0	0.83	0.26	0.57

[a] Schneider 1993
[b] Schneider 1971
[c] Schneeberger 1988
[d] Brown and Ball 1943
[e] Cooper et al. 1957
[f] Laarman & Schneider 1979
[g] Average total mortality calculated from 1955-56 pooled age-frequency data for ages 4 to 10 (Latta 1959).
[h] Laarman & Schneider 1986
[i] Schneider & Lockwood 1979
[j] Total mortality calculated from pooled age-frequency data for 1958-65 trap netting, ages 4 to 8.
[k] Patriarche 1968

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Table 21.9.–Species composition in percent of total weight caught, and catch per acre in numbers and pounds, for lakes seined in Region II (<1800 growing degree days – Figure 21.3) and Region III (≥1800 growing degree days). Reproduced from Schneider (1981).

	Northern Lower Peninsula– Region II[a]				Southern Lower Peninsula– Region III[b]			
	Percent composition		Average catch per acre		Percent composition		Average catch per acre	
Species	Mean	Range	Number	Pounds	Mean	Range	Number	Pounds
Bluegill *Lepomis macrochirus*	36	0-90	284	18	41	tr-83[d]	308	20
Largemouth bass *Micropterus salmoides*	18	0-86	12	6	16	0-84	15	5
White sucker *Catostomus commersoni*	11	0-86	3	3	2	0-54	1	1
Carp *Cyprinus carpio*	3	0-51	tr	1	11	0-92	1	5
Yellow perch *Perca flavescens*	9	tr-69	76	3	7	0-41	42	3
Northern pike *Esox lucius*	6	0-37	2	2	4	0-45	1	1
Pumpkinseed *Lepomis gibbosus*	5	0-38	22	2	5	0-35	32	3
Black crappie *Pomoxis nigromaculatus*	3	0-35	12	2	6	0-49	18	3
Smallmouth bass *Micropterus dolomieu*	3	0-46	1	1	tr	0-23	tr	tr
Rock bass *Ambloplites rupestris*	2	0-13	2	tr	1	0-19	1	tr
Walleye *Stizostedion vitreum*	1	0-52	tr	tr	tr	0-5	tr	tr
Bullhead *Ameiurus* spp.	1	0-9	1	tr	1	0-11	1	tr
Minnows *Cyprinidae*[c]	1	0-22	5	tr	1	0-17	10	1
Grass pickerel *Esox americanus vermiculatus*	tr	0-2	tr	tr	1	0-4	1	tr
Warmouth bass *Lepomis gulosus*	tr	0-tr	tr	tr	1	0-12	4	tr
Lake chubsucker *Erimyzon sucetta*	tr	0-3	tr	tr	1	0-17	3	1
Bowfin *Amia calva*	tr	0-12	tr	tr	tr	0-8	tr	tr
Gar *Lepisosteus* spp.	tr	0-1	tr	tr	1	0-72	tr	tr
Total	100		422	42	100		440	45

[a] For Region II, percent composition data are for 81 lakes and catch per acre data are for 77 lakes.
[b] For Region III, percent composition data are for 148 lakes and catch per acre data are for 144 lakes.
[c] Minnows include cyprinidae (except carp) and, rarely, darters (Etheostomatinae).
[d] tr = trace = <0.5.

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Table 21.10.–Fish community composition (percent by weight) and total fish biomass (lb/acre) for shallow, productive lakes with typical warmwater species in the southern and northern Lower Peninsula. Based on mark-recapture population estimates for all important species and sizes.

	Southern Lower Peninsula					Northern Lower Pen.		All
Species	Mill	Cassidy	Dead	Blueberry	Average	Wakeley	Jewett	average
Bluegill	41	46	46	55	47	54	60	50
Pumpkinseed	10	10	9	12	10	3	3	8
Yellow perch	12	16	5	6	10	tr	3	8
Black crappie	5	tr	1	0	2	tr	14	5
Rock bass	1	tr	0	0	tr	0	1	tr
Largemouth bass	11	7	6	11	9	11	17	11
Northern pike	8	0	6	0	4	23	0	6
Bowfin	3	4	15	0	6	0	0	4
Lake chubsucker	3	2	4	6	4	0	0	3
Brown bullhead	4	9	5	0	5	7	2	5
Yellow bullhead	1	4	3	5	3	2	0	3
Warmouth	1	0	tr	0	tr	0	0	tr
Green sunfish	tr	2	tr	1	1	0	0	tr
Grass pickerel	tr	1	tr	3	2	0	0	tr
Golden shiner	tr	0	tr	1	tr	tr	0	tr
White sucker	tr	0	tr	0	tr	0	0	tr
Other	tr	tr	tr	tr	tr	tr	tr	tr
Total %	100	100	100	100	100	100	100	100
Total lb/acre	109	144	174	197	156	160	100	147

Supplemental lake data

	Mill	Cassidy	Dead	Blueberry	Wakeley	Jewett
Years of estimates	1965-69	1964	1984-85	1984-90	1987	1958
Exploitation	none	avg	v. low	v. low	none	avg
Bluegill growth	slow	avg	fast	fast	avg	slow
Area (acres)	136	46.2	56.6	19.9	168	12.9
Max depth (ft)	25	11	32	24	9	17
Alkalinity	140	127	114	105	46	33
Secchi disk (ft)	8-12	9	10-14	7-8	5-6	4-13
Macrophyte rank	4	3	5	5	5	3
Oxygen-thermal type	4	5	4	4	5	4
Reference (Schneider)	1971	1973b	1993	1993	1998a	1973a

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Table 21.11.–Estimated fish community composition (percent by weight) and total standing crop (lb/acre) for one coolwater (East) and five warmwater lakes with diverse species in the Upper Pennisula.[a]

	Upper Peninsula lake						
Species	Stager	Tepee	Chicago	East	Anderson	Big Shag	Average
Bluegill	57	62	63	5	79	70	56
Pumpkinseed	6	0	1	19	9	16	9
Yellow perch	4	30	0	34	8	8	14
Rock bass	0	0	1	0	0	0	0
Largemouth bass	2	3	1	1	1	4	2
Smallmouth bass	0	0	0	0	0	2	0
Northern pike	0	2	6	1	1	0	2
Northern musky	0	0	0	0	0	tr	0
Lake chubsucker	0	0	0	0	0	0	0
Bullhead spp	0	2	28	tr	0	0	6
White sucker	30	0	0	39	2	tr	14
Other	tr	tr	tr	tr	tr	tr	tr
Total	100	100	100	100	100	100	100
Total lb/acre	123	46	85	178	205	90	121

Supplemental lake data

Year of estimates	1983	1983	1984	1984	1985	1985
Exploitation	avg	avg	avg	avg	avg	avg
Bluegill growth	slow	?	?	?	?	?
Area (acres)	112	115	159	55	50	194
Max depth (ft)	55	39	16	29	29	29
Alkalinity	96	5	18-51	58	119	25

[a] I calculated from Wagner's (1988) mark-and-recapture population estimates, stratified by species into two size groups, and catch data with assumptions about average size and weight (state average). Considering the wide confidence limits on the population estimates and incomplete information, the standing crop estimates could be in error by 25% and should be considered to be tentative. The totals for East and Anderson lakes, nearly 200 lb/acre, seem too high.

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Table 21.12.–Fish community composition (percent by weight) and total fish biomass (lb/acre) for lakes containing simple but fishable and stable fish communities. Based on mark-recapture population estimates for all important species and sizes.

	Lake			
Species	Jewett	Cub	Katherine	Marsh
Bluegill	67			
Yellow perch	16	16		
Largemouth bass		46		
Smallmouth bass		3	100	9
Walleye	17			
White sucker		35		91
Other		tr	tr	tr
Total %	100	100	100	100
Total lb/acre	71	62	10	51

Supplemental lake data

Years of estimates	1992	1967	1967	1967
Exploitation	avg	none	none	none
Bluegill growth	avg	…	…	…
Area (acres)	12.9	28	48	65
Max depth (ft)	17	20	56	40
Alkalinity	33	8	3	4
Secchi disk (ft)	4-13	10	10	10
Macrophyte rank	3	1	1	1
Oxygen-thermal type	4	5	1	2
Reference	Schneider 1973a	Clady 1970	Clady 1970	Clady 1970

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Table 21.13.–Summary of species selectivity of 1.5" trap net, based on percent by weight, relative to mark-recapture estimates and known presence. Reproduced from Schneider (1997). s = spring sample; f = fall sample; ok = within 5% of reference; low = <5% or tr; high = >5%; 0 = not caught but present.

	Lake and date of sample					
Species	Blueberry s1987	Cassidy s1964	Dead s1984	Dead s1985	Mill f1964	**General pattern**
Bluegill	low	ok	low	v. low	v. low	**low**
Pumpkinseed	ok	high	low	low	ok	**varies**
Yellow perch	ok	low	ok	low	low	**low**
Rock bass		ok			ok	**ok**
Black crappie		ok	ok	high	high	**high**
Largemouth bass	low	ok	ok	ok	high	**ok**
Northern pike			high	high	high	**high**
Brown bullhead		ok	high	ok	ok	**ok**
Yellow bullhead	v. high	ok	high	high	ok	**high**
Warmouth			ok	ok	ok	**ok**
Green sunfish	0	ok	0	0	0	**low**
Longear sunfish			0	0		**low**
Grass pickerel	ok	0	ok	0	0	**low**
Chubsucker	ok	ok	ok	ok	ok	**ok**
Bowfin		high	low	high	v. high	**high**
Golden shiner	ok	ok	0	0	0	**low**
White sucker		ok			ok	**ok**
Iowa darter	0		0	0		**0**
Banded killifish		0				**0**
Brook silverside			0	0		**0**
Bluntnose minnow	0	0	0	0		**0**
Fathead minnow	0		0	0		**0**
Blackchin shiner	0	0				**0**
Blacknose shiner		0				**0**

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Table 21.14.–Summary of species selectivity of day electrofishing (220-v AC) relative to mark-recapture and known presence. Reproduced from Schneider (1997). s = spring sample; f = fall sample; ok = within 5% of reference; low = <5% or tr; high = >5%; 0 = not caught but present.

	By number			By weight			
Species	Blueberry s1987	Dead s1985	**Pattern**	Blueberry s1987	Dead s1985	Mill f1964	**General pattern**
Bluegill	v. low	low	**low**	low	v. low	v. low	**v. low**
Pumpkinseed	high	high	**high**	high	high	high	**high**
Yellow perch	ok	low	**ok**	ok	ok	low	**ok**
Rock bass						ok	**ok**
Black crappie		ok	**ok**		ok	ok	**ok**
Largemouth bass	ok	ok	**ok**	ok	ok	ok	**ok**
Northern pike		ok	**ok**		ok	0	**low**
Brown bullhead		ok	**ok**		low	low	**low**
Yellow bullhead	ok	ok	**ok**	ok	ok	0	**ok**
Warmouth		ok	**ok**		ok	ok	**ok**
Green sunfish	0	ok	**ok**	ok	ok	0	**ok**
Longear sunfish		ok	**ok**		ok		**ok**
Grass pickerel	high	ok	**high**	high	ok	ok	**ok+**
Chubsucker	high	ok	**ok+**	high	ok	high	**high**
Bowfin		ok	**ok**		high	v. high	**high**
Golden shiner	ok	ok	**ok**	ok	ok	ok	**ok**
White sucker						ok	**ok**
Iowa darter	0	0	**low**	0	0		**low**
Brook silverside		0	**low**		0		**low**
Bluntnose minnow	0	ok	**low**	0	ok		**low**
Fathead minnow	0	0	**low**	0	0		**low**
Blackchin shiner	ok	0	**low**	0			**low**
Blacknose shiner		ok	**low**				

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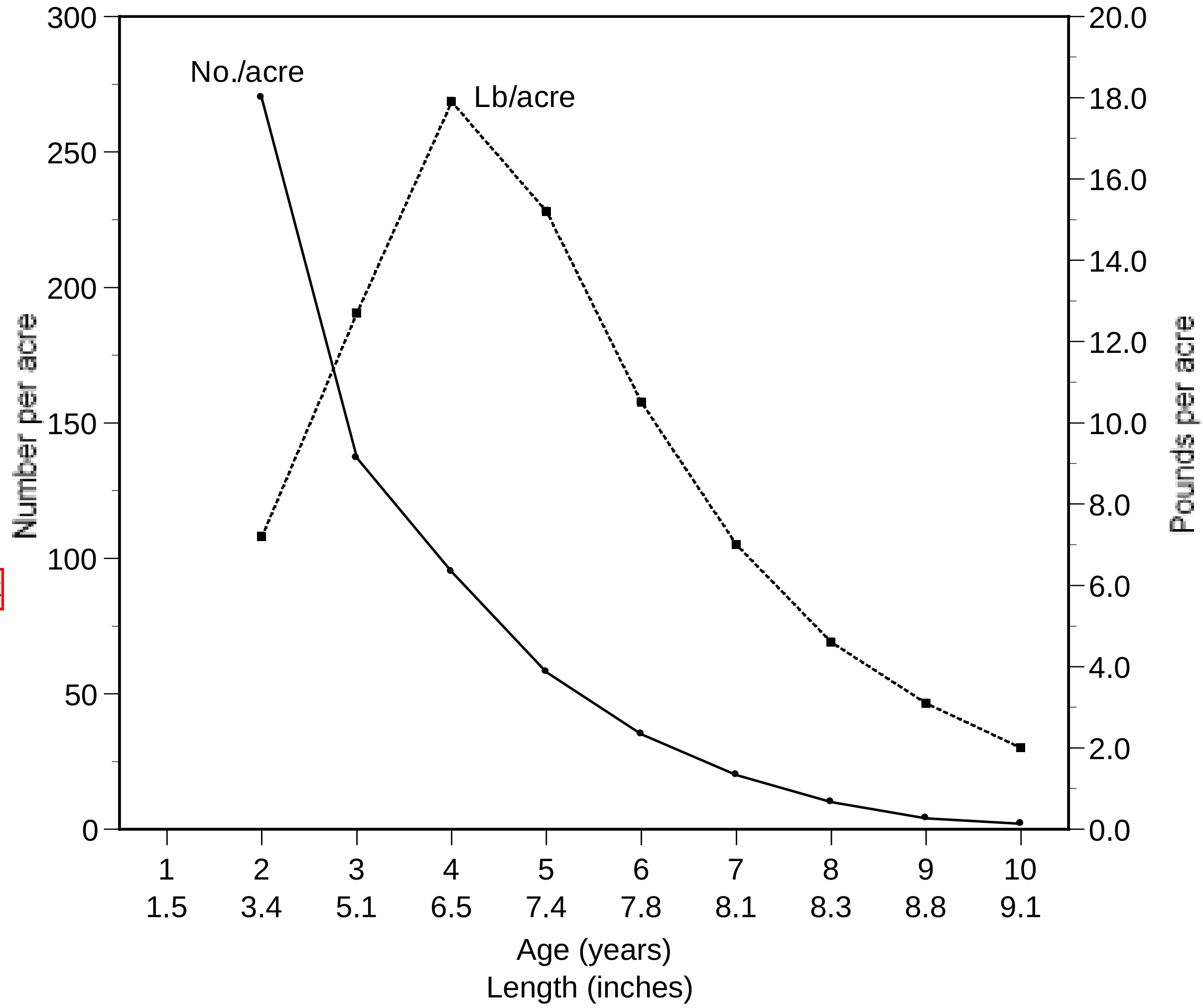

Figure 21.1.–Distributions by age and length of bluegill in Blueberry Pond based on mark-and-recapture population estimates. (Data from Schneider 1993).

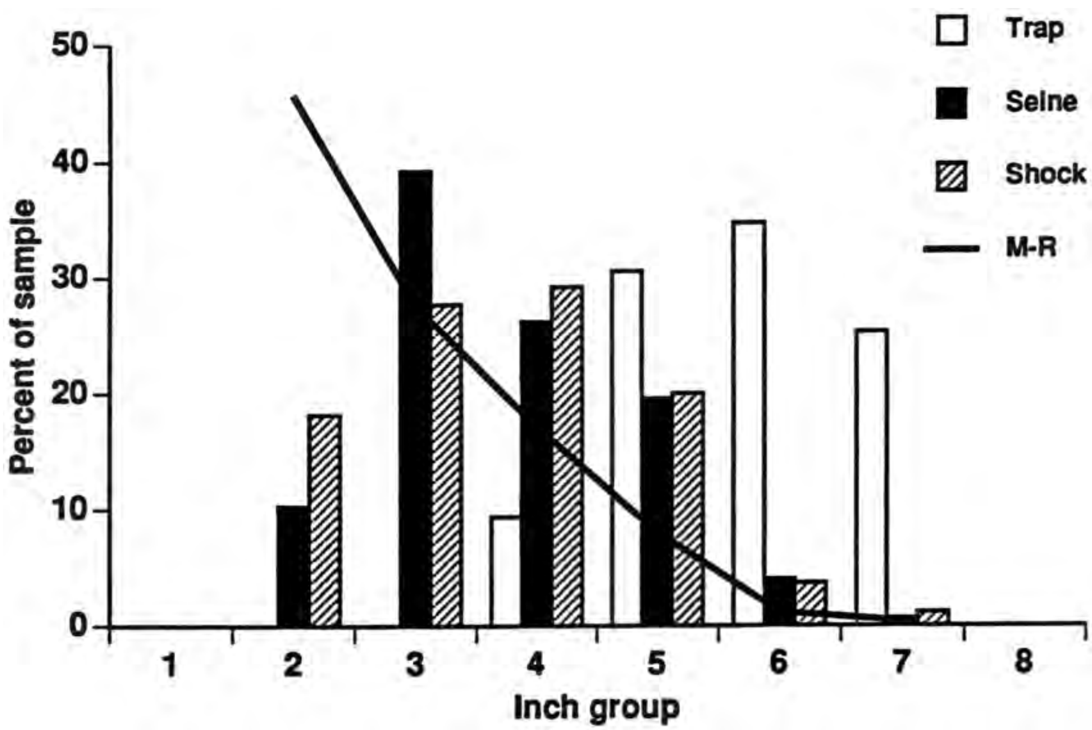

Figure 21.2–Bluegill length-frequency distributions in samples taken by 230-volt AC boom shocker, 800-foot seine (with 1-inch stretched-mesh pot) and trap net (with 1.5-inch stretched-mesh pot). The actual length distribution, based on mark-and-recapture (M-R) population estimates, is shown as a curve to illustrate gear size selectivity. Samples were taken from Mill Lake in fall 1996 (Schneider 1971 and unpublished data). Number of bluegill sampled were 4,267 by electroshocker (10 trips), 5,038 by seine (8 hauls), and 170 by trap net (42 lifts). Reproduced from Schneider (1990.)

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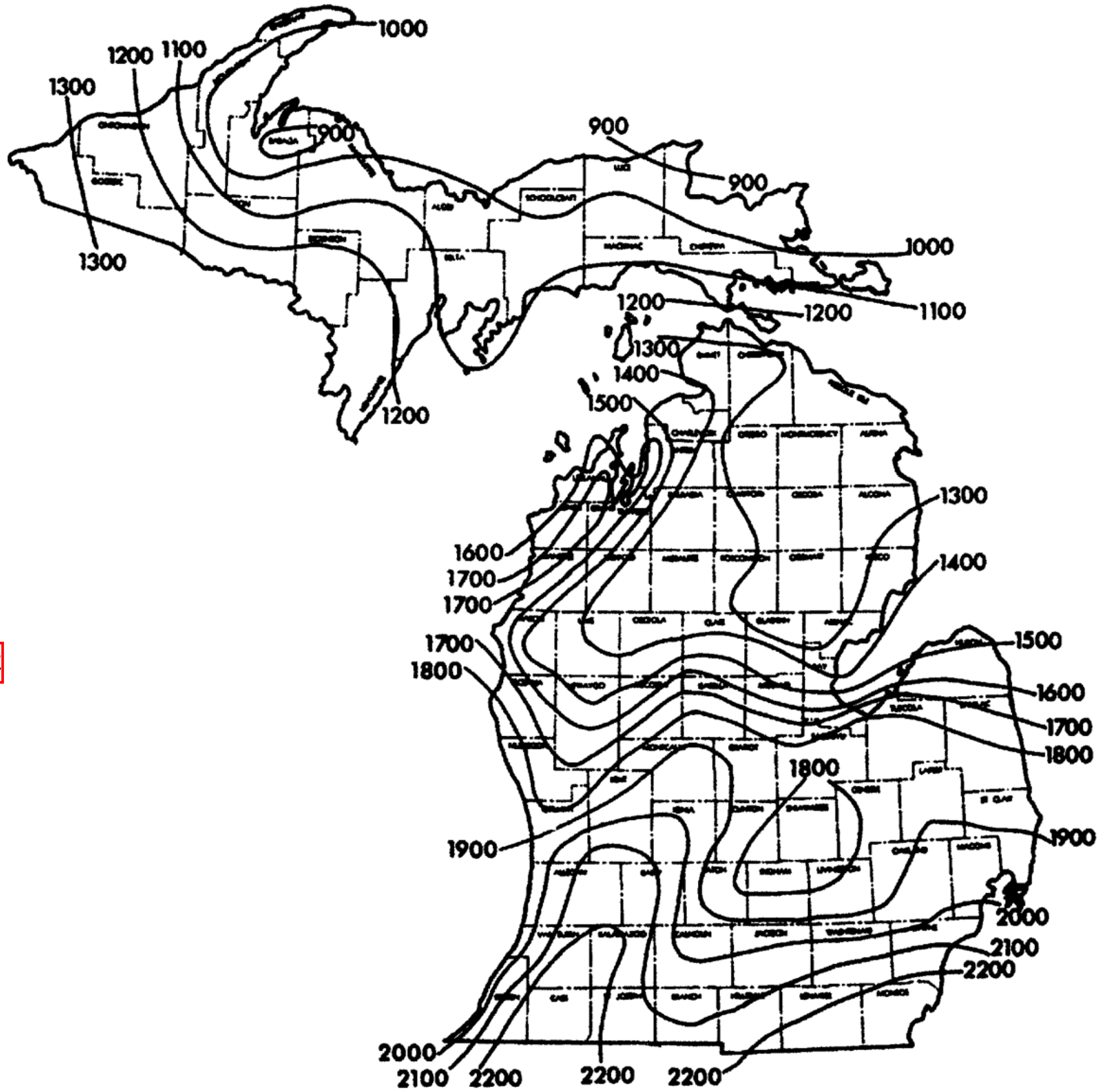

Figure 21.3–Average cumulative growing-degree-days above a base of 55°F, March 1-October 31. Reproduced from Van den Brink et al. (1971).

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Written 1/2000 by J. C. Schneider

Manual of Fisheries Survey Methods II: with periodic updates

Chapter 22: Guidelines for Sampling Warmwater Rivers with Rotenone

P. W. Seelbach, G. L. Towns, and D. D. Nelson

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Chapter 22: Guidelines for Sampling Warmwater Rivers with Rotenone

P. W. Seelbach, G. L. Towns, and D. D. Nelson

Michigan contains a number of medium- to large-sized warmwater rivers, some of which attract significant angler attention. Nearly all of these presently have good-to-excellent water quality and have the potential to be high quality fishery and recreational resources.

Riverine fishes are very difficult to sample with conventional methods. Spot sampling with rotenone has proven to be effective tool (Seelbach et al. 1994). Rotenone samples reveal not only presence/absence of all species – both of sport and conservation interest – but also provide a true picture of relative numbers in the fish community. Periodic rotenone surveys are recommended for complete inventories of warmwater river fish communities and for monitoring the status of these communities through time. Rotenone surveys are not intended to provide annual population estimates.

Rotenone and other fish toxicants are valuable fisheries tools but must be used very judiciously to avoid over-kill of fish. See "Policy and Procedures for the Use of Piscicides and other Compounds by Fisheries Division in Ponds, Lakes, and Streams" dated March 29, 1993. Any project must be preceded by extensive public education and discussion and conducted with great care.

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22.1 Sampling methods

Major river systems should be surveyed with a minimum frequency of once every 20 years. River systems, or portions of systems, that are actively managed or receive a high degree of angler interest should be surveyed more frequently.

The sampling methodologies described below are based on those described by Nelson and Smith (1980) and Towns (1987).

Sampling stations should be selected based on (1) being representative of the particular river reach, (2) having reasonable access, and (3) having velocities sufficient to carry fish downstream to the barrier net. Stations should be approximately 600-700 feet in length, although longer and shorter lengths may be used to accommodate differences in stream size and unusual channel structure or habitat. Measurements should be taken at each station to describe the morphology of the river and to allow calculation of rotenone and potassium permanganate concentrations. Measurements should include water temperature, stream discharge, and station length and average width. Stream discharge can either be measured using a current meter or extrapolated from discharge measured at a nearby U.S. Geological Survey gaging station.

At the downstream end of the station, a blocking net is placed across the river. Where possible, it is best to add a second net approximately half way through the station. This mid-station net will collect upstream fish which might otherwise settle to the stream bottom and be lost. An additional net is set across the upstream end of the station to prevent migration of fish out of the station. Nets of several lengths and depths may be needed to accommodate the various station morphologies encountered. Mesh sizes may range from small mesh (3/16 inch stretch), which can be used with low current velocities, to larger mesh (2-inch stretch), which can be used at higher velocities. Small mesh nets can be assumed to capture all fish of 2 inches in total length and larger and should be used whenever possible. Larger mesh nets will allow small fish to pass through; these are subsampled using several small-mesh fyke nets placed just downstream from the blocking net at random intervals across the river. The catch of these fyke nets can be extrapolated across the total cross-sectional area of the river to yield an estimate of the total number of small fish that pass through the blocking net.

The float line of the barrier net should be attached to a head rope that had been previously set across the river and pulled taut. At most stations braided dacron line can be used for this head rope, however, steel aircraft cable should be substituted at stations where the river is wide and the current is swift. The lead line of the net is held in place with trap net anchors. The lead line should not be anchored until the treatment is ready to begin. This helps to minimize the build-up of debris in the net that tends to pull the float line under the water's surface. In high velocity situations, it may be necessary to attach additional lines to the head rope to prevent downstream sag of the net. These lines should be directed upstream and attached to overhead tree limbs or similar structures.

Rotenone should be applied in most warmwater rivers at a concentration of 3 ppm. For this concentration apply 5 gallons of rotenone per each 100 cfs of river discharge; this amount should be metered into the river to provide a constant concentration throughout an exposure time of 35 minutes. Other concentrations may be calculated on a straight-line proportional basis (3 ppm/5 gallons). Two ppm of rotenone is suggested for clear headwater streams that have low turbidity, low amounts of silt substrate, and where rotenone-resistant fish species are expected to be absent. Even lower concentrations should be used if this method is employed in cold-water trout streams. In rivers with high turbidity, where silt and organic detritus are the predominant substrates, and where large numbers of resistant fish (for example carp and bullheads) are expected, up to 5 ppm of rotenone may be applied. Silt and organic detritus absorb rotenone and thus reduce its effectiveness. Rotenone concentrations higher than 5 ppm should be avoided. In stations with large slow-water pools the leading edge of the rotenone plume is rapidly diluted by the static water volume and either the concentration or exposure time of rotenone must be increased to ensure adequate results. The addition of fluorescein dye at the beginning of rotenone application is useful for tracking the progress of the treated water mass.

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The method used to apply rotenone is based upon water depth at the upstream limit of the station. When the river is shallow and easily wadable, rotenone can be applied by spraying with one or more water pumps. Where the water is too deep to wade, rotenone can be applied from a boat; the rotenone is gravity fed into the outboard motor back-wash while the boat moves back and forth across the river.

Immediately downstream from the blocking net, the rotenone is neutralized by adding potassium permanganate to the river. In most warmwater rivers a concentration of 5 ppm permanganate is sufficient to detoxify 3 ppm rotenone. The permanganate should be metered into the river to provide a constant concentration for 45 minutes. In other situations the concentration of potassium permanganate needed can be calculated using the ratio of 5 parts permanganate to 3 parts rotenone. Permanganate amounts can also be determined according to the ratio of 15 pounds of permanganate to 1 gallon of rotenone. When the flow of rotenone through the station is impeded by a large static water volume, additional application time will be required. In situations where 5 ppm of rotenone has been employed, up to 8.5 ppm of potassium permanganate should be used. Permanganate concentrations above 12 ppm are likely to cause fish mortalities. Extra potassium permanganate or longer exposure times may be used in trout streams where there is great public concern over inadvertent downstream fish mortalities; in warmwater streams the use of extra permanganate is generally not necessary.

The potassium permanganate is first dissolved in river water placed in spray barrels and then sprayed into the river with water pumps. In this instance a double-intake pumping system is required. The smaller intake hose (approximately 3/4" to 1", with shut-off valve) is placed in the spray barrel and the main intake in placed in the river. The rate of permanganate addition is controlled by regulating the small intake valve. Alternatively, the permanganate may be pumped directly from a perforated spray barrel placed directly in the river. In this case, dry permanganate is added to the perforated barrel at a predetermined pound-per-minute rate. At large-river stations several detoxification units are necessary. Two workers are needed per detoxification unit – one to spray and one to add permanganate throughout the spraying period. To ensure detoxification in the event of a pump failure, it is essential to have at least one back-up pump at the detoxification station, pre-tested, primed, and ready.

As many fish as possible should be collected from the station. Dead and distressed fish can be immediately collected with hand nets. Dead fish that accumulate on the barrier net may be allowed to remain. Several sweeps of the entire study area should be made by boat and/or wading to collect fish that settle to the bottom, are washed ashore, or become lodged in obstructions. When it is determined that no additional dead fish are accumulating on the barrier net, the net can be lifted and the fish removed.

22.2 Data collection

The following data collection procedures should be followed:

1. Count and identify to species all fish. If necessary, ice can be used to help preserve fish during identification. Save questionable specimens for verification by experts.
2. Weigh fish in aggregate by species.
3. Measure total length (round down to the nearest inch) of all game fish, sucker species, and carp. For extremely abundant sucker species, individuals should be separated into "less than or equal to 3 inch" and "larger than 3 inch" groups. Individuals in the first group can simply be counted and weighed in aggregate. A random subsample of 400 individuals of the latter group should be measured. The length range of individuals of other species should be recorded.
4. Take scale samples for age analysis from ten fish per inch group for all game fish (take pectoral spines from channel catfish). In typical swift-water reaches, "game fish" include smallmouth bass, rock bass, northern pike, muskellunge, channel catfish, and walleye. In slower reaches "game fish" might also include largemouth bass and crappies.

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22.3 Report format

Results from each survey site should be reported on standard fish collection (R–8058) and fish growth analysis (R–8070) forms, or their electronic equivalents in the Fish Collection System. A Fisheries Technical Report should be written following surveys of major river systems. Report formats should follow that of Towns (1987).

22.4 References

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Prepared 1988 by P. W. Seelbach, G. L. Towns, and D. D. Nelson
Revised 1/2000 by P. W. Seelbach and J. C. Schneider

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Chapter 23: Guidelines for Evaluating Walleye and Muskie Recruitment

William Ziegler and James C. Schneider

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Chapter 23: Guidelines for Evaluating Walleye and Muskie Recruitment

William Ziegler and James C. Schneider

Biologists in Wisconsin have refined catch-per-effort (CPE) methods for surveying and evaluating the recruitment of juvenile walleye and muskellunge over many years. The methods have been extensively tested in Michigan and Minnesota as well, and found to be very useful.

The method usually gives quite reliable results in one sampling trip. However, an additional trip should be made if initial results may not be representative. Results should be viewed as approximations, tempered with experience and common sense, and verified by adult surveys during spawning periods, if possible.

These methods provide a relative index of walleye or muskie recruitment in a timely fashion. That information allows us to monitor stocking success, track natural reproduction, adjust stocking rates, set and alter stocking priorities, and monitor the effects of environmental fluctuations and habitat degradation on reproduction.

23.1 Walleye

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Serns (1982, 1983, and personal communications) developed standardized methods for estimating the recruitment of walleye at three life stages: fall young-of-the-year (yoy), spring yearling, and fall yearling. He provided directions for sampling and for estimating actual population size from CPE. Subsequently, these methods have proven to be very reliable on more than 45 lakes in Wisconsin and northern Michigan and guidelines for ranking CPE have been refined.

23.1.1 Walleye sampling

Collect juvenile walleye with either 220-volt AC or (preferably) DC electrofishing boat at night during fall (yoy and yearling) or spring (yearling), when they are concentrated inshore. Ideal water temperatures (F°) range from mid 70s to high 40s (better, >50). In the fall, such temperatures occur from September to early October in northern Michigan, and somewhat later in southern Michigan. In the spring, such temperatures occur in May and June. Recruitment surveys of smallmouth bass and yellow perch may be conducted concurrently (or sequentially) if they do not hamper collecting a high proportion of stunned walleyes.

Serns recommended that one complete circuit of the shoreline be made for proper use of his population formula. For very large lakes, sampling can be reduced to representative sections, but beware that bias can occur if the best walleye habitats (firm substrates) are not sampled in proportion to their occurrence in the lake. Good habitats can be selected as index stations, where changes in CPE are monitored annually, but it is not appropriate to compute population estimates for the entire lake from good stations alone. These are the minimum standards for sampling effort:

- Lakes with less than two miles of shoreline – shock entire shoreline;
- Lakes with less than 500 acres – shock 2 miles of shoreline;
- Lakes between 500 and 1,200 acres – shock two, 2-mile sections of shoreline;
- Lakes over 1,200 acres – shock three or more 2-mile sections of shoreline.

23.1.2 Walleye evaluation

Serns (1982) provided the following equation for calculating the number of yoy walleye in an entire lake based on sampling the entire shoreline (or a good representative sample) in the fall:

fall yoy walleye/acre = 0.234 (yoy shocked/mile of shoreline)

For example, if the average catch was 20 yoy per mile, the population estimate is 4.7 yoy fingerlings per surface acre (0.234 x 20).

Serns (1983) provided the following equation for calculating the number of yearlings in the entire lake based on sampling the entire shoreline (or a good representative sample) in spring or fall:

yearling walleye/acre = 0.194 (yearling shocked/mile of shoreline)

In the table below are ranks for evaluating the relative strength of yoy year classes in good walleye lakes. These are based on efforts to verify index sampling through subsequent surveys of adult walleye surveys or reliable fishing reports. Ranks are more appropriate for less intensive sampling efforts and index stations than population estimates calculated from equations. Walleye densities calculated from equations have been added to the last column for comparison.

Fall yoy/mile shocked	Year class strength	Calculated number/acre
<45	poor	<11
45 - 130	average	11 - 30
>130	strong	>30

A similar ranking system for evaluating the relative strength of year classes based on either spring or fall yearling indexing is in the table below. It is based on less experience and should be considered tentative.

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Yearling/mile shocked	Year class strength	Calculated number/acre
<20	poor	<4
20 - 90	average	4 - 18
>90	strong	>18

23.2 Muskie

This procedure is based on 10 years of musky evaluation in northern Wisconsin and the Upper Peninsula of Michigan and personal communications with several Wisconsin DNR fisheries biologists, particularly Terry Margenau (Spooner, Wisconsin, Fisheries Research).

23.2.1 Muskie sampling

Muskie electrofishing surveys are best conducted when juvenile fish (age 0 or 1) are concentrated in shallow water during late fall (mid to late October and early November in northern Michigan). Sometimes good catches can also be made in early spring. Water temperatures (F°) at these times range from mid 30s to upper 40s. Recruitment of northern pike may be indexed concurrently. Other comments regarding electrofishing procedures and sampling intensity for muskie are the same as for walleye (above).

23.2.2 Muskie evaluation

Based on efforts to verify results through adult surveys and reliable fishing reports, an understanding has been gained of CPEs that constitute strong and weak year classes for muskie lakes. Guidelines are:

yoy/mile shocked	Yearling/mile shocked	Year class strength
<2	<1	weak
2 - 6	1 - 4	average
>6	>4	strong

23.3 References

Serns, S. L. 1982. Relationship of walleye fingerling density and electrofishing catch per effort in northern Wisconsin lakes. North American Journal of Fisheries Management 2:38-44.

Serns, S. L. 1983. Relationship between electrofishing catch per unit of effort and density of walleye yearlings. North American Journal of Fisheries Management 3:451-452.

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Prepared October 1998 by W. Ziegler and J. C. Schneider

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Manual of Fisheries Survey Methods II: with periodic updates

Chapter 24: Aquatic Nuisance Species Control Policy for Fisheries Division Field Surveys

Amy Hilt

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Chapter 24: Aquatic Nuisance Species Control Policy for Fisheries Division Field Surveys

Amy Hilt

This document was derived from recommendations in various Sea Grant publications, research presented at the International Zebra Mussel and Other Aquatic Nuisance Species Conference in 1996, and the 1998 Coolwater Culture Workshop. Although these guidelines were written specifically for zebra mussels, following these guidelines will also reduce the spread of several other aquatic nuisance species such as Eurasian water milfoil, curlyleaf pondweed, purple loosestrife, and spiny water flea. It will be revised as new information becomes available.

Below are guidelines for disinfecting various types of equipment used in lakes and ponds contaminated with zebra mussels, guidelines for operating rearing ponds, and recommendations for disinfecting water used to transport fish. Keep in mind that:

- The primary factors limiting survival of zebra mussels are moisture and temperature. The maximum out-of-water survival time of zebra mussels in ideal conditions is about 10 days for adults and 3 days for newly settled juveniles. In most situations, we will dealing with either juveniles or veligers in and on our equipment.
- The need for disinfecting can be reduced by scheduling surveys of non-infested waters before surveys of zebra mussel infested waters.

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24.1 Small equipment such as scap nets, measure boards, buckets, rain gear, waders, anchors

- Dry completely and keep dry for 3 days.
- If the equipment is needed prior to 3 days, soak in a solution of 1 part chlorine bleach to 10 parts water (example: 1 gallon of bleach to 10 gallons of water) for a minimum of 30 minutes. Alternatives include thorough rinsing with hot water (> 110F) or freezing (< 0F) for a minimum of 24 hours.

24.2 Large equipment such as trap nets, gill nets, fyke nets, and holding crates

- Inspect all nets carefully. The degree of infestation will depend on how long the nets have been in the water. Look carefully for signs of adult zebra mussels attached to the netting, particularly if the nets have been in the water more than 1 night.
- Stretch nets outdoors until dry, then pack and bring inside to sit for 3 additional days if no mussels were found, 10 days if mussels were found. Bringing equipment inside is recommended because of the potential for rain or dew to keep mussels alive.
- Label each net with the ending day of the quarantine to avoid any confusion as to availability for use.
- If the nets are needed prior to the end of the quarantine period, fill a horse tank with a solution of 1 part chlorine bleach to 10 parts water and soak each net for a minimum of 30 minutes.

24.3 Boats and trailers

- Remove any vegetation clinging to boat, prop, trailer, and other equipment while still at the access site. Zebra mussels readily attach to aquatic vegetation, and Eurasian water milfoil and other exotics can also be transferred that way.
- After returning to the work station, thoroughly rinse the boat inside and out with tap water.
- Rinse off trailer, outboard, and even the truck if it was backed into the water.
- Flush the outboard to remove all lake water from inside the motor. Make sure all vegetation and debris are removed.
- Live wells on shocker boats should be given the chlorine bleach treatment described above. Make sure the intakes and outlets of the live wells are also treated. Chlorine should only be used when it can be completely rinsed away prior to going to another water body. Do not apply chlorine at a launch site.
- After rinsing and flushing, let the boat sit for 3 days in a dry location. If the boat was docked at the lake, the drying time should be increased to 10 days.
- If the boat is needed right away, rinse the boat as mentioned above, only with hot water instead of tap water. It requires a temperature of 110F to kill veligers and 140F to kill adults. Flush the outboard with hot water.
- A quick, easy method for flushing outboards is to use muffs, which can be purchased at any marine store. Hook it up to either a cold or hot water tap—depending on length of time before the outboard may be used again.

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24.4 Rearing ponds

24.4.1 Uncontaminated ponds:

- To prevent contamination by boat, designate one boat for work (fertilizing, netting, etc.) in uncontaminated ponds.
- When harvesting fish, draw transport water from the rearing pond, not another water body.
- After stocking fish into infected water, disinfect any equipment that came in contact with the water.

24.4.2 Contaminated ponds:

- Whenever possible, stock fish from contaminated ponds into contaminated waters. Otherwise, use the transport disinfect recipes below.
- Research has shown that rotenone will kill all ages of zebra mussels at concentrations less than those normally used to treat our ponds. Therefore, if the source of contamination to a pond can be eliminated, the pond can be disinfected by the fall rotenone treatment.

24.5 Fish transport units

The chemical solutions below will kill zebra mussel veligers in water used to transport live fish. These recommendations were made by David A. Culver at the 1998 Coolwater Culture Workshop on January 26, 1998.

1. For brood and other adult fish, and trout and muskellunge greater than 150 mm in length:
   - Treat with 100 mg of 40% formalin per liter of rearing water for minimum of 2 hours.
   - 100 mg of 40% formalin/L = 378.5 mg/gal. = **37.85 g/100 gal**.

2. For hybrid striped bass (only):
   - Treat with 20,000 mg NaCl per liter for minimum of 2 hours during transport.
   - 20,000 mg NaCl/L = 2% =**7.57 kg/100 gal**. = 16.7 lb./100 gal.
3. For fingerlings walleye, saugeye, largemouth bass, hybrid striped bass and channel catfish:
   - Treat first with 750 mg KCl per liter of rearing water;
   - Then add 20 mg of 40% formalin per liter during transport for minimum of 2 hours.
   - 750 mg KCl/L = 2,839 mg/gal. = 284 g/100 gal. **= 1 gal. stock solution/100 gal.**
   - 20 mg of 40% formalin/L = 75.7 mg/gal. = **7.57 g/100 gal.**

Preparation of KCl stock solution from water softener KCl:

Softener salt is 99% KCI and about 0.7% NaCl, so it will work well for us. It comes in a 40 lb. bag, which is enough to treat 6,400 gal. of pond water. To make up a stock solution in advance for future use, dissolve one 40 lb. bag in 64 gallons of water. (This is about 1/4 as concentrated as a saturated solution of KCI at 68F, so it should dissolve okay). Use 1 gal. of the stock solution/100 gal of pond water.

KCI Sources:

Water softener KCl from Dublin Pump, Dublin OH, costs $8.95/40 lb. or $0.50/kg.
Reagent grade KCl from Fisher Scientific (Cat. #P217-10) costs $17.29/kg.

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Chapter 25A: GLEAS Procedure #51 Survey Protocols for Wadable Rivers

Michigan Department of Environmental Quality
Surface Water Quality Division

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Chapter 25A: GLEAS Procedure #51 Survey Protocols for Wadable Rivers

**Michigan Department of Environmental Quality
Surface Water Quality Division**

[Editor's note: Chapter 25 presents methods developed by the Surface Water Quality Division for surveying and evaluating fish, invertebrates, and habitat in wadable streams and rivers. The methods are included in Manual of Fisheries Survey Methods II because they can be useful to Fisheries Division personnel as well. The first section, Chapter 25A, presents qualitative biological and habitat survey protocols. The second section, Chapter 25B, presents methods for scoring and interpreting the resulting metrics.

Chapter 25A consists of a document, revised in January 1997, prepared by Michigan Department of Environmental Quality, Surface Water Quality Division, Great Lakes and Environmental Assessment Section. It has been included here with permission, and has been modified only as needed for formatting. Contents of this report are subject to modification by the authors, and a time lag may occur before such revisions appear in the Manual of Fisheries Survey Methods.]

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REVISED JANUARY, 1997
GLEAS PROCEDURE #51

QUALITATIVE BIOLOGICAL AND HABITAT SURVEY PROTOCOLS FOR WADABLE STREAMS AND RIVERS

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Michigan Department of Environmental Quality
Surface Water Quality Division
Great Lakes and Environmental Assessment Section

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QUALITATIVE BIOLOGICAL AND HABITAT SURVEY PROTOCOLS

I. INTRODUCTION

The development of these Biological and Habitat Survey protocols was a result of the increasing demand for a more vigorous and standardized evaluation of nonpoint source impacts. The nature and diversity of the causes of nonpoint pollution created a need for greater refinement and sophistication of the Surface Water Quality Division standard biological survey procedures in order to assess the degree and causes of these biological impacts. The origins of nonpoint effects often extend throughout an entire watershed basin. Such basin wide effects prevent the traditional upstream/downstream comparisons from providing a true picture of the extent of stream impairment. Methods, therefore, need to be more sensitive and reproducible to consistently detect the changes in the biotic communities caused by possible widespread nonpoint source effects and yet still be applicable to the many differing aquatic systems found throughout Michigan. The application of these biological survey protocols will provide a more accurate and precise database on biological conditions and trends statewide.

The biosurvey protocols consist of three parts including evaluation of the macroinvertebrate community, the fish community, and the habitat quality. Any one or combination of the three categories can be evaluated. The biological integrity of a stream is based on the results of the fish and macroinvertebrate communities.

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These protocols only address qualitative methods for wadable streams. Methods for non-wadable streams and other waterbodies will be developed at a later date. In addition, certain studies may require quantitative, or other alternate methods. The biosurvey protocols presented here do not preclude the use of alternate methods, however, the use of alternate methods will be the exception.

The analysis of the fish, macroinvertebrate, and habitat quality is made according to a set of selected measurements or "metrics". These metrics have been selected from those used by EPA for the Rapid Biological Assessment Protocols, Ohio's Environmental Protection Agency's protocols, the State of Illinois' biological procedures, and those procedures developed specifically for Michigan and tested by MDEQ staff. The metrics represent a wide array of criteria for the majority of biological or habitat conditions known to occur in response to various stream quality conditions. The accuracy of the protocols, however, depends on the selection and evaluation of excellent sites. These excellent sites are selected from streams within each of Michigan's Ecoregions recognized as excellent in quality by biologists. These sites then become the level against which all other field measured stream biological and physical parameters are compared. Each Ecoregion will have several excellent sites, according to stream width. The glacial history of Michigan created five distinct Ecoregions, separable by soil types, topography, and stratigraphy (Omernik, 1987). The Ecoregion approach provides a logical framework to use with these biological monitoring protocols when excellent sites are described within each Ecoregion.

Each survey station is described with up to three numbers, one each for the macroinvertebrate community, the fish community, and the habitat. An excellent quality stream for the Ecoregion would have most metrics performing like an excellent site. Poor quality streams would have most metrics performs substantially different than excellent sites. The use of these metrics creates a uniform and systematic evaluation for each station with the result expressed as a single numerical score. This makes the results easily interpretable, since they are expressed relative to the excellent sites.

These protocols can become the yardstick used to measure the effectiveness of Best Management Practices in controlling basin wide nonpoint source effects, to predict potential intra-basin or regional trends early, and to determine the degree of use attainability of individual waterbodies. The advantages of this approach include greater consistency and accuracy, together with a better overall measurement of total biological integrity and habitat conditions.

II. PRINCIPLES OF FISH, MACROINVERTEBRATE AND HABITAT SURVEYS

Better stream quality is normally indicated by greater warmwater fish and benthic macro-invertebrate diversity and abundance, as well as a more even distribution of individuals among taxa at one station compared with another. Conversely, poorer stream quality is indicated by a lower diversity and abundance at one station when compared to another. Changes in stream quality over time may be recognized at a given station by repeated sampling and comparison of fish and macroinvertebrate data.

Fish and macroinvertebrate community composition generally reflect conditions present for an extended period of time prior to sampling. However, temporary events, such as decreases in dissolved oxygen concentrations or the presence of toxicants, may cause losses of sensitive species within the biological community either by emigration or death. Similarly, an abundance of tolerant organisms may indicate persistent degraded stream quality. Changes in fish or macro-invertebrate community structure will also occur if trophic changes occur due to pollution or perturbation. The emphasis on data interpretation is therefore directed toward evaluating the fish or macroinvertebrate community, which is obtained from these procedures by combining a variety of different community evaluation tools or 'metrics'. These metrics measure a wide spectrum of community attributes and are used in combination to determine biosurvey categories.

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The metrics for coldwater fish have been removed from this version of the procedure. The present data set for coldwater wadable streams in Michigan was not conducive to metric development at this time. Instead, the coldwater fish community is evaluated for the presence of at least 50 fish, anomalies, and percentage of salmonids relative to the total number collected.

The habitat evaluation is also important in determining the nature and degree of abiotic constraints on the biological potential. This evaluation is accomplished through characterizing the stream based on selected physical measurements and descriptive watershed features. The habitat metrics measure a wide range of physical characteristics, which are important to the optimum development and stability of biological communities, and are used to develop habitat survey categories.

III. GENERAL SAMPLING CONSIDERATIONS

1. Sampling should occur between June 1 and September 30 during periods of stable discharge, at times of low or moderate flow. This will help ensure consistency between sampling studies by reducing variability due to flow fluctuations within years or between years.

2. For basin investigations or long-term studies, stations should be sampled during the same time frame to minimize seasonal variability in fish and macroinvertebrate distribution or abundance.

3. Maximum impact of a municipal or industrial discharge usually occurs during summer low stream flow and maximum temperature conditions. Dilution is minimal for pollutants during low flow conditions, while elevated stream temperatures and productivity will produce maximum fluctuations in diurnal oxygen concentrations. High temperatures also increase fish and macroinvertebrate metabolic rates which may amplify toxics effects.

4. Consideration must be given to the sampling sequence. For most sites, the sampling sequence should first be fish, then macroinvertebrates, with habitat evaluation last. This is to insure the least disruption of the communities to be sampled.

5. Record all data on the Stream Survey Cards shown in Appendix J, including a sketch of the station location to assist future sampling. The following channel modifications should be noted by checking the appropriate box(es) on the survey card:

   <u>none</u> - natural stream channel, no evidence of modifications.
   <u>dredged</u> - stream channel has been excavated (widened, deepened, straightened), evidence of dredge spoils along stream banks.
   <u>canopy removal</u> - woody riparian vegetation has been removed from one or both banks either by physical removal or with the use of defoliant sprays.
   <u>snagging</u> - removal of logs, deadfalls, and other large woody debris from the stream channel.
   <u>impounded</u> - station is located either directly upstream of an impoundment or directly downstream of a dam.
   <u>relocated</u> - stream channel has been completely rerouted from the original channel usually to follow a roadway, railway, or has been redirected for industrial purposes (e.g. mill race) or has been rerouted to another watershed.
   <u>bank stabilization</u> - this includes engineered cattle access points or the stream bank has been armored with rip-rap, sheet piling, revetments, etc.
   <u>habitat improvement</u> - identified by the presence of artificial banks (lunker structures), wing deflectors, half-logs, rock dams, etc.

   The presence of attached algae, aquatic macrophytes, or bacterial slimes should also be noted. Although the determination of nuisance conditions will be left to the biologist's professional judgment, the following examples are provided as guidance for identifying nuisance conditions:

   1. Cladophora spp. and/or Rhizoclonium spp. greater than ten inches long and covering greater than 25% of a riffle.
   2. Rooted macrophytes present at densities which would impair the designated uses of the waterbody.
   3. The presence of bacterial slimes.

IV. SITE SELECTION

Site selection in general will be made to meet the objectives of the biological survey. In addition to the objectives of the biological survey, sites must be carefully selected to ensure that all habitats of the waterbody are represented.

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Locally modified sites, such as small impoundments and bridge areas, should be avoided, unless data are needed to assess their effects. When the sampling station is located at a road crossing, sampling should occur upstream to avoid direct influence of the roadway. Sampling near the mouths of tributaries entering large waterbodies should also be avoided, if possible, since these areas will have habitat more typical of the larger waterbody (Karr et al., 1986).

V. QUALITATIVE FISH SAMPLING PROCEDURES AND DATA ANALYSIS TECHNIQUES

Fish Sampling is optional for this procedure. Special consideration should be given to the need for sampling fish in coldwater streams, since there is a limited set of metrics (number collected, anomalies, % coldwater fish) that are available to evaluate the results with.

A. Fish Sampling Procedures

1. The stream shocking unit is the preferred fish sampling device, except where physically impractical. Backpack shocking units may be used when sampling smaller streams or headwaters. All safety procedures must be observed when using these units (see GLEAS procedure No. 48).
2. Fish shocking must always be done in an upstream direction.
3. The sampling effort expended should be sufficient to ensure that all fish species present are sampled in proportion to their occurrence in the stream reach chosen. As a goal, at least 100 individual fish should be examined from each station. This will generally require approximately 30 minutes of electrofishing per station, encompassing 100-300 feet with sufficient sampling to include all significant available habitat. In small streams (10 feet wide), the length of the sampling station should be approximately 100 feet. In moderate size streams (30 feet wide), the length should be approximately 300 feet. In larger streams and rivers, the length of the sampling station should be about 5-10 channel widths. If necessary, increase the length of the selected sampling area. If the number of fish collected is no greater than 100 individuals after 45 minutes, discontinue further sampling and calculate metrics based on reduced sample size.
4. All collected fish should be placed immediately in water filled tubs. Care should be taken to keep fish alive by replenishing the holding tub water and processing the fish as quickly as possible. Tubs may be placed in the stream shocking unit or along the stream banks. A live box may also be placed directly in the stream to hold collected fish. Portable battery operated aerators may also be used.

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B. Data to be Recorded

When sampling has been completed at each station, the following information should be recorded:

1. The location of the sampling stations should be specifically indicated on the station card so that future studies can be repeated at the same station. The station reaches should be identified on a detailed map of the study area together with any necessary comments or descriptions on the field card.
2. Record the names and number of each species collected with a length greater than 1 inch and determine the total number of fish collected. If unsure of correct field

identification, return representatives to the lab for later identification. Regional keys have been chosen for their ease of use and elimination of extraneous taxa. Hubbs and Lagler (1964) should be used as the primary key when identifying all gamefish. For nongame fish, Smith (1988) may be used but verification of identification should be through the use of Hubbs and Lagler (1964). Additional information on Petromyzonidae (lampreys) can be found in Vladykov and Kott (1980).

3. The following externally observable anomalies should be noted as total number of individuals afflicted: bent spine (scoliosis), open lesions, severely eroded fins, fungus patches, growths on skin or fins, tumors, and poor physical condition indicated by severe emaciation, excessive mucus coating, and hemorrhaging. This measurement is meant to apply only to <u>extreme</u> or <u>obvious</u> conditions. Common external parasites, such as copepods (anchorworms), and common visible internal parasites, such as black spot and yellow grub should <u>not</u> be considered anomalies unless extreme or very severe infestations are present. All determinations of anomalies should be compared to those illustrated and presented in Allison et al. (1977).

4. Record the amount of time spent electrofishing at each station including the number of passes through the sampling station and the number of shocking probes used. Also record average stream width (wetted stream channel width at time of sampling) and distance of reach electrofished. Catch per unit effort (CPE) will be calculated as the total number of fish collected divided by the number of minutes spent shocking at each station (catch per minute), and as the number of fish per stream area (catch per square meter).

5. Record the length of all fish listed in Appendix G to inch group or to size range. These data may be used for additional biomass or productivity estimates.

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C. Data Analysis Techniques

Following sample analyses, a Fish Score will be calculated for each warmwater station based on the sum of each of the ten metrics listed below. Each metric score for an individual station is contrasted to the ecoregional excellent sites. A biosurvey category describing the degree of similarity to the excellent sites will be given each station based on the total metric point score calculated. These contrasts and categories are described in separate reports (available upon request).

There are some overriding considerations in this interpretation. When fewer than 50 fish are collected, or when the percent of fish with anomalies exceeds 2%, the site will not be scored following the metrics, but will be considered to be "Poor" (below acceptable quality).

In addition, for coldwater designated streams, the requirement is to have significant populations of salmonids. Therefore, for coldwater designated streams, if the percentage of salmonids relative to total number collected exceeds 1%, the stream will be considered to meet its coldwater designation and overall quality will be judged by the macroinvertebrate metrics.

<u>Metric Description</u>

Metric 1. <u>Total Number of Fish Species</u>. This is total number of fish species collected at each sampling station. For a given watershed size and type of stream (warmwater), total number of fish species decreases with environmental

degradation. This metric is scored by comparison to excellent sites of similar size.

Metric 2. Number of Darter Species. This is the number of species in the genera Ammocrypta, Etheostoma, and Percina (Percidae: Etheostomatinae), and the number of species of Sculpins (Cottidae) and of Madtoms (genus Noturus). These species are sensitive to habitat degradation due to the unique habitats they require for reproduction. Such habitats are degraded by siltation, dredging, or reductions in oxygen content. The presence of one or two taxa may indicate good water quality so care should be taken during sampling to collect all small fish.

Metric 3. Number of Sunfish Species. This is the total number of species in the family Centrarchidae exclusive of largemouth and smallmouth basses (Micropterus sp.). They are particularly responsive to declines in pool habitats and habitat structure such as instream cover (Gammon et al., 1981; Angermeier, 1983).

Metric 4. Number of Sucker Species. This is the total number of species in the family Catostomidae. Many species are not tolerant of habitat and chemical degradation, due to habitat specificity and dominance of benthic insects in their diet. In addition, large size and long lives provide a multiyear integrative perspective.

Metric 5. Number of Intolerant Species. This is the total number of species classified as intolerant (Appendix A). Intolerant fish are those that are sensitive to many types of environmental degradation and tend to be absent from degraded surface waterbodies.

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Metric 6. Percentage of Total Sample as Omnivores. This is the ratio of the number of omnivores to the total number of fish collected. Omnivorous fishes are those species that routinely take significant quantities of both plant and animal material (often including detritus) and have the ability, usually indicated by the presence of a long gut and dark peritoneum, to utilize both. Appendix B contains a list of omnivorous fishes commonly found in Michigan. The common omnivores of small midwestern streams are Pimephales notatus and P. promelas, while Cyprinus carpio and Dorosoma cepedianum, also omnivores, are found over a wider range of stream sizes. Omnivores can become dominant in degraded conditions, apparently as a result of irregular supply of both plants and invertebrate foods. Irregularity in plant or invertebrate availability results in declining abundances for fish that specialize on one food type or the other.

Metric 7. Percentage of Total Sample as Insectivorous Fish. This metric measures the ratio of the number of insectivorous fish to the total number of fish collected and tends to vary inversely with Metric 6. Most cyprinids are insectivores (Carlander 1969, 1977); besides the omnivores mentioned above (Pimephales), some other minnow species are strict herbivores and a few are piscivores. Although a dominant trophic group in Midwestern streams, relative abundance of insectivorous fish decreases with degradation, perhaps in response to variability in supply or production of insects, which in turn may decline in response to alteration of water quality, energy sources, or instream habitat. Appendix C contains a list of insectivorous fish commonly found in Michigan.

Metric 8. Percentage of Total Sample as Piscivores. This metric is a ratio of the number of all species that are predominantly piscivores as adults to the total number of fish collected. Some opportunistic fish species may feed on invertebrates as well as fish, including both fry and juveniles. Do not include species, such as creek chub, that may opportunistically include some fish in their diet only when very large (Fraser and Sise, 1980). Viable and healthy populations of top carnivore species such as smallmouth bass, walleye, northern pike, grass pickerel, and others indicate a healthy, trophically diverse community. Appendix D contains a list of piscivorous fishes commonly found in Michigan.

Metric 9. Percentage of Total Sample as Tolerant Species. This metric is a ratio of the number of tolerant fish to the total number of fish collected. Tolerant fish are those species able to adapt to a wide range of environmental conditions and are often common in highly degraded surface waterbodies. Appendix E provides a list of tolerant species.

Metric 10. Percentage of Total Sample as Simple Lithophilic Spawners. This metric is a ratio of the number of simple lithophilic spawners to the total number of fish collected. Simple lithophilic spawners require clean gravel or cobble for spawning and do not construct nests or provide parental care. They are especially sensitive to sedimentation and siltation of these substrates. Appendix F provides a list of simple lithophilic spawners.

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VI. QUALITATIVE BENTHIC MACROINVERTEBRATE SAMPLING PROCEDURES AND DATA ANALYSIS TECHNIQUES

A. Benthic Macroinvertebrate Sampling Procedures

1. The sampling effort or time expended at each station should be sufficient to assure that taxa present are sampled in proportion to their occurrence in the stream reach chosen. This will generally be about 30 minutes of total sampling time per survey station.

2. Macroinvertebrate samples should be taken from all available habitats within the sample reach using a triangular dip net with a 1 mm mesh or by hand picking. Samples should be taken from both high velocity and low velocity areas within the selected sampling station. It is generally accepted that the optimum habitat for macroinvertebrates includes gravel, cobble, and boulder substrates necessary to support the periphyton-based benthic community. Efforts should be directed toward preferentially sampling these habitats. However, additional organisms may be hand picked or netted from other habitats such as fixed submerged boulders, vegetation, logs, pilings, or other structures. Substrates such as sand and silt should be sampled if present.

3. All organisms collected should first be placed in a bucket to form a single composite sample. The composite sample should be thoroughly rinsed in the sampling net or by using a 1 mm screen. Large organic or inorganic debris fragments should be removed. The remaining sample contents should be distributed into an enamel or plastic counting pan with a lightly colored bottom.

4. The organisms may be anesthetized, if necessary, with soda water to eliminate invertebrate movement. Add just enough water to aid in the even distribution of organisms within the pan. Discard remaining leaf fragments, twigs, and other material.

5. Subsampling of the macroinvertebrate sample can be achieved by using a small fish or minnow net or other device to remove approximately 100 organisms. To lessen sampling bias, the biologist should pick smaller, more cryptic organisms as well as larger more obvious ones not obtained from the subsample. This can be accomplished with forceps or a small bulb pipette and ensures that all taxa representing the sampling station are present in the 100 organism subsample. A subsample of about 100 organisms is designed to assure greater reproducibility and accuracy and to lessen variability due to station habitat variability and sampling effort or method variability. This subsample will provide a consistent size to allow simple or sophisticated statistical data analyses. The invertebrate biological surveys can subsequently be contrasted by ecoregion, watershed, or stream site.

B. Data to be Recorded

1. Organisms should be identified to the taxonomic level indicated in Appendix H. Appendix H also contains a list of the primary keys to be used to identify the macroinvertebrates. Alternate keys may be used, but verification of identification should be through those keys listed in Appendix H. The collected organisms in the subsample should be returned to the laboratory for identification where field identification is not feasible.

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2. When sampling has been completed at each station, the following information should be recorded on the stream survey data sheet:

    a. The sampling area should be identified on a detailed map together with necessary comments on the field card.

    b. The total number of organisms collected.

    c. The numbers of each taxa collected and identified.

    d. Sampling time in minutes (total time for all samplers).

C. Data Analysis Techniques

Following sample analyses, a macroinvertebrate score will be calculated for each station based on the sum of the nine metrics listed below. Each metric score for an individual station is contrasted to the ecoregional excellent sites. A final biosurvey category describing the degree of similarity to the excellent sites will be given each station based on the total metric point score calculated. These contrasts and categories are described in a separate report (available upon request).

<u>Metric Description</u>

Metric 1. <u>Total Number of Taxa</u>. This is the total number of taxa identified, as specified in Appendix H in the macroinvertebrate subsample. Taxa richness has historically been a key component in most all evaluations of macroinvertebrate community integrity. The underlying reason is the basic ecological principle that healthy, stable biological communities have high

species diversity. Increases in number of taxa are well documented to correspond with increasing water quality and habitat suitability. Small, pristine headwater streams may, however, be exceptions and show low taxa richness.

Metric 2. Total Number of Mayfly Taxa. This is the number of taxa in the order Ephemeroptera. Mayflies are an important component of a high quality stream biota. As a group, they are decidedly pollution sensitive and are often the first group to disappear with the onset of perturbation. Thus, the number of taxa present is a good indicator of environmental conditions.

Metric 3. Total Number of Caddisfly Taxa. This is the number of taxa in the order Trichoptera. Caddisflies are often a predominant component of the macroinvertebrate fauna in larger, relatively unimpacted streams and rivers but are also important in small headwater streams. Though tending to be slightly more pollution tolerant as a group than mayflies, caddisflies display a wide range of tolerance and habitat selection among species. However, few species are extremely pollution tolerant and, as such, the number of taxa present can be a good indicator of environmental conditions.

Metric 4. Total Number of Stonefly Taxa. This is the number of taxa in the order Plecoptera. Stoneflies are one of the most sensitive groups of aquatic insects. The presence of one or more taxa is often used to indicate very good environmental quality. Small increases or small declines in overall numbers of different stonefly taxa is thus very critical for correct evaluation of stream quality.

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Metric 5. Percent Mayfly Composition. This is the ratio of the number of individuals in the order Ephemeroptera to the total number of organisms collected. As with the number of mayfly taxa, the percent abundance of mayflies in the total invertebrate sample can change dramatically and rapidly to minor environmental disturbances or fluctuations.

Metric 6. Percent Caddisfly Composition. This is the ratio of the number of individuals in the order Trichoptera to the total number of organisms collected. As with the number of caddisfly taxa, percent abundance of caddisflies is strongly related to stream size with greater proportions found in larger order streams. Optimal habitat and availability of appropriate food type seem to be the main constraints for large populations of caddisflies.

Metric 7. Percent Contribution of the Dominant Taxon. This is the ratio of the number of individuals in the most abundant taxon to the total number of organisms collected. The abundance of the numerically dominant taxon is an indication of community balance. A community dominated by relatively few taxa for example, would indicate environmental stress, as would a community composed of several taxa but numerically dominated by only one or two taxa.

Metric 8. Percent Isopods, Snails, and Leeches. This is the ratio of the sum of the number of individuals in the order Isopoda, class Gastropoda, and class Hirudinea to the total number of organisms collected. These three taxa, when compared as a combined percentage of the invertebrate community, can give an indication of the severity of environmental perturbation present. These organisms show a high tolerance to a variety of physical and chemical parameters. High percentages of these organisms at a sample site are very good evidence for stream degradation.

Metric 9. Percent Surface Dependent. This metric is the ratio of the number of macroinvertebrates which obtain oxygen via a generally direct atmospheric exchange, usually at the air/water interface, to the total number of organisms collected. High numbers or percentages of surface breathers may indicate large diurnal dissolved oxygen shifts or other biological or chemical oxygen demanding constraints. Areas subject to elevated temperatures, low or erratic flows may also show disproportionately high percentages of surface dependent macroinvertebrates. Appendix I contains a list of surface dependent aquatic macroinvertebrates.

VII. HABITAT SURVEY PROCEDURE AND DATA ANALYSIS TECHNIQUES

A. Habitat Evaluation

Each station will be scored for the nine metrics described below. A final habitat survey category describing the overall quality of the fish and macroinvertebrate habitat will be given each station based on the total metric point score calculated.

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Habitat quality parameters are separated into three principal categories: 1. Substrate and Instream Cover; 2. Channel Morphology; and 3. Riparian and Bank Structure. These categories, and different scoring levels, are based on levels of importance in influencing biological community composition. The most important biological habitat parameters are those characterizing bottom substrate and instream cover, estimation of embeddedness, and estimation of water velocity. These three parameters have a direct influence on biological composition and abundance. These metrics have a greater score (20) than other parameters (Table 1) because of their greater importance in affecting biological composition. Parameters associated with channel morphology and structure have a slightly smaller score of 15. Riparian and bank parameters, which may directly affect species composition the least, have the lowest score of 10.

Habitat evaluations are first made on instream habitat, followed by channel morphology, and finally on structural features of the bank and riparian vegetation. Bottom substrate and available cover, embeddedness, and velocity are evaluated in the immediate sampling area, usually the first riffle/pool or run/bend sequence. Channel morphology, riparian and bank structure are evaluated over a larger stream area (primarily upstream where conditions have greater impact on the study site). The actual habitat survey process involves rating the nine metrics as excellent, good, fair, or poor and determining the point scores for each based on the criteria included on the Habitat Survey Data Sheet (Table 1).

The station habitat score is obtained by adding together the individual scores for the nine habitat parameters. The station is then classified as excellent, good, fair, or poor based on its potential to support biological communities using the following rating table.

METRIC	HABITAT SCORING CRITERIA Excellent	Good	Fair	Poor
Substrate and Instream Cover				
1. Bottom Substrate and Available Cover	16-20	11-15	6-10	0-5
2. Embeddedness/Siltation	16-20	11-15	6-10	0-5
3. Water Velocity	16-20	11-15	6-10	0-5
Channel Morphology				
4. Flow Stability	12-15	8-11	4-7	0-3
5. Deposition/Sedimentation	12-15	8-11	4-7	0-3
6. Pools-Riffle-Runs-Bends	12-15	8-11	4-7	0-3
Riparian and Bank Structure				
7. Bank Stability	9-10	6-8	3-5	0-2
8. Bank Vegetation	9-10	6-8	3-5	0-2
9. Streamside Cover	9-10	6-8	3-5	0-2

Habitat Survey Category	Total Point Score (metrics 1-9)
Excellent	≥ 107
Good	≥ 71
Fair	≥ 35
Poor	< 35

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Metric Description

Substrate and Instream Cover

The instream habitat directly pertinent to the support of aquatic communities consists of substrate type and stability, availability of refugia, and migration or passage potential. These parameters are weighted the highest to reflect their degree of importance to biological communities. Examples of the survey categories: Excellent, Good, Fair and Poor are presented in Table 1 together with their respective point scores.

Metric 1. Bottom Substrate. This refers to the availability of suitable, diverse habitat for the support of aquatic organisms. An excellent assessment would indicate the presence of a variety of substrate material and habitat types capable of supporting a large variety of fish and macroinvertebrates. The presence of rock and gravel is generally considered to provide the most desirable cover habitat. However, other forms of habitat may also provide the niches required for community support. Logs and tree roots, for example, along with undercut banks or emergent vegetation provide excellent cover habitat for a variety of organisms, particularly fish. Consider the variety of substrate as well as the amounts of suitable substrates.

Metric 2. Embeddedness/Siltation. This parameter evaluates the degree to which boulders, rubble, logs, or gravel in run or riffle areas are surrounded or covered by fine sediments (sand, clay, or silt). This metric indicates the suitability of the stream substrate in offering clean, unsilted habitat (excellent assessment, Table 1) for benthic macroinvertebrates, such as grazers or filter feeders, as well as offering abundant, suitable sites for fish spawning and egg incubation. Examples of degrees of embeddedness/siltation are depicted in Figure 1. The percent of individual substrate surfaces surrounded or covered by silt should only be examined in relatively fast flowing stream reaches, i.e. run or riffle zones. Disturbing suspended in-stream substrates, like logs or branches and observing downstream silt clouds would indicate high siltation. This metric should be expressed as the degree to which the total overall substrate area in a run/riffle is surrounded or covered with fine sediments or silt.

Metric 3. Stream Velocity. This metric evaluates different velocity/depth combinations. Velocity, in conjunction with depth, has direct influence on the structure of fish and benthic macroinvertebrate communities. The quality of the aquatic habitat can be evaluated in terms of a velocity and depth relationship and categorized according to the relative amounts of each type. As patterned after Oswood and Barber (1982), four general categories of velocity and depth are optimal for fish and benthic macroinvertebrate communities:

a.	Shallow Pool	<1 fps	<1.5 feet deep
b.	Pool	<1 fps	>1.5 feet deep
c.	Run	>1 fps	>1.5 feet deep
d.	Riffle	>1 fps	<1.5 feet deep

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Habitat quality is reduced in the absence of one or more of these velocity/depth combinations, particularly the riffle zone or category d. For example, an optimal site would include all 4 habitats, with no one habitat type present in amounts greater than 50 percent.

Channel Morphology

Channel morphology is determined by the flow regime of the stream, local geology, land surface form, soil, and human activities (Platts et al., 1983). The sediment movement along the channel is influenced by the flowing water forces and the sinuosity of the channel. Both affect the habitat conditions of the indigenous biological communities. A constant supply of water and varied but predictable flows are key ingredients for maintaining biological diversity and stability in running waters.

Metric 4. Flow Stability. The maintenance of adequate water flow is a prime requisite for most organisms typically found in streams. The stability of the flow in a particular stream from season to season is often reflected by the diversity of the biota found there. Stream biota subject to erratic flows with large mid-summer variations beyond the expected spring and fall floods, or subject to periodic occasions of no flow or low flow, will reflect a depauperate biota typical of these adverse flow conditions. The flow contribution to these streams by natural discharges, such as springs or seeps or groundwater recharge, should be contrasted to the extent of flow contributed by point or non-point discharges. The extreme case (poor assessment, Table 1) would be an ephemeral stream, kept flowing in mid-summer only because of the large contributions made by an upstream discharge source. Examination of surroundings for past high water marks or recent flood deposits can help assess the degree of discharge stability.

Metric 5. Deposition/Sedimentation. This metric measures the ratio of stream bottom affected by deposition of larger particles of sediments, clays, or loose sand to the total area of stream bottom in the study station. A stream where extreme sediment, clay, or sand deposition occurs degrades habitat (poor assessment, Table 1), resulting in unsuitable substrates for most aquatic macroinvertebrates, as well as preventing future macroinvertebrate colonization. Deposition of sediment, sand or clay in pools or over run areas is evaluated as percentage of stream bottom area covered with sediment (i.e. a 50 foot covered section in a 100 foot sample station equals 50 percent).

Metric 6. Pools-Riffles-Runs-Bends. This metric evaluates the variety of habitats contained with the study station. A stream with riffles or bends contains better habitat (excellent assessment) for community development than a straight or uniform depth stream (poor assessment). Bends are included because some low gradient streams may not have riffle areas, but excellent habitat can be provided by the cutting action of water at bends (undercut banks). If a stream contains both riffles and bends, the most dominant feature which provides the best habitat should be evaluated.

Riparian and Bank Structure

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Well-vegetated banks are usually stable regardless of bank undercutting; undercutting actually provides excellent cover for fish (Platts et al., 1983). The ability of vegetation and other materials on the streambanks to resist erosion from flowing water is important in determining the stability of the stream channel, and maintaining good instream habitats. However, these parameters, by virtue of the fact that they act indirectly and are outside the immediate instream habitat features, are weighted as slightly less important than the other categories.

Habitat parameters evaluated include observations of both upper and lower bank characteristics. The upper bank is the land area from the break in the general slope of the surrounding land to the normal high water line. It is normally vegetated and is covered by water only in extreme high water periods. Land forms vary from wide, flat floodplains to narrow, steep slopes. The lower bank is the intermittently submerged portion of the stream cross section from the normal high water line to the lower water line.

Metric 7. Bank Stability. This metric is evaluated by observing existing or potential detachment of soil from the upper and lower stream bank and its potential movement into the stream. Steeper banks are generally more subject to erosion and failure, and may not support stable vegetation. Streams with poor banks will often have poor instream habitat. Adjustments should be made in areas with clay banks where steep, raw areas may not be as susceptible to erosion as other soil types.

Metric 8. Bank Vegetative Stability. This metric evaluates the density of bank vegetation (or amount of boulder, cobble, or gravel material) covering the bank and provides an indication of bank stability and potential for instream sedimentation. Bank soil is held in place by well established plant root systems. Over 80% of the streambank covered by vegetation or otherwise stabilized would result in an excellent assessment (Table 1). Erosional protection may also be provided by boulder, cobble, or gravel material.

Metric 9. Streamside Cover. This metric evaluates the quality of streamside material in terms of potential as habitat, providing food sources, stream-shading ability and escape cover or refuge for fish. A rating is obtained by visually determining the dominant vegetation type covering the exposed stream bank. Large numbers of dense shrubs would result in an excellent assessment (Table 1).

VIII. OVERALL APPLICATION AND INTEGRATION

A. Relationship of Habitat Quality and Biological Condition

The optimum biological community stability and biological diversity of a site for both fish and macroinvertebrates may be determined by the quality of the habitat at that site. Excellent habitat will allow for high quality biological communities. Community responses to minor alteration in habitat are often subtle and may result in insignificant changes. As habitat quality continues to decline, however, recognizable and measurable biological changes (impairments) occur. These changes, in the absence of confounding water quality effects, are generally in direct proportion to the degree of habitat change. Once habitat becomes severely degraded, measurable changes in the biological communities become harder to recognize and measure. The biological communities existing under these habitat degraded conditions are represented by opportunistic species, which are more tolerant of such habitat perturbations and often insensitive to further habitat degradation. This may result in a poor habitat characterization corresponding to either a moderately or severely impacted biological community depending on the specific site and situation.

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In areas of good or excellent habitat, biological communities will reflect degraded conditions when adverse water quality effects exist. As habitat degrades further in the continued presence of water quality problems, such as chemical toxicants or nutrient enrichment, the biological communities may show less dramatic changes as each community becomes dominated by tolerant and opportunistic species.

B. Application

Each site should be carefully evaluated using the habitat and the biological protocols. The lowest biological category assigned to either fish or macroinvertebrate will be used to categorize the overall station's biological condition. If, for example, an excellent fish community survey together with an excellent macroinvertebrate community is matched with poor habitat survey, then the site would be categorized as excellent. When the fish community is scored 'excellent', the habitat scored 'excellent', and the macroinvertebrate community scored 'poor', then the site would be categorized as poor.

IX. QUALITY ASSURANCE/QUALITY CONTROL

As with any scientific study, quality must be assured and tested before the results can be accepted. Quality assurance is accomplished through use of professional and trained biologists, establishment of thorough field training, defined collection guidelines, and comprehensive field documentation and data analysis.

A. Training

All personnel conducting surveys are trained in a consistent manner (preferably by the same person) to ensure that the surveys are conducted properly and in a standardized fashion. At least one investigator for each site will be a professional biologist trained and skilled in field aquatic sampling methods and organism identification.

B. Standard Procedures

The standard procedures described in this document are followed in the surveys. Field experience and taxonomic expertise requirements must be met by staff involved in surveys. Any deviations from the procedures should be documented as to the reason for deviation.

Field crew personnel will be alternated to maintain objectivity in the surveys.

C. Documentation

The field data sheets (stream survey cards, Appendix J) are filled out as completely and as accurately as possible to provide a record in support of the survey and analysis conclusions.

Field and laboratory data sheets and final reports are filed in the GLEAS raw data files and report files, respectively.

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D. Habitat Assessment

All personnel are appropriately trained in the evaluation technique and periodic cross-checks are conducted among personnel to promote consistency.

E. Benthic Collections

The data developed during the benthic collection efforts is directly comparable to data developed at other sites because: (1) all habitats are sampled at each site, and (2) a uniform method (consistent unit of effort, 100-organism count) is used for benthic data acquisition. To ensure reproducible data, well characterized sites are periodically resampled by a variety of investigators.

F. Fish Collections

Data comparability is maintained by using similar collection methods and sampling effort in waterbodies of similar size. Also, where possible, major habitats (riffle, run, pool) are sampled at each site, and the proportion of each habitat type sampled, should be comparable.

Data reproducibility is ensured by having a variety of investigators periodically resample well characterized sites.

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Table 1. Habitat Assessment Field Data Sheet

Habitat Parameter	Excellent	Good	Fair	Poor
Bottom Substrate / Available Cover	Greater than 50% rubble, gravel, submerged logs, undercut banks, or other stable habitat. 16-20	30-50% rubble, gravel or other stable habitat. Adequate habitat. 11-15	10-30% rubble, gravel or other stable habitat. Habitat availability less than desirable. 6-10	Less than 10% rubble, gravel or other stable habitat. Lack of habitat is obvious. 0-5
Embeddedness / Siltation	Gravel, logs, cobble, and boulder particles have between 0 and 25% of their surface covered by fine sediment / silt. 16-20	Gravel, logs, cobble, and boulder particles have between 25 and 50% of their surface covered by fine sediment / silt. 11-15	Gravel, logs, cobble and boulder particles have between 50 and 70% of their surface covered by fine sediment / silt. 6-10	Gravel, logs, cobble, and boulder particles have over 75% of their surface covered by fine sediment / silt. 0-5
Velocity: / Depth: pool - <1ft/s >1.5ft shallow pool - <1ft/s <1.5ft run - >1ft/s >1.5ft riffle - >1ft/s <1.5ft	All habitats well represented. None greater than 50% of total area. 16-20	Only 3 of the 4 habitat categories present. Or if all 4 are present, one greater than 50% total area. 11-15	Only 2 of the 4 habitat categories present. 6-10	Dominated by one velocity/ depth category (usually pool). 0-5
Flow stability	Continual flow all year. Natural water supply substantial. 12-15	Seasonal high flows. Low flow constant or nearly so. Some point discharge contributes to flow. 8-11	Periodic high and low flows. Irregular flow pattern. Discharges contribute substantially to low flow. 4-7	Ephemeral stream. Usually no mid-summer flow. If it flows year-round, discharges form major contribution to low flow. 0-3
Bottom Deposition / Sedimentation	Less than 5% of the bottom affected by deposition. Hard bottom substrate. 12-15	5-30% affected. Some deposition in pools. Soft bottom mainly in pools. 8-11	30-50% affected. Deposits, obstructions, constrictions and bends. Some filling of pools with sediments/sand. Soft bottom more common. 4-7	More than 50% of the bottom affected. Pools almost absent due to deposition. Only large rocks in riffle exposed. Soft bottom, loose deposits very common, often deep. 0-3
Pools-Riffles-Runs-Bends	Variety of habitats. Deep riffles and pools. 12-15	Adequate depth in pools and riffles. Bends provide habitat. 8-11	Occasional riffle or bend. Bottom contours provide some habitat. 4-7	Straight stream. Generally all flat water or shallow riffle. 0-3
Bank Stability	Stable. No evidence of erosion or bank failure. Side slopes generally <30%, little potential for future problem. 9-10	Moderately stable. Infrequent, small areas of erosion mostly healed over. Side slopes up to 40%. Slight erosion potential in extreme floods. 6-8	Moderately unstable. Moderate frequency and size of erosional areas. Side slopes up to 60% on some banks. High erosion potential in extreme floods. 3-5	Unstable. Many eroded areas. Side slopes >60% common. “Raw” areas frequent along straight sections and bends. 0-2
Bank Vegetative Stability	Over 80% of the stream bank surfaces covered by vegetation or boulders and cobble. 9-10	50-79% of the stream bank surfaces covered by vegetation, gravel or larger material. 6-8	25-49% of the stream bank surfaces covered by vegetation, gravel or larger material. 3-5	Less than 25% of the stream bank surfaces covered by vegetation, gravel or larger material. 0-2
Streamside Cover	Dominant vegetation is shrub. 9-10	Dominant vegetation is of tree form. 6-8	Dominant vegetation is grass or forbes. 3-5	Over 50% of the stream bank has no vegetation. Dominant material is soil, rock, bridge materials, or mine tailings. 0-2

Appendix A

Michigan Fishes Classified as Intolerant

Common Name	**Scientific Name**
Petromyzontidae (lampreys)	
Sea lamprey (ammocete)	Petromyzon marinus
Silver lamprey (ammocete)	Ichthyomyzon unicuspis
Silver lamprey (adult)	Ichthyomyzon unicuspis
Northern brook (ammocete)	Ichthyomyzon fossor
Northern brook (adult)	Ichthyomyzon fossor
Chestnut lamprey (ammocete)	Ichthyomyzon castaneus
Chestnut lamprey (adult)	Ichthyomyzon castaneus
American brook (ammocete)	Lampetra appendix
American brook (adult)	Lampetra appendix
Acipenseridae (sturgeons)	
Lake sturgeon	Acipenser fulvescens
Polydontidae (paddlefish)	
Paddlefish	Polydon spatula
Hiodontidae (Mooneyes)	
Mooneye	Hiodon tergisus
Salmonidae (trouts)	
Rainbow trout	Oncorhynchus mykiss
Brown trout	Salmo trutta
Brook trout	Salvelinus fontinalis
Coho salmon	Oncorhynchus kisutch
Chinook salmon	Oncorhynchus tshawytscha
Pink salmon	Oncorhynchus gorbuscha
Lake herring	Coregonus artedi
Lake whitefish	Coregonus cupeaformis
Bloater	Coregonus hoyi
Deepwater cisco	Coregonus johannae
Kiyi	Coregonus kiyi
Blackfin cisco	Coregonus nigripinnis
Shortnose cisco	Coregonus reighardi
Shortjaw cisco	Coregonus zenithicus
Pygmy whitefish	Prosopium coulte
Round whitefish	Prosopium cylindraceum
Atlantic salmon	Salmo salar
Lake trout	Salvelinus namaycush
Arctic grayling	Thymallus arcticus
Esocidae (pikes)	
Muskellunge	Esox masquinongy

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Appendix A (continued)

Common Name	Scientific Name
Cyprinidae (minnows and carps)	
Bigeye chub	Notropis amblops
River chub	Nocomis micropogon
Pugnose shiner	Notropis anogenus
Bigeye shiner	Notropis boops
Ironcolor shiner	Notropis chalybaeus
Weed shiner	Notropis texanus
Blackchin shiner	Notropis heterodon
Blacknose shiner	Notropis heterolepis
Spottail shiner	Notropis hudsonius
Silver shiner	Notropis photogenis
Rosyface shiner	Notropis rubellus
Southern redbelly dace	Phoxinus erthrogaster
Longnose dace	Rhinichthys cataractae
Redside dace	Clinostomus elongatus
Pearl dace	Margariscus margarita
Silver chub	Macrhybopsis storeriana
Pugnose minnow	Opsopoedus emiliae
Cottidae (sculpins)	
Mottled sculpin	Cottus bairdii
Slimy sculpin	Cottus cognatus
Spoonhead sculpin	Cottus ricei
Deepwater sculpin	Myoxocephalus thompsoni
Catostomidae (suckers)	
Longnose sucker	Catostomus catostomus
Creek chubsucker	Erimyzon oblongus
Northern hog sucker	Hypentelium nigricans
Black buffalo	Ictiobus niger
Spotted sucker	Minytrema melanops
Silver redhorse	Moxostoma anisurum
River redhorse	Moxostoma carinatum
Black redhorse	Moxostoma duquesnei
Shorthead redhorse	Moxostoma macrolepidotum
Greater redhorse	Moxostoma valenciennesi
Ictaluridae (Bullhead, Catfish)	
Stonecat	Noturus flavus
Cyprinodontidae (topminnows)	
Banded killifish	Fundulus diaphanus
Gasterosteidae (sticklebacks)	
Ninespine stickleback	Pungitius pungitius

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Appendix A (continued)

Common Name	**Scientific Name**
Centrarchidae (sunfish)	
Rock bass	Ambloplites rupestris
Smallmouth bass	Micropterus dolomieu
Percidae (perch)	
Eastern sand darter	Ammocrypta pellucida
Rainbow darter	Etheostoma caeruleum
Iowa darter	Etheostoma exile
Least darter	Etheostoma microperca
Orangethroat darter	Etheostoma spectabile
Banded darter	Etheostoma zonale
Channel darter	Percina copelandi

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Appendix B
Michigan Fish Classified as Omnivores

Common Name	**Scientific Name**
Cyprinidae	
Goldfish	Carassius auratus
Common Carp	Cyprinus carpio
Golden Shiner	Notemigonus crysoleucas
Fathead minnow	Pimephales promelas
Bluntnose minnow	Pimephales notatus
Creek chub	Semotilus atromaculatus
Blacknose dace	Rhinichthys atratulus
European rudd	Scardinius erthropthalmus
Catastomidae	
White sucker	Catostomus commersoni
Quillback	Carpoides cyprinus
Umbridae	
Central mudminnow	Umbra limi
Ictaluridae	
Black Bullhead	Ameiurus melas
Brown bullhead	Ameiurus nebulosus
Yellow bullhead	Ameiurus natalis

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Appendix C
Michigan Fish Classified as Insectivores

Common Name	Scientific Name
Acipenseridae (sturgeons)	
Lake Sturgeon	Acipenser fulvescens
Hiodontidae (Mooneyes)	
Mooneye	Hiodon tergisus
Salmonidae (trouts)	
Lake whitefish	Coregonus cupeaformis
Pygmy whitefish	Prosopium coulteri
Round whitefish	Prosopium cylindraceum
Artic grayling	Thymallus arcticus
Cyprinidae (minnows and carps)	
Lake chub	Couesius plumbeus
Bigeye chub	Notropis amblops
Hornyhead chub	Nocomis biguttatus
River chub	Nocomis micropogon
Emerald shiner	Notropis atherinoides
Bigeye shiner	Notropis boops
Ironcolor shiner	Notropis chalybaeus
Common shiner	Luxilus cornutus
Striped shiner	Luxilus chrysocephalus
Central bigmouth shiner	Notropis dorsalis
Blackchin shiner	Notropis heterodon
Blacknose shiner	Notropis heterolepis
Spottail shiner	Notropis hudsonius
Silver shiner	Notropis photogenis
Rosyface shiner	Notropis rubellus
Spotfin shiner	Cyprinella spilopterus
Sand shiner	Notropis stramineus
Redfin shiner	Lythrurus umbratilis
Mimic shiner	Notropis volucellus
Suckermouth minnow	Phenacobius mirabilis
Silverjaw minnow	Notropis buccatus
Finescale dace	Phoxinus neogaeus
Longnose dace	Rhinichthys cataractae
Redside dace	Clinostomus elongatus
Pearl dace	Margariscus margarita
Silver chub	Macrhybopsis storeriana
Pugnose minnow	Opsopoedus emiliae
Cottidae (sculpins)	
Mottled sculpin	Cottus bairdii
Slimy sculpin	Cottus cognatus

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Appendix C (continued)

Common Name	**Scientific Name**
Spoonhead sculpin	Cottus ricei
Deepwater sculpin	Myoxocephalus thompsoni
Catostomidae (suckers)	
Longnose sucker	Catostomus catostomus
Creek chubsucker	Erimyzon oblongus
Lake chubsucker	Erimyzon sucetta
Norther hog sucker	Hypentelium nigricans
Bigmouth buffalo	Ictiobus cyprinellus
Black buffalo	Ictiobus niger
Spotted sucker	Minytrema melanops
Silver redhorse	Moxostoma anisurum
River redhorse	Moxostoma carinatum
Black redhorse	Moxostoma duquesnei
Golden redhorse	Moxostoma erythrurum
Shorthead redhorse	Moxostoma macrolepidotum
Greater redhorse	Moxostoma valenciennesi
Ictaluridae (Bullhead, Catfish)	
Stonecat	Noturus flavus
Margined madtom	Noturus insignis
Tadpole madtom	Noturus gyrinus
Brindled madtom	Noturus miurus
Northern madtom	Noturus stigmosus
Aphredoderidae (pirate perch)	
Pirate perch	Aphredoderus sayanus
Atherinidae (silversides)	
Brook silversides	Labidesthes sicculus
Cyprinodontidae (topminnows)	
Banded killifish	Fundulus diaphanus
Starhead topminnow	Fundulus dispar
Blackstripe topminnow	Fundulus notatus
Gasterosteidae (sticklebacks)	
Brook stickleback	Culaea inconstans
Threespine stickleback	Gasterosteus aculeatus
Ninespine stickleback	Pungitius pungitius
Centrarchidae (sunfish)	
Green sunfish	Lepomis cyanellus
Pumpkinseed	Lepomis gibbosus

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Appendix C (continued)

Common Name	**Scientific Name**
Orangespotted sunfish	Lepomis humilis
Bluegill	Lepomis macrochirus
Longear sunfish	Lepomis megalotis
Redear sunfish	Lepomis microlophus
Percidae (perch)	
Eastern sand darter	Ammocrypta pellucida
Rainbow darter	Etheostoma caeruleum
Iowa darter	Etheostoma exile
Greenside darter	Etheostoma blennioides
Fantail darter	Etheostoma flabellare
Least darter	Etheostoma microperca
Johnny darter	Etheostoma nigrum
Orangethroat darter	Etheostoma spectabile
Banded darter	Etheostoma zonale
Logperch	Percina caprodes
Channel darter	Percina copelandi
Blackside darter	Percina maculata
River darter	Percina shumardi
Ruffe	Gymnocephalus cernuus
Percopsidae (Trout-perch)	
Trout-perch	Percopsis omiscomaycus
Sciaenidae (drums)	
Freshwater drum	Aplodinotus grunniens
Gobiidae (gobies)	
Round goby	Neogobius melanostomus
Tubenose goby	Proterorhinus marmoratus
Poeciliidae (livebearers)	
Western mosquitofish	Gambusia affinis

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Appendix D
Michigan Fish Classified as Piscivores

Common Name	Scientific Name
Spotted gar	Lepisosteus oculatus
Longnose gar	Lepisosteus osseus
Bowfin	Amia calva
American eel	Anguilla rostrata
Channel catfish	Ictalurus punctatus
Flathead catfish	Pylodictis olivaris
Grass pickerel	Esox americanus vermiculatus
Northern pike	Esox lucius
Muskellunge	Esox masquinongy
Burbot	Lota lota
White perch	Morone americana
White bass	Morone chrysops
Rock bass	Ambloplites rupestris
Largemouth bass	Micropterus salmoides
Smallmouth bass	Micropterus dolomieu
Walleye	Stizostedion vitreum
Sauger	Stizostedion canadense

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Appendix E
Michigan Fishes Classified as Tolerant

Common Name	Scientific Name
Amiidae (bowfins)	
Bowfin	Amia calva
Umbridae (mudminnows)	
Central mudminnow	Umbra limi
Cyprinidae (minnows and carps)	
Goldfish	Carassius auratus
Common carp	Cyprinus carpio
Creek chub	Semotilus atromaculatus
Golden shiner	Notemigonus crysoleucas
Fathead minnow	Pimephales promelas
Bluntnose minnow	Pimephales notatus
Blacknose dace	Rhinichthys atratulus
European rudd	Scardinius erythropthalmus
Catostomidae (suckers)	
White sucker	Catostomus commersoni
Ictaluridae (Bullhead, Catfish)	
Yellow bullhead	Ameiurus natalis
Centrarchidae (sunfish)	
Green sunfish	Lepomis cyanellus
Percidae (perch)	
Johnny darter	Etheostoma nigrum
Sciaenidae (drums)	
Freshwater drum	Aplodinotus grunniens

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Appendix F
Michigan Fishes Classified as Simple Lithophilic Spawners

Common Name	**Scientific Name**
Acipenseridae (sturgeons)	
Lake sturgeon	Acipenser fulvescens
Polydontidae (paddlefish)	
Paddlefish	Polydon spatula
Hiodontidae (mooneyes)	
Mooneye	Hiodon tergisus
Cyprinidae (minnows and carps)	
Lake chub	Couesius plumbeus
Bigeye shiner	Notropis boops
Common shiner	Luxilus cornutus
Striped shiner	Luxilus chrysocephalus
Silver shiner	Notropis photogenis
Rosyface shiner	Notropis rubellus
Suckermouth minnow	Phenacobius mirabilis
Southern redbelly dace	Phoxinus erthrogaster
Blacknose dace	Rhinichthys atratulus
Longnose dace	Rhinichthys cataractae
Pearl dace	Margariscus margarita
Catostomidae (suckers)	
Longnose sucker	Catostomus catostomus
White sucker	Catostomus commersoni
Northern hog sucker	Hypentelium nigricans
Spotted sucker	Minytrema melanops
Silver redhorse	Moxostoma anisurum
River redhorse	Moxostoma carinatum
Black redhorse	Moxostoma duquesnei
Golden redhorse	Moxostoma erythrurum
Shorthead redhorse	Moxostoma macrolepidotum
Greater redhorse	Moxostoma valenciennesi
Percidae (perch)	
Rainbow darter	Etheostoma caeruleum
Orangethroat darter	Etheostoma spectabile
Banded darter	Etheostoma zonale
Logperch	Percina caprodes
Channel darter	Percina copelandi
Blackside darter	Percina maculata
River darter	Percina shumardi

Appendix F (continued)

Common Name	**Scientific Name**
Sauger	Stizostedion canadense
Walleye	Stizostedion vitreum
Ruffe	Gymnocephalus cernuus
Gadidae (codfishes)	
Burbot	Lota lota

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Appendix G

The following fish are to be measured to inch group:

Percidae (Perches)	
Yellow perch	Perca flavescens
Sauger	Stizostedion canadense
Walleye	Stizostedion vitreum
Cyprinidae (minnows)	
Creek chub	Semotilus atromaculatus
Pearl dace	Margariscus margarita
Goldfish	Carassius auratus
Common carp	Cyprinus carpio
Common shiner	Notropis cornutus
Hornyhead chub	Nocomis biguttus
River chub	Nocomis micropogon
Golden shiner	Notemigonus crysoleucas

All members of the families:

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Catostomidae (suckers)
Lepistosteidae (gars)
Amiidae (bowfin)
Anquillidae (eel)
Clupeidae (herring)
Osmeridae (smelts)
Salmonidae (salmon, trouts, whitefish)
Esocidae (pike)
Ictaluridae (bullheads , catfish)
Percichthyidae (temperate basses)
Centrarchidae (sunfishes)
Sciaenidae (drums)

Appendix H

Phylogenetic order for macroinvertebrates, the level of taxonomy, and the primary keys to be used for site evaluations.

Phylum	Class	***Order***	*Sub-order*	**Family**
Porifera (Pennak, 1989)				
Platyhelminthes				
	Turbellaria (Pennak, 1989)			
Nematomorpha (Pennak, 1989)				
Bryozoa (Pennak, 1989)				
Annelida				
	Oligochaeta (Pennak, 1989)			
	Hirudinea (Klemm, 1972)			
Arthropoda				
	Crustacea			
		Isopoda (Pennak, 1989)		
		Amphipoda (Pennak, 1989)		
		Decapoda (Pennak, 1989)		
	Arachnoidea			
		Hydracarina (Pennak, 1989)		
	Insecta (Merritt and Cummins, 1996)			
		Ephemeroptera		
				Baetidae
				Baetiscidae
				Caenidae
				Ephemerellidae
				Ephemeridae
				Heptageniidae
				Isonychiidae
				Leptophlebiidae
				Oligoneuriidae
				Polymitarcyidae
				Potamanthidae
				Siphlonuridae
				Tricorythidae
		Odonata		
			Zygoptera	
				Calopterygidae
				Coenagrionidae
				Lestidae
			Anisoptera	
				Aeshnidae
				Cordulegastridae
				Corduliidae
				Gomphidae
				Libellulidae
				Macromiidae

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Appendix H (continued)

Phylum	Class	***Order***	*Sub-order*	**Family**
		Plecoptera		
				Capniidae
				Chloroperlidae
				Leuctridae
				Nemouridae
				Peltoperlidae
				Perlidae
				Perlodidae
				Pteronarcyidae
				Taeniopterygidae
		Hemiptera		
				Belostomatidae
				Corixidae
				Gelastocoridae
				Gerridae
				Mesoveliidae
				Naucoridae
				Nepidae
				Notonectidae
				Pleidae
				Veliidae
		Megaloptera		
				Corydalidae
				Sialidae
		Neuroptera		
				Sisyridae
		Trichoptera		
				Beraediae
				Brachycentridae
				Glossosomatidae
				Helicopsychidae
				Hydropsychidae
				Hydroptilidae
				Lepidostomatidae
				Leptoceridae
				Limnephilidae
				Molannidae
				Odontoceridae
				Philopotamidae
				Phryganeidae
				Polycentropodidae
				Psychomyiidae
				Rhyacophilidae
				Sericostomatidae
		Lepidoptera		
				Noctuidae
				Pyralidae

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Appendix H (continued)

Phylum	Class	***Order***	*Sub-order*	**Family**
		Coleoptera		
				Chrysomelidae
				Curculionidae
				Dryopidae
				Dytiscidae
				Elmidae
				Gyrinidae
				Haliplidae
				Heterocerodea
				Hydrophilidae
				Hydraenidae
				Lampyridae
				Limnichidae
				Noteridae
				Psephenidae
				Ptilodactylidae
				Scirtidae
		Diptera		
				Athericidae
				Ceratopogonidae
				Chaoboridae
				Chironomidae
				Culicidae
				Dixidae
				Dolichopodidae
				Empididae
				Ephydridae
				Muscidae
				Psychodidae
				Ptychopteridae
				Sciomyzidae
				Simuliidae
				Stratiomyidae
				Syrphidae
				Tabanidae
				Thaumaleidae
				Tipulidae
Mollusca				
				Gastropoda (Burch, 1991)
				Pelecypoda (Burch, 1991)

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Appendix I
Surface Dependant Macroinvertebrates

Hemiptera
- All Families

Coleoptera
- All Adults (other than Elmidae and Dryopidae)
- Dytiscidae larvae
- Hydrophilidae larvae
- Hydraenidae larvae
- Heteroceridae larvae

Diptera
- Culicidae larvae
- Ptychopteridae larvae
- Chaoboridae larvae (except Chaoborus sp.)
- Stratiomyidae
- Dolichopodidae
- Syrphidae

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Appendix J

MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY
SURFACE WATER QUALITY DIVISION

STREAM SURVEY CARD
(Revised - November 1996)

STORET NO.: __________________

STATION NUMBER: _________ INVESTIGATOR(S):____ DATE: ______/______/______

BODY OF WATER: _______________________________________ LOCATION: ____

COUNTY: _________________________ TOWNSHIP: ____________________________________ T ______ R ______ S ______ GPS: ______________

STREAM TYPE: ( )Coldwater ( )Warmwater SURVEY TYPE: ( )PS ( ) NPS ECOREGION: _______________________________________

WEATHER: ( )Sunny ( )Partly Cloudy ( )Cloudy ( )Rainy AIR TEMP.: _________ WATER TEMP.: _________

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AVG. STREAM WIDTH ______ ft. AVG. DEPTH ______ ft SURFACE VELOCITY _______ ft./sec. ESTIMATED FLOW: ________cfs

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STREAM MODIFICATIONS:
( ) None
( ) Dredged
( ) Canopy Removal
( ) Snagging
( ) Impounded
( ) Relocated
( ) Bank Stabilization
( ) Habitat Improvement

Attached algae and macrophytes: _________________________
____
____

Nuisance aquatic plant or slimes conditions present? Y / N

STATION SKETCH AND NOTES :

Appendix J (continued)

Location Sampled____ Date______________

Length sampled ___________	Time sampled__________	Gear type (circle): bps	stream shocker	boat shocker	other				
Species length (in)									In
1									1
2									2
3									3
4									4
5									5
6									6
7									7
8									8
9									9
10									10
11									11
12									12
13									13
14									14
15									15
16									16
17									17
18									18
19									19
20									20
>20									>20

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For individuals >20" record actual length

Species length (in)									In
1									1
2									2
3									3
4									4
5									5
6									6
7									7
8									8
9									9
10									10
11									11
12									12
13									13
14									14
15									15
16									16
17									17
18									18
19									19
20									20
>20									>20

Number of Anomalies_________ Number/Species of tagged/fin clipped fish____________

Description:

Appendix J (continued)

Species								
length (in)								In
1								1
2								2
3								3
4								4
5								5
6								6
7								7
8								8
9								9
10								10
11								11
12								12
13								13
14								14
15								15
16								16
17								17
18								18
19								19
20								20
>20								>20

For individuals >20" record actual length

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Species								
length (in)								In
1								1
2								2
3								3
4								4
5								5
6								6
7								7
8								8
9								9
10								10
11								11
12								12
13								13
14								14
15								15
16								16
17								17
18								18
19								19
20								20
>20								>20

Additional station comments

Station Number:

Length Sampled (ft):

Area Sampled (sq ft):

Appendix J (continued)

Sampling Time: # Probes Gear: boat / ss / bps # Passes:

Number of Anomalies:

Comments:

Petromyzontidae (Lampreys)
Sea lamprey (a/l) _____
Silver lamprey (a/l) _____
Northern brook lamprey (a/l) _____
Chestnut lamprey (a/l) _____
American brook lamprey (a/l) _____

Lepisosteidae (Gars)
*Spotted gar _____
*Longnose gar _____

Amiidae (Bowfins)
*Bowfin _____

Clupeidae (Herrings)
*Alewife _____
*Gizzard shad _____

Salmonidae (Salmon/Trout)
*Rainbow trout _____
*Brown trout _____
*Brook trout _____
*Coho _____
*Chinook _____

Umbridae (Mudminnow)
Central mudminnow _____

Esocidae (Pike)
*Grass pike _____
*Northern pike _____
*Muskellunge _____

Cyprinidae (Minnows and Carp)
Central stoneroller _____
Lake chub _____
*Goldfish _____
*Carp _____
Bigeye chub _____
*Horneyhead chub _____
*River chub _____
*Creek chub _____
*Golden shiner _____
Pugnose shiner _____
Emerald shiner _____
Bigeye shiner _____
Ironcolor shiner _____
*Common shiner _____
Central bigmouth shiner _____
Blackchin shiner _____
Blacknose shiner _____
Spottail shiner _____
Silver shiner _____
Rosyface shiner _____
Spotfin shiner _____
Sand shiner _____
Redfin shiner _____
Mimic shiner _____
Brassy minnow _____
Fathead minnow _____
Bluntnose minnow _____
Suckermouth minnow _____
Silverjaw minnow _____
Northern redbelly dace _____
Southern redbelly dace _____
Finescale dace _____
Blacknose dace _____
Longnose dace _____
Redside dace _____
*Pearl dace _____

Cottidae (Sculpins)
Mottled sculpin _____
Slimy sculpin _____

Catostomidae (Suckers)
*Longnose sucker _____
*White sucker _____
*Creek chubsucker _____
*Lake chubsucker _____
*Northern hog sucker _____
*Spotted sucker _____
*Silver redhorse _____
*River redhorse _____
*Black redhorse _____
*Golden redhorse _____
*Shorthead redhorse _____
*Greater redhorse _____

Ictaluridae (Bullhead/Catfish)
*Black bullhead _____
*Brown bullhead _____
*Yellow bullhead _____
Stonecat _____
Tadpole madtom _____
Brindled madtom _____
*Channel catfish _____
*Flathead catfish _____

Aphredoderidae (Pirate perch)
Pirate perch _____

Atherinidae (Silversides)
Brook silverside _____

Cyprinodontidae (Topminnows)
Banded killifish _____
Blackstripe topminnow _____

Gasterosteidae (Sticklebacks)
Brook stickleback _____
Threespine stickleback _____

Perchicthyidae (Temp. bass)
*White bass _____
*White perch _____

Centrarchidae (Sunfishes)
*Rock bass _____
*Green sunfish _____
*Pumpkinseed _____
*Warmouth _____
*Orangespotted sunfish _____
*Bluegill _____
*Longear sunfish _____
*White crappie _____
*Black crappie _____
*Largemouth bass _____
*Smallmouth bass _____

Percidae (Perch)
N. sand darter _____
Rainbow darter _____
Iowa darter _____
Greenside darter _____
Fantail darter _____
Orangethroat darter _____
Johnny darter _____
Blackside darter _____
Logperch _____
*Yellow perch _____
*Walleye _____

Percopsidae (Trout-perch)
Trout-perch _____

Anguillidae (Eels)
*American eel _____

Gadidae (Cod)
*Burbot _____

Sciaenidae (Drums)
*Freshwater drum _____

Cobitidae (Loaches)
Oriental weatherfish _____

Other family/species:
_______________ _____
_______________ _____
_______________ _____
_______________ _____

* = Measured length

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Appendix J (continued)

BENTHIC MACROINVERTEBRATES

Station Number:____________
Time Sampled:____________
Area Sampled:____________
Comments:________________
____

PORIFERA ______
PLATYHELMINTHES
Turbellaria ______
NEMATOMORPHA ______
BRYOZOA ______
ANNELIDA
Hirudinea ______
Oligochaeta ______
ARTHROPODA
Crustacea
Amphipoda ______
Decapoda ______
Isopoda ______
Arachnoidea
Hydracarina ______
Insecta
Ephemeroptera
Ametropodidae ______
Baetiscidae ______
Baetidae ______
Caenidae ______
Ephemerellidae ______
Ephemeridae ______
Heptageniidae ______
Isonychiidae ______
Leptophlebiidae ______
Metretopodidae ______
Polymitarcyidae ______
Potamanthidae ______
Siphlonuridae ______
Tricorythidae ______
Odonata
Anisoptera
Aeshnidae ______
Cordulegastridae ______
Corduliidae ______
Gomphidae ______
Libellulidae ______
Macomiidae ______
Zygoptera
Calopterygidae ______
Coenagrionidae ______
Lestidae ______
Plecoptera
Capniidae ______
Chloroperlidae ______
Leuctridae ______
Nemouridae ______
Peltoperlidae ______
Perlidae ______
Perlodidae ______
Pteronarcyidae ______
Taeniopterygidae ______

Hemiptera
Belostomatidae ______
Corixidae ______
Gelastocoridae ______
Gerridae ______
Mesoveliidae ______
Naucoridae ______
Nepidae ______
Notonectidae ______
Pleidae ______
Saldidae ______
Veliidae ______
Megaloptera
Corydalidae ______
Sialidae ______
Neuroptera
Sisyridae ______
Trichoptera
Brachycentridae ______
Glossosomatidae ______
Helicopsychidae ______
Hydropsychidae ______
Hydroptilidae ______
Lepidostomatidae ______
Leptoceridae ______
Limnephilidae ______
Molannidae ______
Odontoceridae ______
Philopotamidae ______
Phryganeidae ______
Polycentropodidae ______
Psychomyiidae ______
Rhyacophilidae ______
Sericostomatidae ______
Uenoidae (*Neophylax*) ______
Lepidoptera
Noctuidae ______
Pyralidae ______
Coleoptera
Dryopidae ______
Dytiscidae ______
Elmidae ______
Gyrinidae (a/l) ______
Haliplidae (a/l) ______
Heteroceridae ______
Hydraenidae ______
Hydrophilidae ______
Lampyridae (a/l) ______
Noteridae (a/l) ______
Psephenidae(a/l) ______
Ptilodactylidae (a/l) ______
Scirtidae (a/l) ______

Diptera
Athericidae ______
Ceratopogonidae ______
Chaoboridae ______
Chironomidae ______
Culicidae ______
Dixidae ______
Dolichopodidae ______
Empididae ______
Ephydridae ______
Muscidae ______
Ptychopteridae ______
Psychodidae ______
Sciomyzidae ______
Simuliidae ______
Stratiomyidae ______
Syrphidae ______
Tabanidae ______
Thaumaleidae ______
Tipulidae ______
MOLLUSCA
Gastropoda
Ancylidae ______
Bithyniidae ______
Hydrobiidae ______
Lymnaeidae ______
Physidae ______
Planorbidae ______
Pleuroceridae ______
Pomatiopsidae ______
Valvatidae ______
Viviparidae ______
Pelecypoda
Dreissenidae ______
Pisidiidae ______
Sphaeriidae ______
Unionidae ______
__________ ______
__________ ______
__________ ______
__________ ______

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Appendix J (continued)

Habitat Assessment Field Data Sheet

Habitat Parameter	Excellent	Good	Fair	Poor
Bottom Substrate / Available Cover	Greater than 50% rubble, gravel, submerged logs, undercut banks, or other stable habitat. 16-20	30-50% rubble, gravel or other stable habitat. Adequate habitat. 11-15	10-30% rubble, gravel or other stable habitat. Habitat availability less than desirable. 6-10	Less than 10% rubble, gravel or other stable habitat. Lack of habitat is obvious. 0-5
Embeddedness / Siltation	Gravel, logs, cobble, and boulder particles have between 0 and 25% of their surface covered by fine sediment / silt. 16-20	Gravel, logs, cobble, and boulder particles have between 25 and 50% of their surface covered by fine sediment / silt. 11-15	Gravel, logs, cobble and boulder particles have between 50 and 70% of their surface covered by fine sediment / silt. 6-10	Gravel, logs, cobble, and boulder particles have over 75% of their surface covered by fine sediment / silt. 0-5
Velocity: Depth: pool - <1ft/s >1.5ft shallow pool - <1ft/s <1.5ft run - >1ft/s >1.5ft riffle - >1ft/s <1.5ft	All habitats well represented. None greater than 50% of total area. 16-20	Only 3 of the 4 habitat categories present. Or if all 4 are present, one greater than 50% total area. 11-15	Only 2 of the 4 habitat categories present. 6-10	Dominated by one velocity/ depth category (usually pool). 0-5
Flow stability	Continual flow all year. Natural water supply substantial. 12-15	Seasonal high flows. Low flow constant or nearly so. Some point discharge contributes to flow. 8-11	Periodic high and low flows. Irregular flow pattern. Discharges contribute substantially to low flow. 4-7	Ephemeral stream. Usually no mid-summer flow. If it flows year-round, discharges form major contribution to low flow. 0-3
Bottom Deposition / Sedimentation	Less than 5% of the bottom affected by deposition. Hard bottom substrate. 12-15	5-30% affected. Some deposition in pools. Soft bottom mainly in pools. 8-11	30-50% affected. Deposits, obstructions, constrictions and bends. Some filling of pools with sediments/sand. Soft bottom more common. 4-7	More than 50% of the bottom affected. Pools almost absent due to deposition. Only large rocks in riffle exposed. Soft bottom, loose deposits very common, often deep. 0-3
Pools-Riffles-Runs-Bends	Variety of habitats. Deep riffles and pools. 12-15	Adequate depth in pools and riffles. Bends provide habitat. 8-11	Occasional riffle or bend. Bottom contours provide some habitat. 4-7	Straight stream. Generally all flat water or shallow riffle. 0-3
Bank Stability	Stable. No evidence of erosion or bank failure. Side slopes generally <30%, little potential for future problem. 9-10	Moderately stable. Infrequent, small areas of erosion mostly healed over. Side slopes up to 40%. Slight erosion potential in extreme floods. 6-8	Moderately unstable. Moderate frequency and size of erosional areas. Side slopes up to 60% on some banks. High erosion potential in extreme floods. 3-5	Unstable. Many eroded areas. Side slopes >60% common. “Raw” areas frequent along straight sections and bends. 0-2
Bank Vegetative Stability	Over 80% of the stream bank surfaces covered by vegetation or boulders and cobble. 9-10	50-79% of the stream bank surfaces covered by vegetation, gravel or larger material. 6-8	25-49% of the stream bank surfaces covered by vegetation, gravel or larger material. 3-5	Less than 25% of the stream bank surfaces covered by vegetation, gravel or larger material. 0-2
Streamside Cover	Dominant vegetation is shrub. 9-10	Dominant vegetation is of tree form. 6-8	Dominant vegetation is grass or forbes. 3-5	Over 50% of the stream bank has no vegetation. Dominant material is soil, rock, bridge materials, or mine tailings. 0-2

Manual of Fisheries Survey Methods II: with periodic updates

Chapter 25B: GLEAS Procedure 51 Metric Scoring and Interpretation

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Chapter 25B: GLEAS Procedure 51 Metric Scoring and Interpretation

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Surface Water Quality Division:

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[Editor's note: Survey protocols for sampling wadable streams and rivers developed by the Surface Water Quality Division, Michigan Department of Natural Resources, were presented in Chapter 25A. This Chapter, 25B, presents their methods for scoring and interpreting the resulting metrics. This information has been reproduced here, with permission, as it appeared in Michigan Department of Environmental Quality, Surface Water Quality Division, Staff Report MI/DEQ/SWQ-96/068, as revised 5/98. Note that formatting, headers/footers, and page numbers have been added to match the style of Manual of Fisheries Survey Methods II. Contents of this report are subject to modification by the authors, and a time lag may occur before such revisions appear in the Manual of Fisheries Survey Methods.]

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MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY
SURFACE WATER QUALITY DIVISION
JUNE 1996

STAFF REPORT

UPDATE OF GLEAS PROCEDURE 51 METRIC SCORING AND INTERPRETATION

Great Lakes and Environmental Assessment Section (GLEAS) Procedure 51 describes qualitative biological and habitat survey protocols for wadable streams. This report serves to document the scoring and interpretation of the results from Procedure 51 sampling for biological communities.

GENERAL CONCEPT

The general premise that is used in the interpretation of the biological sampling results is that the professional biologists can recognize excellent or poor fish or macroinvertebrate communities, and that these communities can be described by a set of metrics. The metric scores will change as the quality of the community changes, with the excellent distinctly different from the poor community. This general premise was then used to describe the excellent communities, using the variability among the excellent communities to establish appropriate scoring levels.

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SCORING

A scale of +1, 0, -1 was used to score each metric. This scale was chosen to facilitate better and rapid communication of results. The scores were based on the following scale:

+1 = Community performing better than the average condition found at the excellent sites;

0 = Community performing between the average condition and (minus) 2 standard deviations from the average condition found at excellent sites;

-1 = Community performing outside of (minus) 2 standard deviations from average condition found at the excellent sites.

Each metric for the fish and macroinvertebrate communities was evaluated for scoring based on these criteria. The number of taxa metrics were found to vary with stream width at small widths (less than 30 feet wide). Therefore, each number of taxa metric was plotted following the Maximum Species Richness technique (Karr, 1981) to determine the stream width at which the line slope become flat (zero). After this point, all excellent sites were grouped for evaluation.

FISH METRICS

Fish metrics were scored only for warmwater streams. Coldwater designated streams were not scored because the available metrics do not adequately describe the variety of streams presently designated as coldwater in Michigan. The interpretation of coldwater fish results will be discussed later.

Four of Michigan's five Ecoregions were scored for warmwater fish. The fifth Ecoregion (North Central Hardwoods) was not scored due to a lack of warmwater sites. The results of this scoring are presented in Table 1 and Figures 1-19. The number of stations used is indicated in Table 2.

There were some modifications to the general scoring. These modifications were:

1. For fish metrics 2, 3 and 4 (Darters, Sunfish and Suckers), the data distribution was skewed by the few number of species found. Therefore, the mean and standard deviation approach was determined to not be appropriate. The scoring for these metrics was done by dividing the Maximum Species Richness line into thirds. This is similar to the approach used by Karr (1981) and Lyons (1992).

2. For metric 5 (# Intolerant taxa), the HELP and ECB Ecoregion scores were modified to be the same as the SMNITP Ecoregion. This was because of two factors: 1) all the other scores for the number of taxa metrics were virtually the same as SMNITP; and 2) using the Maximum Species Richness line divided into thirds yielded the same result.

3. For a few of the percentile scores, modifications were made when 2 standard deviations from the mean of the excellent sites fell outside the 0-100% range. This modification was to put these ranges at 1% or 99%. This was done for metric 9 (% Piscivores), metric 8 (% Insectivores – NLF, ECB), metric 10 (Simple Lithophilic Spawners – HELP) and metric 6 (% Tolerants – ECB).

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MACROINVERTEBRATE METRICS

Macroinvertebrate metrics were scored for all five Ecoregions. Stream types (warmwater and coldwater) were found to be similar and combined for scoring within each Ecoregion. The results of this scoring are presented in Table 3 and Figures 20-34. The number of stations used in developing these metrics are shown in Table 4.

There were some modifications to the general scoring process. These modifications were in the percentile scores when 2 standard deviations from the mean of the excellent sites was less than zero. In two instances this occurred, and the score was set at 1% – in metric 5 (% Mayfly – ECB) and metric 6 (% Caddisfly – ECB).

INTERPRETATION OF SCORES

Each site can now be scored using the metrics and the scoring scale developed for fish and macroinvertebrates. There are 10 fish metrics, therefore the scoring will range from +10 to -

10 for the fish community. There are 9 macroinvertebrate metrics, therefore the scoring will range from +9 to -9 for the macroinvertebrate community.

The interpretation of the score involves determining whether the site performs like excellent sites, poor sites, or between excellent and poor, which was termed acceptable. If a site performs in most metrics like an excellent site, it will be classified as an excellent site. Similarly, if a site performs in most metrics substantially different than an excellent site, it will be classified as a poor site. This results in scores of +5 or higher being classified as excellent, and scores of -5 or lower being classified as poor. Acceptable sites, those streams meeting Water Quality Standards, are scored between excellent and poor, in the range of +4 to -4. A site with a score of 0 is exactly neutral, with no tendency toward excellent or poor. A site with a positive score of +4 or less is tending toward excellent. A site with a negative score of -1 to -4 is tending toward poor.

For the fish community, there are some additional considerations when interpreting the results. First, for designated coldwater streams, the metrics developed do not apply to these streams. Instead, to determine if the coldwater designated use is being met, the presence of salmonids at 1% or greater in the fish community will be interpreted as meeting the coldwater designated use. For determining stream quality in these cases, the macroinvertebrate community will be used to determine this.

Second, as described in Procedure 51, there are two overriding factors which will immediately classify the fish community as poor. These factors include the inability to collect over 50 fish at a site, or the presence of anomalies at a rate greater than 2% of the fish community.

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Table 1. Summary of warmwater fish metric scores for wadable streams.

Ecoregion: SMNITP

Metric	Stream Width (ft)	+1	0	-1
1. Total Taxa	<15	>.92w	0.6w-0.92w	<0.60w
	≥15	>13	10-13	<10
2. Darter Taxa	<17	>.23w	.11w-.23w	<.11w
	≥17	>3	2-3	<2
3. Sunfish Taxa	<15	>.22w	.11w-.22w	<.11w
	≥15	>3	2-3	<2
4. Sucker Taxa	<18	>.15w	.074w-.15w	<.074w
	≥18	>2	2	<2
5. Intolerant Taxa	<21	>.23w	.14w-.23w	<.14w
	≥21	>4	3-4	<3
6. % Tolerant	All	<20	20-53	>53
7. % Omnivore	All	<16	16-46	>46
8. % Insectivore	All	>64	64-31	<31
9. % Piscivore	All	>14	14-1	<1
10. % Simple Lithophilic Spawners	All	>41	41-2	<2

w = average stream width in feet

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Table 1. Continued

Ecoregion: NLF

Metric	Stream Width (ft)	+1	0	-1
1. Total Taxa	<11 ≥11	>1.2w >12	0.76w-1.2w 8-12	<.76w <8
2. Darter Taxa	<10 ≥10	>.27w >2	.14w-.27w 2	<.14w <2
3. Sunfish Taxa	All	>0	--	0
4. Sucker Taxa	<13 ≥13	>.1w >1	.05w-.1w 1	<.05w 0
5. Intolerant Taxa	<13 ≥13	>.24w >3	.16w-.24w 2-3	<.16w <2
6. % Tolerant	All	<38	38-90	>90
7. % Omnivore	All	<29	29-83	>83
8. % Insectivore	All	>50	50-1	<1
9. % Piscivore	All	>10	10-1	<1
10. % Simple Lithophilic Spawners	All	>41	41-2	<2

w = average stream width in feet

Table 1. Continued

Ecoregion: HELP

Metric	Stream Width (ft)	+1	0	-1
1. Total Taxa	<12	>1.2w	.76w-1.2w	<.76w
	≥12	>14	10-14	<10
2. Darter Taxa	<15	>.22w	.11w-.22w	<.11w
	≥15	>3	2-3	<2
3. Sunfish Taxa	<20	>.17w	.085w-.17w	<.085w
	≥20	>3	2-3	<2
4. Sucker Taxa	<15	>.14w	.066w-.14w	<.066w
	≥15	>2	2	<2
5. Intolerant Taxa	<24	>.19w	.096w-.19w	<.096w
	≥24	>4	3-4	<3
6. % Tolerant	All	<39	39-75	>75
7. % Omnivore	All	<31	31-72	>72
8. % Insectivore	All	>62	62-15	<315
9. % Piscivore	All	>3	3-1	<1
10. % Simple Lithophilic Spawners	All	>47	47-1	<1

w = average stream width in feet

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Table 1. Continued

Ecoregion: ECB

Metric	Stream Width (ft)	+1	0	-1
1. Total Taxa	<6 ≥6	>2.2w >13	1.1w-2.2w 7-13	<1.1w <7
2. Darter Taxa	<9 ≥9	>.44w >3	.22w-.44w 2-3	<.22w <2
3. Sunfish Taxa	<12 ≥12	>.22w >2	.11w-.22w 2	<.11w <2
4. Sucker Taxa	<10 ≥10	>.2 w >2	.1w-.2w 2	<.1w <2
5. Intolerant Taxa	<11 ≥11	>.36w >4	.27w-.36w 3-4	<.27w <3
6. % Tolerant	All	<53	53-99	>99
7. % Omnivore	All	<36	36-88	>88
8. % Insectivore	All	>47	47-1	<1
9. % Piscivore	All	>5	5-1	<1
10. % Simple Lithophilic Spawners	All	>33	33-9	<9

w = average stream width in feet

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Table 2. Number of stations used in developing fish metrics. Stations are from 1990-1994 database.

Ecoregion:	SMNITP	NLF	HELP	ECB	NCH	Total
Excellent Sites:	24	7	7	7	---	45
Other Sites:	151	15	53	18	---	237
Total:	175	22	60	25	---	282

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Table 3. Summary of Invertebrate Metric Scores for Wadable Streams.

Ecoregion: SMNITP

Metric	Stream Width (ft)	+1	0	-1
1. Total Taxa	<7	>3.3w	1.7w-3.3w	<1.7w
	≥7	>24	12-24	<12
2. Mayfly Taxa	<12	>.3w	.1w-.3w	<.1w
	≥12	>3	2-3	<2
3. Caddisfly Taxa	<8	>.6w	.21w-.6w	<.21w
	≥8	>4	2-4	<2
4. Stonefly Taxa	All	>0	--	0
5. % Mayfly	All	>18	18-3	<3
6. % Caddisfly	All	>28	28-4	<4
7. % Dominance	All	<20	20-37	>37
8. % Isopod, Snail, Leech	All	<4	4-10	>10
9. % Surface Dependent	All	<7	7-19	>19

w = average stream width in feet

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Table 3. Continued

Ecoregion: HELP

Metric	Stream Width (ft)	+1	0	-1
1. Total Taxa	<14	>2.3w	1.3w-2.3w	<1.3w
	≥14	>31	18-31	<18
2. Mayfly Taxa	<27	>.14w	.09w-.14w	<.09w
	≥27	>3	2-3	<2
3. Caddisfly Taxa	<14	>.29w	.14w-.29w	<.14w
	≥14	>3	2-3	<2
4. Stonefly Taxa	All	>0	--	0
5. % Mayfly	All	>23	23-15	<15
6. % Caddisfly	All	>22	22-3	<3
7. % Dominance	All	<16	16-22	>22
8. % Isopod, Snail, Leech	All	<6	6-13	>13
9. % Surface Dependent	All	<10	10-23	>23

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w = average stream width in feet

Table 3. Continued

Ecoregion: NLF

Metric	Stream Width (ft)	+1	0	-1
1. Total Taxa	<10	>2.7w	1.1w-2.7w	<1.1w
	≥10	>27	11-27	<11
2. Mayfly Taxa	<11	>.42w	.18w-.42w	<.18w
	≥11	>4	3-4	<3
3. Caddisfly Taxa	<10	>0.6w	0.3w-0.6w	<0.2w
	≥10	>5	3-5	<3
4. Stonefly Taxa	<13	0.15w	0.08w-0.15w	<0.08w
	≥13	>1	1	0
5. % Mayfly	All	>21	21-3	<3
6. % Caddisfly	All	>29	29-3	<3
7. % Dominance	All	<17	17-27	>27
8. % Isopod, Snail, Leech	All	<4	4-13	>13
9. % Surface Dependent	All	<5	5-13	>13

w = average stream width in feet

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Table 3. Continued

Ecoregion: NCH

Metric	Stream Width (ft)	+1	0	-1
1. Total Taxa	<10	>2.2w	1.5w-2.2w	<1.5w
	≥10	>22	15-22	<15
2. Mayfly Taxa	<11	>.39w	0.14w-.39w	<.14w
	≥11	>4	2-4	<2
3. Caddisfly Taxa	<10	>.54w	.22w-.54w	<.22w
	≥10	>5	3-5	<3
4. Stonefly Taxa	All	>1	1	0
5. % Mayfly	All	>30	10-30	<10
6. % Caddisfly	All	>41	10-41	<19
7. % Dominance	All	<23	23-37	>37
8. % Isopod, Snail, Leech	All	<1	1-2	>2
9. % Surface Dependent	All	<1	1-2	>2

w = average stream width in feet

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Table 3. Continued

Ecoregion: ECB

Metric	Stream Width (ft)	+1	0	-1
1. Total Taxa	<5	>3.7w	1.9w-3.7w	<1.9w
	≥5	>18	10-18	<10
2. Mayfly Taxa	<12	>.26w	.10w-.26w	<.10w
	≥12	3	2-3	<2
3. Caddisfly Taxa	<12	>.3w	.11w-.3w	<.11w
	≥12	3	2-3	<2
4. Stonefly Taxa	All	>0	--	0
5. % Mayfly	All	>313	13-1	<1
6. % Caddisfly	All	>24	24-1	<1
7. % Dominance	All	>39	39-77	>77
8. % Isopod, Snail, Leech	All	<3	3-13	>13
9. % Surface Dependent	All	<12	12-26	>26

w = average stream width in feet

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Table 4. Number of stations used in developing invertebrate metrics. Stations are from 1990-1994 database.

Ecoregion:	SMNITP	NLF	HELP	ECB	NCH	Total
Excellent:	39	12	8	7	7	73
Other:	352	71	89	25	50	587
Total:	391	83	97	32	57	660

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Chapter 26: Stream Status and Trends Program Sampling Protocols

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Chapter 26: Stream Status and Trends Program Sampling Protocols

Todd C. Wills, Troy G. Zorn, and Andrew J. Nuhfer

Michigan's streams are a valuable, productive, and sustainable resource. For example, Michigan's "top quality" coldwater streams alone support wild populations of brook and brown trout estimated at over 10.7 million fish (based on 1967 Anonymous; Gowing and Alexander 1980). The number of naturally reproduced age-1 brook and brown trout in Michigan's streams (estimated at over 2.7 million fish) is about 3.4 times greater than the number produced annually by MDNR Fisheries Division hatcheries for stocking in streams (MDNR Fisheries Division 1995). In addition, many of these streams serve as important spawning and rearing grounds for other highly prized salmonids (e.g., steelhead [rainbow trout], Chinook salmon, and coho salmon) and numerous potamodromous fishes caught primarily in the Great Lakes. Abundant natural production of wild fishes provides forage for many species of wildlife (Alexander 1977) and humans. Each year, Michigan's lakes and streams provide recreation for over 277,000 trout and salmon anglers (average of 277,479 for 1991–95; Michigan License Control Commission). In addition, many warmwater streams have provided highly valued fisheries, primarily for smallmouth bass, within the last few decades (Lockwood et al. 1995).

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Successful management of these systems rests on Fisheries Division's ability to describe their status, detect adverse changes to them, and respond through the appropriate management action. However, with more than 36,000 miles of streams, this is a challenging task. Fisheries Division needs to be able to respond to a variety of questions regarding Michigan's stream resources. Seven common questions, posed by managers, researchers, and the public, are:

1. What types of fish live in this stream reach?
2. Why doesn't a certain species occur in this stream?
3. Why don't you stock trout in this stream?
4. How have fish populations changed through time in this stream?
5. What factors are responsible for the change?
6. Is the change specific to this stream, or is it common among other streams in the region or state?
7. Is the change outside of what would be considered normal for this type of stream?

A sampling design with the flexibility to address questions across various spatial and temporal scales is needed. Some questions (e.g., 1–3) are comparative, requiring biotic and abiotic data for evaluating different types of streams. Other questions (e.g., 4) require long-term, site-specific data, where variables changing through time exert the greatest influence on population trends. Other temporally extensive data are needed to answer questions (e.g., 5) regarding possible causes for change. Comparable data on fish communities are needed to answer questions (e.g., 6) on how widespread observed patterns are. Finally, data need to be collected for a sufficiently long period of time to determine the "normal" levels of variation for different types of streams (i.e., answer question 7).

The Division's sampling history shows that we have alternated between attempting to describe the spatial distribution of fishery resources and describing temporal trends in those resources. Early sampling was spatially extensive, followed by a shift to temporally extensive sampling, and then a shift back to spatially extensive sampling. Historically, stream surveys have not been coordinated between or within management units, or with the research section. Consequently, these surveys have been conducted using a variety of methods and sampling gear. Since databases were not shared or coordinated, little thought was given to using data from several management units to answer regional- or statewide-scale questions, and until recently, current differences in methods among management units prevented such uses of the survey data. Often, little information is available about the stream community other than fish population estimates or catch data. Such sampling approaches leave managers and researchers unequipped to answer pertinent questions and address issues faced by the state's stream resources, both through time and over multiple spatial scales. The Stream Status and Trends Program (SSTP) uses standardized sampling protocols and both a network of fixed sites and a stratified random sampling design to address questions at the most relevant spatial and temporal scales.

26.1 Overview of sampling plan

The general approach of the SSTP is to sample stream *communities* representative of streams across the state. However, data need to be collected over a sufficient period of time and an array of stream types to address common questions. Therefore, the design of the SSTP incorporates two different, yet complementary, types of sampling. A stratified random sampling design is used primarily for general resource inventory and to provide information to compare different valley segments and stream systems. Fixed sites are used for specifically looking at trends in important resources (i.e., coldwater and smallmouth bass streams) and testing hypotheses (Table 26.1). The following paragraphs discuss each type of sampling in more detail.

26.1.1 Random site sampling (stratified random sampling design)

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The SSTP uses a stratified random design for describing the status of our stream resources. The primary purpose of these data is to characterize different types of streams in the state, and to answer questions best answered by comparing different streams. These data also provide a low-resolution (yet statistically robust) means for evaluating temporal trends among different types (strata) of streams. However, differences among sites and streams within strata may add considerable variation to the "mean condition" for the year, making it difficult to detect subtle changes. Approximately 60% of Fisheries Division's SSTP sampling effort is allocated toward this design.

The primary sampling unit for the stratified random sampling design is the river valley segment, stratified according to management unit, stream size (defined by catchment area), and temperature class (as described by Seelbach et al. [1997] for Michigan's Lower Peninsula, and ongoing Study 662, Inventory and classification of Michigan rivers and river fish communities, for Michigan's Upper Peninsula). Size attributes are based upon the catchment area at the midpoint of the valley segment as follows:

- Small (<40 mi^2).–easily shocked;
- Medium (40–179 mi^2).–high to medium shocking efficiency;
- Large (180–620 mi^2).–medium to low shocking efficiency due to depth;
- Very large (>620 mi^2).–non-wadeable, boomshocking waters.

26.1.2 Fixed site sampling

The SSTP uses a network of fixed sites (rather than a stratified random sampling approach) for obtaining the high-resolution picture of temporal trends needed in stream types supporting valuable fisheries. The use of fixed sites allows managers and researchers to control for river- and site-level characteristics (e.g., river hydrology, local channel characteristics, and woody debris abundance) that exert consistent, and often considerable, influence on fish abundance. For example, by using fixed sites to control for differences among rivers, 50% changes in brown trout abundance in four Michigan streams (South Branch Paint River, and North and South branches and mainstem Au Sable River) could be detected with 3, 3, 4, and 9 years, respectively, of before and after data. More than 15 years of similar data would be needed to detect the same change if random sampling had occurred (Figure 26.1; Zorn, unpublished data).

Among Michigan streams with long-term data on trout abundance, 48% of the variation in brown trout levels and 22% of the variation in brook trout abundance were due to characteristics of the sites being sampled (Wiley et al. 1997). Brown trout trend data for several sites on the South Branch of the Au Sable River show that sites sampled within a stream segment show similar patterns in fish abundance through time. In addition, these data show that actual abundances vary considerably and fairly consistently among sites, i.e., some sites were always "better" for brown trout than others (Figure 26.2). So, if one randomly chose one of these four sites each year for trend monitoring, considerable site-level variation would be added to the data, making it difficult to discern a temporal trend that was actually common to all sites. The use of fixed sites in the SSTP helps to control for such differences and increase our ability to detect and describe temporal trends in fish abundance.

The SSTP uses a network of fixed sites, stratified by drainage area and connectivity to the Great Lakes, to provide additional resolution for describing temporal trends at regional and larger spatial scales in stream types supporting valuable fisheries (e.g., better quality, wadeable, wild trout and smallmouth bass streams). Fixed sampling sites are dispersed throughout the state with the sampling effort for each stratum being proportional to the geographic distribution of stream types. In other words, northern Michigan has proportionately more trout sites, while southern Michigan has more smallmouth bass sites. Population estimates are made for salmonids to maintain continuity and comparability of data over time. Catch-per-unit-effort data are used for smallmouth bass because others have shown it is not possible to generate valid population estimates for Michigan streams (Lockwood et al. 1995). Catch-per-unit-effort data are also periodically collected for all other non-game species. Locations having existing data collection programs, such as United States Geological Survey (USGS) gauges and long-term population estimate stations, are favored as fixed sites. Approximately 40% of Fisheries Division's SSTP sampling effort is put towards fixed site sampling. Fixed sites are sampled in a 3 years on, 3 years off rotation to provide broader geographic coverage, yet enable estimates of year to year survival at sites.

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Additional trend data may be desired for important events that happen at other times of the year. For example, the need to monitor trends in natural reproduction (or smolt production) of species such as lake sturgeon and Chinook salmon may arise. Such targeted sampling efforts will be addressed as special projects or on an as-needed basis.

26.2 Data collection and recording

26.2.1 General protocols

Standard SSTP data sheets are provided to accommodate any fisheries and habitat information that should be collected when sampling. Be thorough when filling these data sheets out, as they will later assist in data entry and error checking. Filling in some of the basic information on the data sheets in the office will assist in expediting the data recording process in the field. Copies of the standard SSTP data sheets are available at the end of this document (Appendix A), or electronically on the DNR Intranet.

Use the SURVEY INFORMATION form as a guide to note the following:

- <u>Stream survey details</u>.–Note the beginning and ending date of the complete survey (fish and habitat data collection), as well as the water body, valley segment identification number, station location (e.g., number of feet upstream or downstream from bridge, road, etc.), county, and township, range, and section (if available). Record the GPS (global positioning systems) coordinates of station boundaries in decimal degrees to five places past the decimal point. A line is available to briefly describe the location of the station, or you may map it on the back of the data sheet. Check appropriate boxes. Note the first initial and last name of all crew members.

- Effort details.–Note the beginning and ending date and time for the survey effort, as well as the sampling gear used (include gear inventory number as this will help in identifying suspect data due to faulty gear).
- Gear notes.–Record the number of probes used, as well as the voltage, duty cycle, and pulse if applicable. Note any problems or suspect gear as necessary.
- Sampling conditions.–Record the water temperature (and the time it was recorded), air temperature, and conductivity. Check the appropriate boxes regarding electrofishing efficiency, weather, water level, and water color.
- Site assessment data.–Rapidly assess site conditions using the check boxes provided on page 2 of the SURVEY INFORMATION form. Use the blank section at the bottom of this data sheet for notes, maps, or comments as necessary.
- Herps data.–Record any observations and incidental collections of herps (reptiles and amphibians) on the HERPS OBSERVATION data sheet. Include number and size data for each species.
- Habitat data.–Similar protocols are used for collecting habitat data at wadeable random and fixed sites. See "Habitat sampling protocols" below.

26.2.2 Random site protocols

26.2.2.1 Determining sampling locations for randomly selected river valley segments.–An ArcReader project is available that will allow you to view locations of river valley segments that are randomly selected for sampling under the SSTP. The project also shows road crossings and is useful for identifying specific locations for sampling. The ArcReader project for identifying locations of valley segments scheduled for random sampling, as well as an up-to-date random site list, can be found on the DNR Intranet.

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A copy of the data on compact disk was also distributed to each management unit in the spring of 2003. The zipped file is quite large (93 megabytes), so you may wish to locate your office copy rather than downloading. A separate file containing instructions is located at the same network address. A copy of the instructions is also attached to this document (Appendix B).

26.2.2.2 Fisheries data.–Once the random valley segments to be sampled are located, follow the instructions below for collecting fisheries data at random sites. Try to schedule fisheries surveys at random sites between June 15 and September 15, but preferably between July 15 and August 30. Also, try to sample during the same time period each year.

In addition to the information specified under "General protocols," use the SURVEY INFORMATION form as a guide to note the following:

- Stream survey details.–Check the box for "Random site one-pass" as the purpose.
- Effort details.–In general, use a stream shocker and record the number of probes used (see "Gear Notes" on the data sheet). If overhanging brush or woody debris prohibits the use of a stream shocker, two backpack electrofishing units operated in tandem are an acceptable alternative. A single backpack electrofishing unit is acceptable for very small streams. All electrofishing that is conducted at random sites with a stream shocker or backpack electrofishing unit should be completed in an upstream direction. Use a boomshocker for non-wadeable large rivers and very large rivers. Boomshock in a downstream direction on one bank only, and use dip nets with ½-in square mesh. Note the length and width of the sampling station, as station length varies with stream size. Random valley segments identified for sampling are classified by stream size on the random site list. Recommended lengths for random site survey stations are:

- Small streams <15 feet wide.–500 feet,
- Small streams ≥15 feet wide.–800 feet,
- Medium streams.–1200 feet,
- Large streams.–1500 feet (may require boomshocker),
- Very large streams.–1 mile (requires boomshocker).

Use the RANDOM SITE ONE-PASS RUN form to record information for all fish species encountered on the random site surveys. Conduct one-pass electrofishing for all fish species to obtain catch-per-unit-effort (CPUE) data. Fish less than 1 in long can be ignored. Measure and count all game fishes and all large-bodied (>8 in) non-game fishes (for example, suckers) to obtain length-frequency data and CPUE. For small, non-game fishes obtain a total count and length range (size of smallest and largest individual captured of each species measured to 0.1 in). Also collect length-frequency data for a representative sample of about 30 fish per species. If large numbers occur for a small, non-game fish species, then the weight of a 30-fish subsample and the bulk weight of the remaining individuals can be used to estimate the total number caught. For example: if 15 lb of creek chubs were collected and 30 fish weighed a total of 0.25 lb, then the total number of fish collected = 15 lb x (30 fish/ 0.25 lb) = 1800 fish.

Collect scale samples from 10 fish per in group for species of interest.

26.2.3 Fixed site protocols

26.2.3.1 Locating fixed sites.–An up-to-date fixed site list can be found on the DNR Intranet.

Fixed sites are sampled in a 3 years on, 3 years off rotation. The sites on the current rotation will always be highlighted in bold on the fixed site list.

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26.2.3.2 Fisheries data.–Once the fixed sites to be sampled are identified, follow the instructions below for collecting fisheries data at fixed sites. Try to schedule fisheries surveys at fixed sites between August 1 and October 15, but preferably between August 15 and September 15. Also, try to sample during the same time period each year. Use the "Survey information" form as a guide to note the following:

- Stream survey details.–Note the historic site name if applicable. In addition to recording the GPS coordinates of station boundaries, record the GPS coordinates of the half-way point (see "Effort details" below), in decimal degrees to five places past the decimal point. Check the box for "Fixed site marking and recapture run" as the purpose.
- Effort details.–Use a stream shocker and record the number of probes used (see "Gear Notes" on the data sheet). Block nets are optional, but should be used consistently. Identify, map (see Manual of Fisheries Survey Methods II, Figure 2.2), and place permanent stakes at boundaries, as well as the half-way point, of electrofishing stations. Use the lengths of pre-existing, long-term population estimate stations if they exist. Otherwise, station lengths at fixed sites are 1000 feet.

Use FIXED SITE MARKING RUN OR SMALLMOUTH BASS RUN and FIXED SITE RECAPTURE RUN forms to record information for all fish species encountered on the survey. Methods for target species are as follows (mark-recapture population estimates should be used for salmonid species at all fixed sites):

- Small streams.–Preferably complete the marking run at two fixed sites in day 1, and complete the recapture run in day 2. If this would cause excessive time and travel, then complete the marking and recapture run in the same day.

- Medium-size, coldwater (trout) streams.–Conduct traditional mark-recapture population estimates for all salmonid species (day 1 – marking run, day 2 – recapture run).
- Medium-size, smallmouth bass streams.–Use a stream shocker with 3 probes for all sites. Shock the entire left and right bank in an upstream direction to obtain CPUE. Multiple stream shocking units (one to cover each bank separately) are acceptable.

Record length-frequency data on all large-bodied (>8 in) non-game fishes in the first half of the station in year two of the 3-year shocking cycle only. For small-bodied, non-game fishes, simply count all fish. This will require that non-game species are collected in the first half of both the left and right banks at smallmouth bass sites. Note the occurrence of new species on the recapture run, but do not include them with quantitative data collected from the first pass. In years one and three of the 3-year shocking cycle, the sampling of non-game fishes is not required.

Collect scale samples from target species only. Record the length of scale-sampled fish to the nearest tenth of an inch. Obtain scale samples from 10 fish per inch group for fish 4 in or larger. Measure 10 fish to the tenth of an inch per inch group for fish 3 in and smaller and enter into the Fish Collection System as age-0. Avoid releasing scale-sampled fish in the upper one-half of the survey station to minimize numbers of fish migrating out of the station prior to the recapture run.

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Note: Concerns regarding cases of low catch of resident trout at SSTP fixed sites in the Upper and northern Lower peninsulas were brought forward in the first 2 years after the SSTP was initiated. Low catches at fixed sites create a problem, as one of the primary objectives of the fixed site sampling design is to obtain a high resolution picture of temporal trends in stream types supporting valuable fisheries. If catches are too low, the confidence intervals surrounding population estimates may be too wide to make the estimates useful (depending upon capture efficiency). Accordingly, the information gained from sampling at such sites may not be worth expending the necessary time and effort needed for data collection. This raises the question of whether or not certain sites should be dropped from the fixed site rotation.

If you feel that the catch at a particular fixed site is too low (or if it is repeatedly low), please contact a SSTP coordinator to discuss whether or not to keep the site in the fixed site rotation. Ideally, 100 fish should be marked to achieve the desired confidence; however, this may not be possible in all circumstances. If capture efficiency is good, and an even smaller number of fish (50) are marked, precise estimates can still be made. The following guidelines are given under the assumption that the capture efficiency is acceptable (50-75%):

1. If at least 50 resident trout (brook trout and brown trout combined) are marked, a minimum of 12 fish (~25%) should be >4.5 in in length (i.e., age 1 or older).
2. If less than 50 resident trout (brook trout and brown trout combined) are marked, a minimum of 12 fish should be >4.5 in in length (i.e., age 1 or older).
3. The suggestions in 1 and 2 apply to resident species only. There is no minimum for potamodromous species (rainbow trout, Chinook salmon, and coho salmon).

If a particular stream fails to provide an adequate catch, it can be considered for removal from the program only after consultation with the appropriate management biologist and a SSTP coordinator. If a fixed site is dropped from the rotation, all efforts should be made to find a suitable replacement as soon as possible. The following guidelines (in order of priority), are used to define sites that may be suitable for inclusion in the fixed site rotation:

1. High-quality fishery, amenable to sampling.
2. Presence of a USGS gauge.
3. Site helps provide a spatially-broad (even) geographic coverage of fixed sites.
4. Existence of long-term fish abundance data.
5. Simultaneous sampling of other parameters (water chemistry, invertebrates, etc.) by others.

26.2.4 Habitat sampling protocols

***26.2.4.1 General information.*–**Habitat sampling occurs in year 1 of each 3-year shocking cycle for the fixed sites, and on each survey for the random sites. Try to collect habitat data as close to the time of the fish survey as possible. Habitat sampling methods are described below, and in detail on the habitat data sheets.

***26.2.4.2 Gear.*–**Besides waders and raingear, the standard gear required for habitat sampling consists of, (2) 100 or 250-foot measuring tapes, (2) 3–4 foot pieces of rebar, (2) clamps to hold the tape taught across the transect, (2) sticks 6-feet long with marks at 6, 12 18, and 24 in (for measuring large woody debris), a GPS unit, a clipboard, data sheets, pencils, a current meter, a graduated rule for measuring depth, and station marking equipment (paint, flagging, stakes, and a hammer).

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***26.2.4.3 Locating transects and sampling points.*–**Habitat data are recorded from evenly-spaced transects and include width, depth, and substrate measurements at points across the transect (Table 26.2). Point sampling on a transect always occurs from left to right when facing upstream. For point sampling at random sites, note that the thalweg is defined as the deepest part of the channel (which usually carries the bulk of the river's current). Transects are always numbered from downstream to upstream (i.e., transect 1 is furthest downstream). Transect spacing and point sampling protocol for random sites follow the methods of the Wisconsin Department of Natural Resources (Simonson et al. 1994), which have known levels of precision and accuracy (Wang et al. 1996).

***26.2.4.4 Riparian zone conditions.*–**Use the RIPARIAN and BANK CONDITION data sheet to document riparian habitat at each transect, including riparian vegetation and bank condition (refer to the appropriate vegetation and bank stability classes on the data sheet). Note the dominant vegetation (>50%) within 30 feet from the water's edge and 30 feet upstream and 30 feet downstream of the transect (don't count islands). Complete riparian measurements as if the stream was at bankfull stage, but note the presence of exposed substrate when the water level is low.

***26.2.4.5 Width, depth, and substrate.*–**Two forms (RANDOM SITE TRANSECT HABITAT data sheet and FIXED SITE TRANSECT HABITAT data sheet) are available for width, depth, and substrate measurements at the transects. Measure stream width (to the nearest foot) as the wetted width of the channel; for braided channels measure the width of each island and record both the wetted and total width of the channel (include the island when calculating total channel width, but not the wetted width). Note the predominant mesohabitat type as pool, riffle, or run. The following definitions may be helpful in identifying the appropriate mesohabitat type:

- Pools.–Have deeper than average maximum depths, with no obvious surface turbulence or broken water. Water velocities are always slow.
- Riffles.–Have shallower than average maximum depths and obvious surface turbulence. Water velocity is faster than average.

- Runs.–Have average maximum depths and little or no surface turbulence. Water velocities may be fast or slow, but water surface is generally smooth.

Take depth and substrate data at the properly spaced sampling points along the entire transect and record island as a substrate type when islands occur (refer to the data sheet for the entire list of substrate classes). Measure stream depth to the nearest tenth of a foot and record the dominant substrate, the percent of wood, and the percent of rooted plants in a 1-foot diameter circle at the sampling point. Wood is defined as any woody material that is dense enough to provide fish cover, such as root wads and woody debris. When gravel substrate is encountered, record the appropriate embeddedness code (refer to the data sheet for a definition of each embeddedness code). Note that only gravel receives a measurable embeddedness code. All other substrates receive an unmeasurable embeddedness code. Don’t leave any blanks on the transect habitat data sheets. If a value equals zero, then enter “0” in the appropriate column.

26.2.4.6 Large woody material.–Data for lineal and areal counts of large woody material (>6 in in diameter and >6 feet long) in the channel are recorded on the LARGE WOODY DEBRIS COUNT DATA form. Measure the number of full, 6-foot stick lengths, by diameter, for individual logs at least 6 feet long and in contact with water at least 6 in deep. Logs that are less than 6 feet in length, or logs that are not in contact with water at least 6 in deep, do not count as large woody debris. Only measure the portion of the log in water >6 in deep. Lengths of logs that are >12 in in diameter are measured from the base to the point on the log where the diameter becomes <6 in. Each individual 6-foot stick length equals one length class on the LARGE WOODY DEBRIS COUNT DATA form. For example, a 12-in diameter log that is 18 feet long and in 6 in of water would count as three 12-in length classes. A 30-foot long log in 6 in of water that is 18 in in diameter at the base, tapers to 12 in in diameter after 12 feet, 6 in in diameter after 18 feet, and 4 in in diameter after 24 feet would count as two 18-in length classes, one 12-in length class, and one 6-in class. The portion of the log less than 6 in in diameter is not counted.

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Record areal dimensions of natural log jams, beaver dams, brush deposits, and artificial structures to the nearest foot (record lineal feet for wing deflectors). Only record the area of natural or artificial structure that is in water >6 in deep. Refer to the data sheet for the proper natural and artificial structure codes. The following definitions may be helpful for identifying the proper structure types:

- Artificial log jam.–Same definition as log jam, except structure was built by humans.
- Brush deposits.–Piles of brush in streams, such as beaver lodges or food caches.
- Individual log.–Individual logs placed in channel as cover.
- Log jam.–three or more large diameter (>6 in) intermingled logs in water at least 6 in deep.
- Lunker structure.–Overhanging structure built into stream bank.
- Raft.–Sunken rafts that look like something built by Tom Sawyer.
- Riprap.–Rocks placed along the stream edge to stabilize a bank and deflect the current.
- Wing deflector.–Lineal walls placed in the channel to deflect the current.

26.2.4.7 Discharge.–Three different data sheets are available for recording discharge measurements (DISCHARGE DATA SHEET FOR RIVERS GENERALLY <30’ WIDE, DISCHARGE DATA SHEET FOR RIVERS GENERALLY 30-60’ WIDE, and DISCHARGE DATA SHEET FOR RIVERS GENERALLY >60’ WIDE). Choose the appropriate discharge data sheet based upon the width of the stream to be sampled. Collect one discharge measurement at one location at the time of habitat sampling (for wadeable streams only). Measure stream depth (to the nearest tenth of a foot) and velocities where the channel is straight, canal-like, and has laminar flow (not at bridges). Measure water velocities at 0.6 times the depth (for example, if the depth is equal to 1 foot, measure the velocity at 0.6 feet below the water surface). Set the flow meter to average values over 10 seconds.

26.2.4.8 Temperature.–Use the TEMPERATURE LOGGER DEPLOYMENT form to track the deployment and recovery of temperature loggers for stream temperature measurements. Collect hourly temperature measurements year-round for all 3 years of the shocking cycle on fixed sites. For random sites, temperature loggers should be deployed at a minimum from June 1 to August 31, but where possible should be deployed for a full year. Be sure to note the logger model and serial number as well as any information pertaining to the delayed start option. Also note the date and time of deployment and recovery, as well as the surface water temperature (this will help to identify any erroneous temperature data recorded by the logger after it is removed from the water). Space is provided to note and map the location of the temperature logger to assist in recovery.

Note: Temperature is probably *the* most critical habitat feature for stream fishes. Thus, measuring temperature is a priority.

26.2.4.9 Water quality.–The Department of Environmental Quality (DEQ) will be sampling some of our fixed and random sites and providing water quality data, but there is presently no comprehensive DEQ plan for water quality sampling at all fixed or random sites. Water chemistry data will be used when available, but not collected as part of this program.

26.3 Data management in the Fish Collection System

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Once field work is completed, all fisheries and habitat data collected for the SSTP must be entered into the Fish Collection System (FCS). Do not combine multiple surveys in the same river from different sites, valley segments, or years into one survey folder. Each survey conducted at an individual sampling site in a given year should have its own survey folder in the FCS. Note that all standardized data sheets for the SSTP have space available to identify the water body, valley segment, and date sampled. Group all data sheets for completed surveys by water body and date so that all data are available in one location. This will expedite data entry, as well as error checking.

Be thorough and complete (yet succinct) in comments and descriptions and fill out as many screens as possible for each survey within the FCS. The intent of the standardized data sheets is to assist you in collecting all of the pertinent information associated with a survey, and to ensure that this information is stored in the FCS. Such detail can help in future data analysis or in identifying suspect data. Double-check your data entry in the FCS. Hurried data entry often leads to inaccurate survey results and data analysis problems in the future. Review the available summary reports and population estimates. Do they seem reasonable for the data that you collected? Are there any apparent problems? If so, correct them immediately, while the data are fresh in your mind, rather than waiting.

Refer to the Fish Collection System User's Guide for general instructions on entering fish and habitat survey data. For Stream Status and Trends Program surveys, remember the following notes in particular when completing the survey folder "Details" and "Efforts" tabs in the FCS. Doing so will greatly assist in querying and summarizing data in the future.

26.3.1 Survey folder "Details" tab

1. All SSTP surveys must be identified with a "Primary purpose of collection" of "Status and Trends." Purposes such as "Population estimate," "General survey," or "Research project" are inappropriate.
2. Use the "Fixed or random" drop-down menu to distinguish fixed and random site surveys.

3. Enter a brief, specific description under “Purpose note.” If the survey is for a fixed site specify the site name, year of the rotation (e.g., year 1 of 3), and “fixed;” for random sites specify the valley segment identification number, road crossing, and “random.”
4. Enter the valley segment identification number in the “Valley Seg. I.D.” field.

26.3.2 Survey folder “Efforts” tab

1. Under “Details,” enter the “Total effort quantity” in feet for all surveys. For fixed sites, use acres as the “Alternative total effort quantity;” for random sites use seconds.
2. Enter the marking run first and the recapture run second for fixed sites, all other efforts should follow. For smallmouth bass fixed sites, enter separate efforts for the left and right bank.
3. Create a separate effort (effort quantity should be half of the total station length in feet) for the non-game species collection at fixed sites in year 2 of the 3-year rotation. For smallmouth bass fixed sites, enter separate efforts for the left and right bank.
4. Create a separate effort (with “Other” as the gear used) for scale envelopes. Enter scale data for all inch groups captured. Don’t forget to enter age-0 fish.
5. Use a brief, specific “Location” description in the “Site Characteristics” tab. Specify whether the effort is for the marking or recapture run for salmonid fixed sites, or the left or right bank for smallmouth bass fixed sites.
6. Enter the site length and width in feet in the “Site Characteristics” tab (this calculates the acreage in the population estimate spreadsheet).
7. Fill out as much information as possible in other spaces (weather, water, stream conditions, etc.).
8. Enter GPS coordinates for the site by using the “Electro. Stations” button in the limnology effort.

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26.3.3 Fish Collection System improvements

After the initiation of the SSTP, the FCS was upgraded to accommodate the wide range of fisheries and habitat variables (including temperature from electronic temperature loggers) collected by management units during SSTP sampling. In addition to storing fisheries data, the FCS is capable of limited data analysis, such as summary reports and population estimates, although these analyses are limited to single systems. Conducting data analyses within the FCS to compare fisheries data across multiple systems is currently not possible. Yet, many of the questions that the SSTP will address require this ability. For example, a manager may wish to know if changes in fish populations are unique to one stream of interest, or if they are common among other streams in the region or state. Such questions require the ability to conduct data analysis and comparisons across multiple stream systems and types at different regional scales.

Upgrading the FCS to conduct data analysis across systems and regions is important to providing the information Fisheries Division personnel need for effective management of Michigan’s stream resources. Ideally, this information should be provided in a manner that is easily accessible and simple to utilize. Stream Status and Trends Program coordinators will continue to collaborate with Fisheries Division database personnel in charge of the operation and maintenance of the FCS to provide an easily accessible, user-friendly, web-based interface to the database. The ability of the FCS to query, analyze, and provide output from data of interest within and across systems will be of great utility to managers and researchers, as well as the public concerned with the quality of stream resources. In addition to addressing complex questions requiring comparisons among systems, such an interface will allow managers to easily address questions received from the public regarding a single stream of interest.

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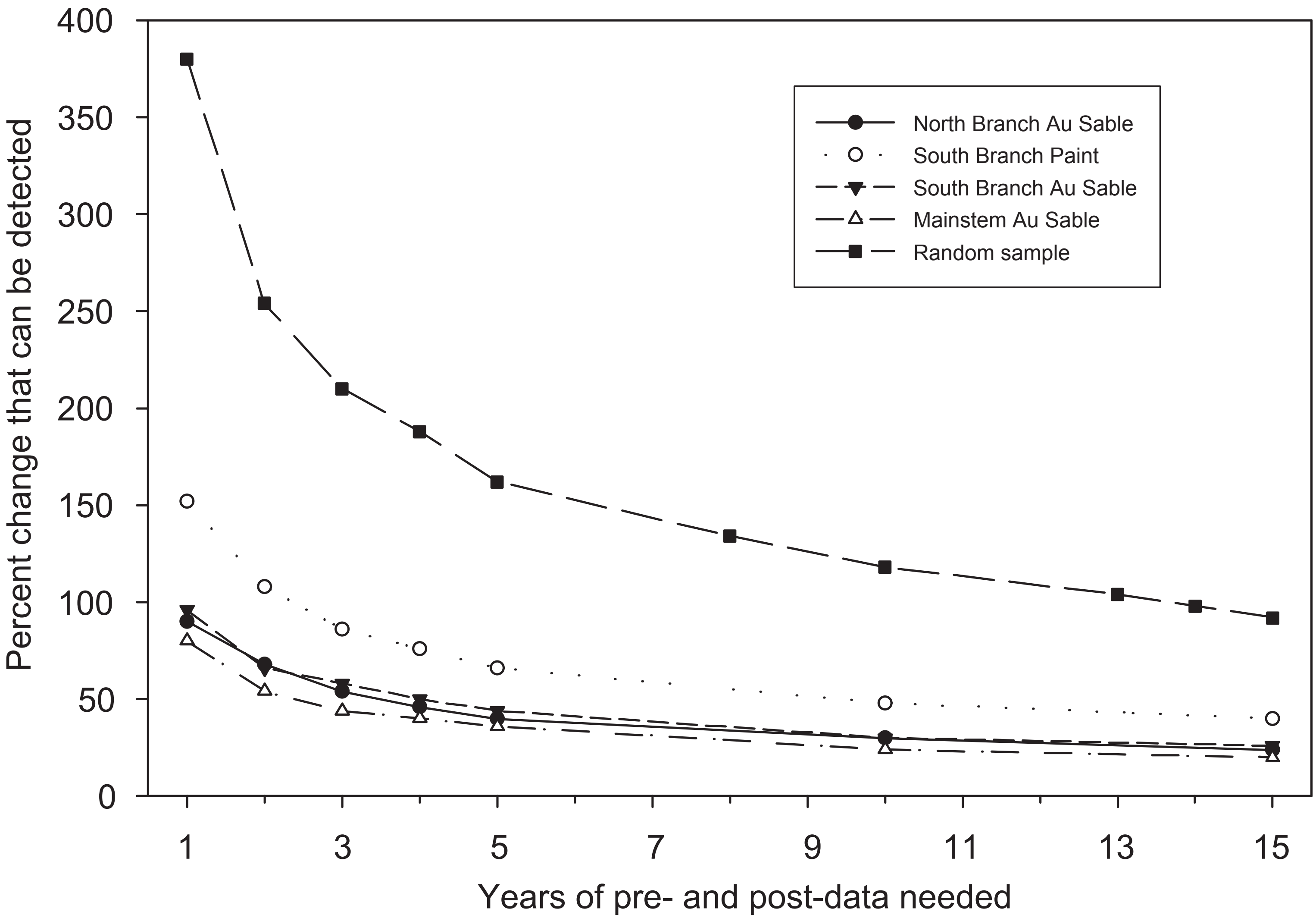

Figure 26.1.–Brown trout trend detection ability at fixed vs. random sites.

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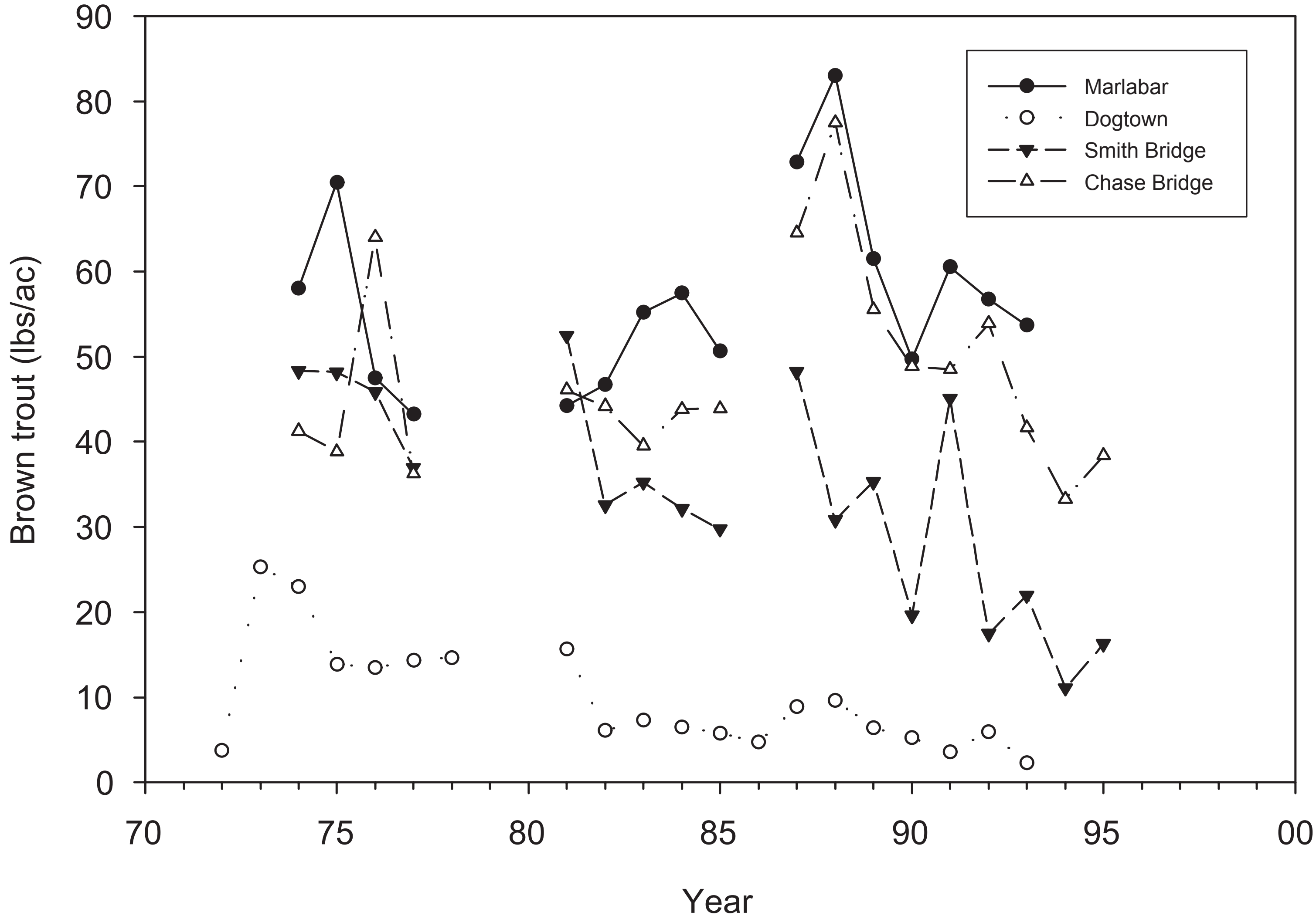

Figure 26.2.–Consistent differences and similar trends among sites in the South Branch Au Sable River.

Table 26.1.–Overview of random and fixed site sampling design for the SSTP.

	Random sites (60% of effort)	Fixed sites (40% of effort)
Objectives	• Describe stream resource • Characterize valley segment strata • Used for answering comparative questions (i.e., Why is this stream marginal for trout?) • Describe temporal trends by strata; low resolution due to site level differences within strata, but high confidence if there is a change	• Ecosystem study (increase understanding of ecological mechanisms that influence valuable fisheries) • Describe long term trends • Describe baseline variation in population levels and fish growth, survival, and reproductive success • Quantify rates of change in stream habitat characteristics • Provide high resolution data for “early” detection of temporal trends, with broad geographic coverage • Contrast land-locked and Great Lakes connected streams
Types of streams	• All stream types	• Higher quality representatives of valuable fishery types • Wadeable reaches • Study streams: Landlocked small and medium wild trout Potamodromous small and medium wild trout Medium smallmouth bass
Statewide sampling design	• Late summer samples • Stratified random sampling using valley segment strata	• Late summer, biennial (3 year on-off) samples at fixed sites • Sites distributed across the state with effort proportional to distribution of the resource (more trout sites in the north and more bass sites in the south) • Try to cover major valley segment types • Preference for sites having USGS gages and existing long-term fish data
Type and frequency of data		
Fish:	• CPUE for all species	• Population estimates for trout to maintain continuity and comparability of data over time, CPUE for all other species
Temperature:	• Continuous data from temperature loggers	• Continuous temperature data from temperature loggers
Discharge:	• Periodic discharge measurements	• Discharge data in cooperation with the USGS
Habitat:	• Detailed measurements of riparian and in-stream features	• Periodic detailed measurements of riparian and in-stream features

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Table 26.2.–Spacing of transects and sample points for SSTP habitat sampling.

Size strata	Station length (feet)	Transect spacing (feet)	Space between sampling points on transect
Random sites			
Small (<15’ wide)	500	40	1/5, 2/5, 3/5, 4/5 across channel, at thalweg
Small (≥15’ wide)	800	60	1/5, 2/5, 3/5, 4/5 across channel, at thalweg
Medium	1200	90	1/5, 2/5, 3/5, 4/5 across channel, at thalweg
Large	1500	110	1/5, 2/5, 3/5, 4/5 across channel, at thalweg
Very large	1 mile	400	1/5, 2/5, 3/5, 4/5 across channel, at thalweg
Fixed sites			
Small	1000*	75	2’
Medium	1000*	75	3’

*Or length of historic index station.

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26.4 Literature cited

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CITATION Ch26

Written in 2006 by T. C. Wills, T. G. Zorn, and A. J. Nuhfer

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CITATION Ch26

Appendix A

Copies of the standard SSTP data sheets (also available electronically on the DNR Intranet).

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FISH COLLECTION: SURVEY INFORMATION (reduced to fit on this page).

DNR

Stream Status and Trends Program
Fish collection

Survey information
Page 1
Revised 3/22/04

Stream survey details:

Begin date: ______________ End date: ______________ GPS[1]: Upstream Middle Downstream

Water body: ________________________________ Lat: __________ __________ __________

Station: ________________________________ Long: __________ __________ __________

VSEC I.D. ______________ County: ______________ T. ________ R. ________ Sec. ________

Station description[2] (describe or map on back of sheet): ________________________________

Purpose: Fixed site marking and recapture run ☐ Random site one pass ☐ Other (explain): ______________

Check if station is inaccessible: ☐ Check if station is intermittent/dry: ☐ Check if station has Great Lakes access: ☐

Has station been stocked w/in last 5 years? Yes ☐ No ☐ If yes, indicate species: ______________

Crew (first initial, last name): ________________________________

Effort details:

Effort number: ______ Beginning date: __________ Time: __________ Ending date: __________ Time: __________

Effort number: ______ Beginning date: __________ Time: __________ Ending date: __________ Time: __________

Gear: Boomshocker ☐ Backpack ☐ Barge ☐ EF Unit I.D. no. ______________

Station length[3] (ft): __________ Station width (ft): __________ Acres: __________ Check if block nets were used[4]: ☐

Gear notes:

No. of anodes: __________ Volts: __________ Duty cycle: __________ Pulse: __________

Notes: ________________________________

Sampling conditions:

Water temp (^{o}F): __________ Air temp (^{o}F): __________ Time of temperature recording: __________ AM ☐ PM ☐

Conductivity (µs/cm): __________ Notes: ________________________________

Electrofishing efficiency: Low ☐ Med. ☐ High ☐ Water level: Very high ☐ High ☐ Avg. ☐ Low ☐ Very Low ☐

Weather: Clear ☐ P. Cloudy ☐ Overcast ☐ Rain ☐ Water color: Clear ☐ Gry ☐ Brn ☐ Blk ☐ Green ☐

[1]Record GPS coordinates in decimal degrees to 5 decimal places.
[2]Include access point with reference to nearest road or highway.
[3]**Fixed sites**: Use lengths of pre-existing long-term pop'n estimate stations if they exist. Otherwise, station lengths are 1000'.
Random sites: Sm. stream <15' wide=500', >15' wide=800'; med. stream=1200'; lg. stream=1500', very lg. stream=boomshock for 1 mile.
[4]Fixed sites: Block nets are optional, but should be used consistently.

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FISH COLLECTION: SURVEY INFORMATION, page 2 (reduced to fit on this page).

DNR

Stream Status and Trends Program
Fish collection

Survey information
Page 2
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Water body and station: ____________________ Begin date: __________ End date: __________

Site assessment data: *The purpose of this section is to provide a **rapid** assessment of on-site conditions…devote time accordingly.*

Physical appearance:	Upstream of section midpoint (Check all that apply)				Downstream of section midpoint (Check all that apply)			
Invertebrates[5]	Abundant ☐	Moderate ☐	Sparse ☐	Absent ☐	Abundant ☐	Moderate ☐	Sparse ☐	Absent ☐
Floating algae	Abundant ☐	Moderate ☐	Sparse ☐	Absent ☐	Abundant ☐	Moderate ☐	Sparse ☐	Absent ☐
Filamentous algae	Abundant ☐	Moderate ☐	Sparse ☐	Absent ☐	Abundant ☐	Moderate ☐	Sparse ☐	Absent ☐
Turbidity	Abundant ☐	Moderate ☐	Sparse ☐	Absent ☐	Abundant ☐	Moderate ☐	Sparse ☐	Absent ☐
Oil sheen	Abundant ☐	Moderate ☐	Sparse ☐	Absent ☐	Abundant ☐	Moderate ☐	Sparse ☐	Absent ☐
Foam	Abundant ☐	Moderate ☐	Sparse ☐	Absent ☐	Abundant ☐	Moderate ☐	Sparse ☐	Absent ☐
Trash	Abundant ☐	Moderate ☐	Sparse ☐	Absent ☐	Abundant ☐	Moderate ☐	Sparse ☐	Absent ☐
Comments (presence of crayfish, minnows):								

Instream cover:	Upstream of section midpoint (Check all that apply)				Downstream of section midpoint (Check all that apply)			
Undercut banks	Abundant ☐	Moderate ☐	Sparse ☐	Absent ☐	Abundant ☐	Moderate ☐	Sparse ☐	Absent ☐
Overhanging vegetation	Abundant ☐	Moderate ☐	Sparse ☐	Absent ☐	Abundant ☐	Moderate ☐	Sparse ☐	Absent ☐
Deep pools	Abundant ☐	Moderate ☐	Sparse ☐	Absent ☐	Abundant ☐	Moderate ☐	Sparse ☐	Absent ☐
Boulders	Abundant ☐	Moderate ☐	Sparse ☐	Absent ☐	Abundant ☐	Moderate ☐	Sparse ☐	Absent ☐
Aquatic plants	Abundant ☐	Moderate ☐	Sparse ☐	Absent ☐	Abundant ☐	Moderate ☐	Sparse ☐	Absent ☐
Logs/woody debris	Abundant ☐	Moderate ☐	Sparse ☐	Absent ☐	Abundant ☐	Moderate ☐	Sparse ☐	Absent ☐
Comments:								

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Notes, maps, or additional comments:

[5]Note invertebrate abundance on hard surface (such as rock or wood).

FISH COLLECTION: FIXED SITE MARKING RUN OR SMB RUN (reduced to fit on this page).

DNR

Stream Status and Trends Program
Fish collection

Fixed site
Marking run or
Smallmouth bass run
Revised 3/14/06

Water body: ______________________ Date: ____________ Page ______ of ______

Station: ____

Target species[1,2]: ____________ Start time: ________ AM ☐ PM ☐ End time: ________ AM ☐ PM ☐

Crew[3] (first initial, last name): ______________________________

Inch group	Species	Species	Species	Species	Species	Species	Species	Species
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								
25								

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[1]In one year of the 3-year shocking cycle collect length-frequency data on all large-bodied non-game fishes in the first half of the station. For small-bodied non-game fishes, count all fish. In the other two years, sampling of non-game fishes is not required.
[2]Scale sample target species only. Sample 10 fish per inch group for fish > 4 inches. For fish < 4 inches measure 10 fish per inch group to a tenth of an inch and enter into Fish Collection System as age-0.
[3]Note additional comments as necessary on back of data sheet.

FISH COLLECTION: FIXED SITE RECAPTURE RUN (reduced to fit on this page).

DNR

Stream Status and Trends Program
Fish collection

Fixed site
Recapture run
Revised 3/22/04

Water body: ______________________ Date: ______________ Page ________ of ________

Station: ____

Target species[1]: ______________ Start time: __________ AM ☐ PM ☐ End time: __________ AM ☐ PM ☐

Crew[2] (first initial, last name): ____

Inch group	Species		Species		Species		Species	
	Unmarked	Marked	Unmarked	Marked	Unmarked	Marked	Unmarked	Marked
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								
25								

[1]Note occurrences of new species on the recapture run, but do not include them with quantitative data from the first pass.
[2]Note any additional comments as necessary on back of data sheet.

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FISH COLLECTION: RANDOM SITE ONE-PASS RUN (reduced to fit on this page).

DNR

Stream Status and Trends Program
Fish collection

Random site
One-pass run
Revised 3/22/04

Water body: ______________________ Date: ______________ Page ________ of ________

Station: ____

Crew[1] (first initial, last name): ______________________________

VSEC I.D. ____________ Start time: ____________ AM ☐ PM ☐ End time: ____________ AM ☐ PM ☐

Inch Group[2]	Species	Species	Species	Species	Species	Species
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
26						
27						
28						
29						
30						

Subsamples (small, non-game species only)	Species										
A. Weight of 30 fish:											
B. Total wt. of all fish:											
Total number of fish: (30 / **A**) X **B**											

[1]Note any additional comments as necessary on back of data sheet.
[2]Scale sample 10 fish per inch group for species of interest.

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HERPS OBSERVATION (reduced to fit on this page).

DNR

Stream Status and Trends Program
Herps observation

Revised 3/22/04

Water body: ______________________ Date: ____________ Page ______ of ______

Station: ____

Crew[1] (first initial, last name): ______________________________

Species	Number	Size[2]	**Species**	Number	Size[2]
Turtles:			Eastern Gray Tree Frog		
Snapping			Northern Spring Peeper		
Softshell			Western Chorus Frog		
Spotted*			Bullfrog		
Wood***			Green Frog		
Eastern Box***			Pickerel Frog		
Blandings***			Northern Leopard Frog		
Map			Mink Frog		
Painted			Wood Frog		
Red-eared Slider			Copes Gray Tree Frog		
Musk			Boreal Chorus Frog***		
Lizards:			**Snakes:**		
5-lined Skink			Kirtlands**		
6-lined Race Runner***			Copperbelly Water**		
Salamanders:			Northern Water		
Eastern Tiger			Queen		
Spotted			Brown		
Blue Spotted			Northern Red-bellied		
Marbled*			Eastern Garter		
Small-mouthed**			Butler's Garter		
Four-toed			Northern Ribbon		
Mudpuppy			Northern Ringneck		
Central Newt			Eastern Hognose		
Red-spotted Newt			Blue Racer		
Red-backed			Black Rat***		
Western Lesser Siren			Eastern Fox*		
Frogs and Toads:			Eastern Milk		
Eastern American Toad			Smooth Green		
Fowler's Toad			Eastern Massasauga***		
Blanchard's Cricket Frog***			Western Fox		

[1]Note any additional comments as necessary on back of sheet.
[2]Turtles: measure straight-line length of shell (end-to-end without measuring curve). All other herps: measure total length. Enter data under "Actual" column in the "Herps Observation" section of the Fish Collection System.

***Threatened** ****Endangered** *****Special concern**

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NOTES AND EQUIPMENT, page 2 (reduced to fit on this page).

DNR

Stream Status and Trends Program

Notes and equipment list

Revised 3/22/04

Try to collect habitat data as close to the time of fish survey as possible.

Water body: ______________________________

Station: ______________________________

Date: ________________

Equipment needed for measuring habitat:

	Check:
(1) GPS unit (set to record data in decimal degrees)	☐
(2) 100' or 250' tapes, rerod and clamps (to hold tape taut across transect)	☐
(1) Clipboard, data sheets, pencils	☐
(1) Current meter (set to average over 10 seconds)	☐
(1) Graduated stick for measuring stream depth	☐
(2) LWD sticks (6' long w/marks at 6", 12", 18", and 24")	☐
(1) Station marking supplies (paint, flagging, stakes, hammer)	☐
Raingear	☐
Waders	☐

Spacing of transects and sample points:

Size category	Electrofishing station length (ft)	Transect spacing (ft)	Space between sampling points on transect (ft)
Random sites			
Small (<15' wide)	500	40	1/5, 2/5, 3/5, 4/5 across transect and at the thalweg
Small (>15' wide)	800	60	1/5, 2/5, 3/5, 4/5 across transect and at the thalweg
Medium	1200	90	1/5, 2/5, 3/5, 4/5 across transect and at the thalweg
Large	1500	110	1/5, 2/5, 3/5, 4/5 across transect and at the thalweg
Very large	1 mile	400	1/5, 2/5, 3/5, 4/5 across transect and at the thalweg
Fixed sites			
Small	1000' or length of historic station	75	2
Medium	1000' or length of historic station	75	3

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Miscellaneous definitions:

Riffles: Have shallower than average maximum depths and obvious surface turbulence. Water velocity is faster than average.

Runs: Have average maximum depths and little or no surface turbulence. Water velocities may be fast or slow, but water surface is generally smooth.

Pools: Have deeper than average maximum depths, with no obvious surface turbulence or broken water. Water velocities are always slow.

Thalweg: The deepest part of the channel (usually carries the bulk of the river's current).

Artificial log jam: Same definition as log jam, except structure was built by humans.

Brush deposits: Piles of brush in streams, such as beaver lodges of food caches.

Individual log: Individual logs placed in channel as cover.

Log jam: 3 or more large diameter (>6") intermingled logs in water at least 6" deep.

Lunker structure: Overhanging structure built into stream bank.

Raft: Sunken rafts that look like something built by Tom Sawyer.

Riprap: Rocks placed along the stream edge to stabilize a bank and deflect the current.

Wing deflector: Lineal walls placed in the channel to deflect the current.

RIPARIAN AND BANK CONDITION DATA SHEET (reduced to fit on this page).

DNR

Stream Status and Trends Program
Riparian and bank condition data sheet

Revised 3/22/04

Water body: ______________________________

Station: ______________________________

Date: ______________

Crew: ______________________________

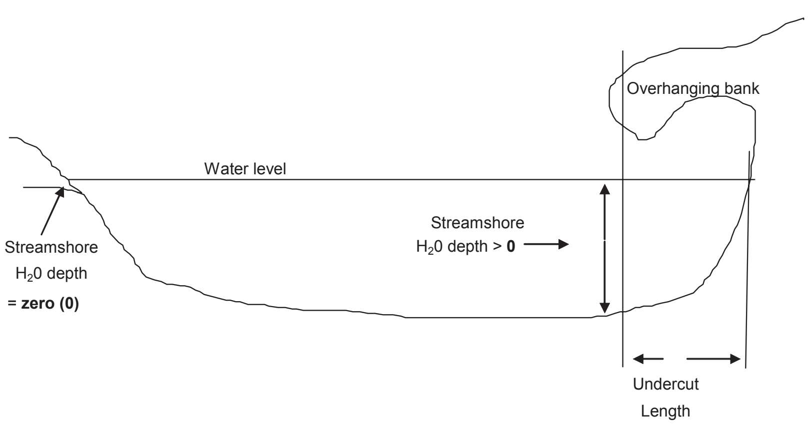
Riparian zone measurements:
Record dominant vegetation (>50%) within 30' from waters edge and 30' upstream and 30' downstream from transect. Don't count islands. Complete riparian measurements as if stream is at bankfull stage. Note presence of exposed substrate when water level is low.

Riparian vegetation classes:
YD – Yard/lawn
AP - Agriculture, pasture
AR – Agriculture, row crops
GF – Grassland, forb
TA – Tag alder types
SC – Small coniferous trees (up to 6" dbh)
LC – Large coniferous trees (>6" dbh)
SD – Small deciduous trees (up to 6" dbh)
LD – Large deciduous trees (>6" dbh)

Streambank vegetative stability:
Assuming the channel was full of water, look at where the river would touch the streambank.

Stability classes:
1 – **Good <25%** of streambank is bare soil
2 – **Fair 25-50%** of streambank is bare soil
3 – **Poor 50-75%** of streambank is bare soil
4 – **Very poor >75%** of streambank is bare soil

	Left bank (facing upstream)					**Right bank** (facing upstream)				
Transect number	Riparian class	Bank stability	Undercut length (x.x ft)	Streamshore H_20 depth (x.x ft)	Comments	Riparian class	Bank stability	Undercut length (x.x ft)	Streamshore H_20 depth (x.x ft)	Comments
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										



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RANDOM SITE TRANSECT HABITAT DATA SHEET (reduced to fit on this page).

DNR

Stream Status and Trends Program
Random site transect habitat data sheet

Page 1
Revised 3/22/04

Water body: ______________________________

Station: ______________________________

Date: ______________ VSEC I.D. ______________

Crew: ______________________________

Comments: ______________________________

GPS coordinates of electrofishing station

Record in decimal degrees to 5 places past decimal.

	Latitude	Longitude
Upstream end:		
Downstream end:		

Transects are numbered from downstream to upstream (i.e. transect 1 is furthest downstream).
Don't forget *to characterize bank and riparian condition on both banks of each transect!*
Note on islands: *Put a "Y" under "Island" when transect crosses an island. Include island when calculating total channel width, but not wetted width. On transects, take data along the whole transect and record island as a substrate type when island occurs.*
Distance from left bank is facing upstream, and depths are measured to a tenth of a foot.
Record dominant substrate, % wood, and % rooted plants in a 1' diameter circle at sample point.
Substrates – C – clay, **D** – detritus/silt, **S** – sand, **G** – gravel (<2.5"), **SC** – small cobble (2.5-5"), **LC** – large cobble (5-10"), **B** – boulder (>10"), **W** – wood, **BE** – bedrock, **ISL** – island
Wood = brush that is dense enough to provide fish cover (root wads, woody debris, etc.).
Embeddedness classes for gravel – **0** = <50% (<50% of vertical profile of gravel buried in fines), **1** = >50%, **9** = unmeasurable or N/A.
Leave no blanks! *If a value equals zero then enter "0".*

	Width for braided channels (record to nearest ft)					Channel width (ft)		Predominant habitat type (check one)	Island? ("Y" if yes)
Transect #	Channel	Island	Channel	Island	Channel	Wetted	Total		
1								Pool ☐ Riffle ☐ Run ☐	
2								Pool ☐ Riffle ☐ Run ☐	
3								Pool ☐ Riffle ☐ Run ☐	
4								Pool ☐ Riffle ☐ Run ☐	
5								Pool ☐ Riffle ☐ Run ☐	
6								Pool ☐ Riffle ☐ Run ☐	
7								Pool ☐ Riffle ☐ Run ☐	
8								Pool ☐ Riffle ☐ Run ☐	
9								Pool ☐ Riffle ☐ Run ☐	
10								Pool ☐ Riffle ☐ Run ☐	
11								Pool ☐ Riffle ☐ Run ☐	
12								Pool ☐ Riffle ☐ Run ☐	
13								Pool ☐ Riffle ☐ Run ☐	
14								Pool ☐ Riffle ☐ Run ☐	
15								Pool ☐ Riffle ☐ Run ☐	
16								Pool ☐ Riffle ☐ Run ☐	

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Trans. #	Portion of width from left bank	Depth (ft)	Sub-strate	Embed. class (0, 1, 9)	Wood (%)	Plants (%)
1	0.2					
1	0.4					
1	0.6					
1	0.8					
1	Thalweg					
2	0.2					
2	0.4					
2	0.6					
2	0.8					
2	Thalweg					
3	0.2					
3	0.4					
3	0.6					
3	0.8					
3	Thalweg					

Trans. #	Portion of width from left bank	Depth (ft)	Sub-strate	Embed. class (0, 1, 9)	Wood (%)	Plants (%)
4	0.2					
4	0.4					
4	0.6					
4	0.8					
4	Thalweg					
5	0.2					
5	0.4					
5	0.6					
5	0.8					
5	Thalweg					
6	0.2					
6	0.4					
6	0.6					
6	0.8					
6	Thalweg					

RANDOM SITE TRANSECT HABITAT DATA SHEET, page 2 (reduced to fit on this page).

DNR

Stream Status and Trends Program
Random site transect habitat data sheet

Page 2
Revised 3/22/04

Water body and station: ________________ Date: ________

Trans. #	Portion of width from left bank	Depth (ft)	Sub-strate	Embed. class (0, 1, 9)	Wood (%)	Plants (%)	Trans. #	Portion of width from left bank	Depth (ft)	Sub-strate	Embed. class (0, 1, 9)	Wood (%)	Plants (%)
7	0.2						12	0.2					
7	0.4						12	0.4					
7	0.6						12	0.6					
7	0.8						12	0.8					
7	Thalweg						12	Thalweg					
8	0.2						13	0.2					
8	0.4						13	0.4					
8	0.6						13	0.6					
8	0.8						13	0.8					
8	Thalweg						13	Thalweg					
9	0.2						14	0.2					
9	0.4						14	0.4					
9	0.6						14	0.6					
9	0.8						14	0.8					
9	Thalweg						14	Thalweg					
10	0.2						15	0.2					
10	0.4						15	0.4					
10	0.6						15	0.6					
10	0.8						15	0.8					
10	Thalweg						15	Thalweg					
11	0.2						16	0.2					
11	0.4						16	0.4					
11	0.6						16	0.6					
11	0.8						16	0.8					
11	Thalweg						16	Thalweg					

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Notes or comments:

FIXED SITE TRANSECT HABITAT DATA SHEET (reduced to fit on this page).

DNR

Stream Status and Trends Program

Fixed site transect habitat data sheet

Page 1
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Water body: ______________________

Station: ______________________

Date: ______________________

Crew: ______________________

Comments: ______________________

GPS coordinates of electrofishing station

Record in decimal degrees to 5 places past decimal.

	Latitude	Longitude
Upstream end:		
Downstream end:		

Transects are numbered from downstream to upstream (i.e. transect 1 is furthest downstream).
Don't forget *to characterize bank and riparian condition on both banks of each transect!*
Note on islands: *Put a "Y" under "Island" when transect crosses an island. Include island when calculating total channel width, but not wetted width. On transects, take data along the whole transect and record island as a substrate type when island occurs.*
Distance from left bank is facing upstream, and depths are measured to a tenth of a foot.
Record dominant substrate, % wood, and % rooted plants in a 1 ft. diameter circle at sample point.
Substrates – C – clay, **D** – detritus/silt, **S** – sand, **G** – gravel (<2.5"), **SC** – sm cobble (2.5-5"), **LC** – lg cobble (5-10"), **B** – boulder (>10"), **W** – wood, **BE** – bedrock, **ISL** – island
Wood = brush that is dense enough to provide fish cover (root wads, woody debris, etc.).
Embeddedness classes for gravel – **0** = <50% (<50% of vertical profile of gravel buried in fines), **1** = >50%, **9** = unmeasurable or N/A.
Leave no blanks! *If a value equals zero then enter "0".*

	Width for braided channels (record to nearest ft)					Channel width (ft)		Predominant habitat type (check one)	Island? ("Y" if yes)
Transect #	Channel	Island	Channel	Island	Channel	Wetted	Total		
1								Pool ☐ Riffle ☐ Run ☐	
2								Pool ☐ Riffle ☐ Run ☐	
3								Pool ☐ Riffle ☐ Run ☐	
4								Pool ☐ Riffle ☐ Run ☐	
5								Pool ☐ Riffle ☐ Run ☐	
6								Pool ☐ Riffle ☐ Run ☐	
7								Pool ☐ Riffle ☐ Run ☐	
8								Pool ☐ Riffle ☐ Run ☐	
9								Pool ☐ Riffle ☐ Run ☐	
10								Pool ☐ Riffle ☐ Run ☐	
11								Pool ☐ Riffle ☐ Run ☐	
12								Pool ☐ Riffle ☐ Run ☐	
13								Pool ☐ Riffle ☐ Run ☐	
14								Pool ☐ Riffle ☐ Run ☐	
15								Pool ☐ Riffle ☐ Run ☐	
16								Pool ☐ Riffle ☐ Run ☐	

Trans. #	Distance from left bank	Depth (ft)	Sub-strate	Embed. class (0, 1, 9)	Wood (%)	Plants (%)	Trans. #	Distance from left bank	Depth (ft)	Sub-strate	Embed. class (0, 1, 9)	Wood (%)	Plants (%)

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FIXED SITE TRANSECT HABITAT DATA SHEET, page 2 (reduced to fit on this page).

Stream Status and Trends Program

Fixed site transect habitat data sheet

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Revised 3/22/04

Water body and station: ____ Date: ____________

Trans. #	Distance from left bank	Depth (ft)	Sub-strate	Embed. class (0, 1, 9)	Wood (%)	Plants (%)	Trans. #	Distance from left bank	Depth (ft)	Sub-strate	Embed. class (0, 1, 9)	Wood (%)	Plants (%)

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DISCHARGE DATA SHEET FOR RIVERS GENERALLY <30' WIDE (reduced to fit on this page).

DNR

Stream Status and Trends Program

Discharge data sheet for rivers generally <30' wide

Revised 3/22/04

Water body: ______________________________

Station: ______________________________

Date: ______________

Crew: ______________________________

Description of discharge measurement transect location: ______________________________

GPS coordinates of discharge transect location[1]: Latitude ______________ Longitude ______________

Measure depths and velocities where the channel is straight, canal-like, and has laminar flow (not at bridges).
Distance from left bank is facing upstream, and depths are measured to a tenth of a foot.
Measure velocities at 0.6 times the depth. Example – If depth = 1.0 ft, the measure velocity at 0.6 ft below the water surface.
Set flow meter to average over 10 seconds.

Distance from left bank (ft)	Depth (ft)	Velocity (ft/s)	Distance from left bank (ft)	Depth (ft)	Velocity (ft/s)
0			21		
1			22		
2			23		
3			24		
4			25		
5			26		
6			27		
7			28		
8			29		
9			30		
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					

[1]Record GPS coordinates of discharge transect location in decimal degrees to 5 places past the decimal.

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DISCHARGE DATA SHEET FOR RIVERS GENERALLY 30–60’ WIDE (reduced to fit on this page).

DNR

Stream Status and Trends Program

Discharge data sheet for rivers generally 30-60’ wide

Revised 3/22/04

Water body: ______________________________

Station: ______________________________

Date: ________________

Crew: ______________________________

Description of discharge measurement transect location: ______________________________

GPS coordinates of discharge transect location[1]: Latitude ______________ Longitude ______________

Measure depths and velocities where the channel is straight, canal-like, and has laminar flow (not at bridges).
Distance from left bank is facing upstream, and depths are measured to a tenth of a foot.
Measure velocities at 0.6 times the depth. Example – If depth = 1.0 ft, the measure velocity at 0.6 ft below the water surface.
Set flow meter to average over 10 seconds.

Distance from left bank (ft)	Depth (ft)	Velocity (ft/s)
0		
2		
4		
6		
8		
10		
12		
14		
16		
18		
20		
22		
24		
26		
28		
30		
32		
34		
36		
38		
40		

Distance from left bank (ft)	Depth (ft)	Velocity (ft/s)
42		
44		
46		
48		
50		
52		
54		
56		
58		
60		

[1]Record GPS coordinates of discharge transect location in decimal degrees to 5 places past the decimal.

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DISCHARGE DATA SHEET FOR RIVERS GENERALLY >60' WIDE (reduced to fit on this page).

DNR

Revised 3/22/04

Stream Status and Trends Program

Discharge data sheet for rivers generally >60' wide

Water body: ______________________________

Station: ______________________________

Date: ______________

Crew: ______________________________

Description of discharge measurement transect location: ______________________________

GPS coordinates of discharge transect location[1]: Latitude ______________ Longitude ______________

Measure depths and velocities where the channel is straight, canal-like, and has laminar flow (not at bridges).
Distance from left bank is facing upstream, and depths are measured to a tenth of a foot.
Measure velocities at 0.6 times the depth. Example – If depth = 1.0 ft, the measure velocity at 0.6 ft below the water surface.
Set flow meter to average over 10 seconds.

Distance from left bank (ft)	Depth (ft)	Velocity (ft/s)
0		
3		
6		
9		
12		
15		
18		
21		
24		
27		
30		
33		
36		
39		
42		
45		
48		
51		
54		
57		
60		
63		
66		
69		
72		
75		
78		
81		
84		
87		
90		
93		
96		
99		
102		
105		
108		

Distance from left bank (ft)	Depth (ft)	Velocity (ft/s)
111		
114		
117		
120		
123		
126		
129		
132		
135		
138		
141		
144		
147		
150		
153		
156		
159		
162		
165		
168		
171		
174		
177		
180		
183		
186		
189		
192		
195		
198		
201		
204		
207		
210		
213		
216		
219		

[1]Record GPS coordinates of discharge transect location in decimal degrees to 5 places past the decimal.

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LARGE WOODY DEBRIS COUNT DATA SHEET (reduced to fit on this page).

DNR

Stream Status and Trends Program

Large woody debris count data sheet

Revised 3/22/04

Water body: ____________________

Station: ____________________

Date: ____________________

Crew: ____________________

Large woody debris - *Record individual logs at least 6' long in contact with water at least 6" deep. Measure portion of log in water 6+" deep.*
Note: Lengths of logs that are >12" dbh are measured from the base to the point on the log where diameter becomes <6".

Length classes (# of full 6' stick lengths – one mark per observation)

Dbh class	1	2	3	4	5	6	7	8+
>6"								
>6"								
>6"								
>6"								
>6"								
>12"								
>12"								
>12"								
>12"								
>12"								
>18"								
>18"								
>18"								
>24"								
>24"								

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Natural log jams, beaver dams, and brush deposits – *Record areal dimensions of each jam to the nearest 3'.*
Type codes: **LJN** – natural log jam, **BD** – beaver dam, **BrD** – brush deposit
Log jam definition: 3 or more large diameter (>6") intermingled logs in water at least 6" deep.

Individual log jam dimensions (length x width in ft)

Type	Length (ft)	Width (ft)	Type	Length (ft)	Width (ft)	Type	Length (ft)	Width (ft)

Artificial structures – *Record areal dimensions of each structure (lineal feet for wing deflectors).*
Type codes: **LJ** – log jam, **LS** – lunker structure, **R** – raft, **RR** – riprap, **S** – stump clumps, **W** – wing deflectors, **Log** – individual log
Only record area of structure in water >6" deep.

Type	Length (ft)	Width (ft)	Type	Length (ft)	Width (ft)	Type	Length (ft)	Width (ft)

TEMPERATURE LOGGER DEPLOYMENT (reduced to fit on this page).

DNR

Stream Status and Trends Program
Temperature Logger Deployment

Revised 3/22/04

Water body: ____________ GPS[1]: Lat ____________ Long ____________

County: ____________ T. ______ R. ______ Sec. ______ VSEC I.D. ______

Location description[2] (describe or map below):

Logger model: ____________ Logger number: ____________ Interval: 1 hour

Delayed start: Yes ☐ No ☐ If yes: Start date: ______ Start time: ______ AM ☐ PM ☐

Date deployed: ______ Time deployed: ______ AM ☐ PM ☐ Surface temp. (°F) ______

Date recovered: ______ Time recovered: ______ AM ☐ PM ☐ Surface temp. (°F) ______

Notes, maps, or additional comments:

[1]Record GPS coordinates of logger location in decimal degrees to 5 decimal places
[2]Note location of logger in relation to landmarks for future reference. Be specific.

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Appendix B

Instructions for using the ArcReader project to locate randomly selected river valley segments.

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Instructions for using the ArcReader project to locate randomly selected river valley segments.

1. Install ArcReader 8.3 from http://www.esri.com/software/arcgis/arcreader/download.html. You'll need administrative rights to complete the installation. Alternatively, you can have a microcomputer technician complete the installation for you.

2. Copy the "Random_Segment_Locator" folder from your office cd or the DNR Intranet to your hard drive.

3. Start ArcReader.

4. Open the file "Random Segment Locator.pmf" in the "Random_Segment_Locator" subdirectory on your hard drive.

5. Click on the "MI Streams Dissolved by FMUs" data layer in the left pane to highlight it (do not uncheck the box).

6. Click on the binocular icon or click on "Edit" and then on "Find".

7. From the "Find" screen, select "MI Streams Dissolved by FMUs" from the "In layers" pull-down menu. Under "Search" select "In fields" and "SEGMENT_ID".

8. Enter the valley segment identification number from the random site list on the "Find" line and hit the "Find" button.

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9. In the bottom window of the "Find" screen, click on the line showing the segment that was found. It will also flash and be highlighted on the map.

10. You can zoom in on the segment to see road crossings with the magnifying glass icon with the plus sign in it by drawing a square over the area of interest. Road names will appear if you zoom in far enough.

    Note: Since the intent of the random sampling portion of the Streams Status and Trends Program is to describe all the different river habitats in the state (rather than changes at a site over time), it is recommended that surveys occur at new access sites rather than previously-surveyed sites. If the entire valley segment is not publicly accessible, make a note and notify a SSTP coordinator (Wills or Zorn) so that the valley segment can be removed from the random site list. Do not conduct the survey.

11. You can zoom back to the previous selection by clicking on the icon that looks like a big, dark blue arrow pointing to the left.

12. Repeat steps 7 to 11 until all random segments have been located. If you find, over time, that you are falling behind on the list of random valley segments to be surveyed, don't panic. Simply continue where you left off on the list the previous year. The number of sites scheduled for completion will be adjusted through time as the SSTP progresses and personnel become more familiar with the sampling protocols.