Manual of Fisheries Survey Methods II: with periodic updates

Chapter 2: Modules for Lake and Stream Surveys

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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.

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).

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.

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.

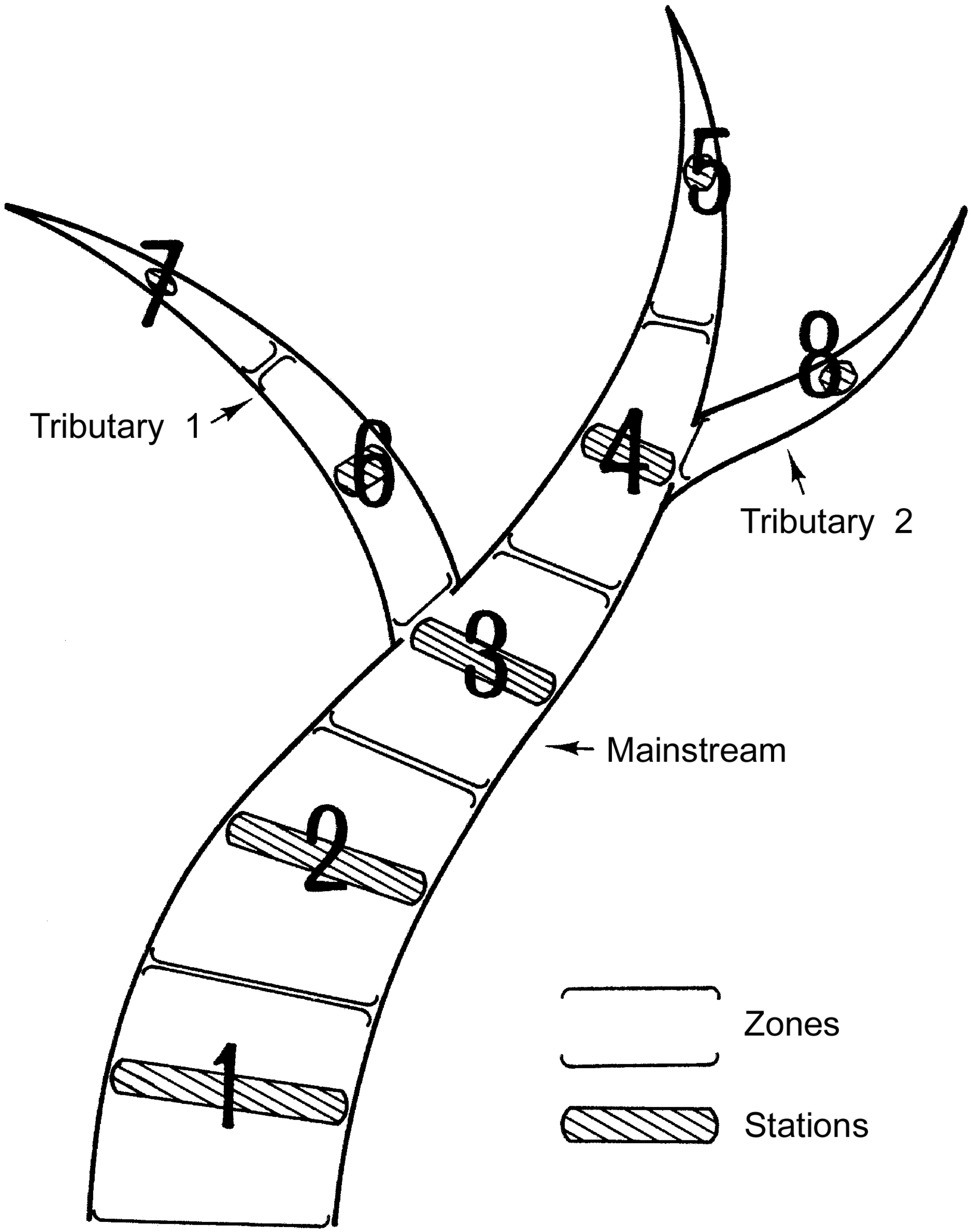
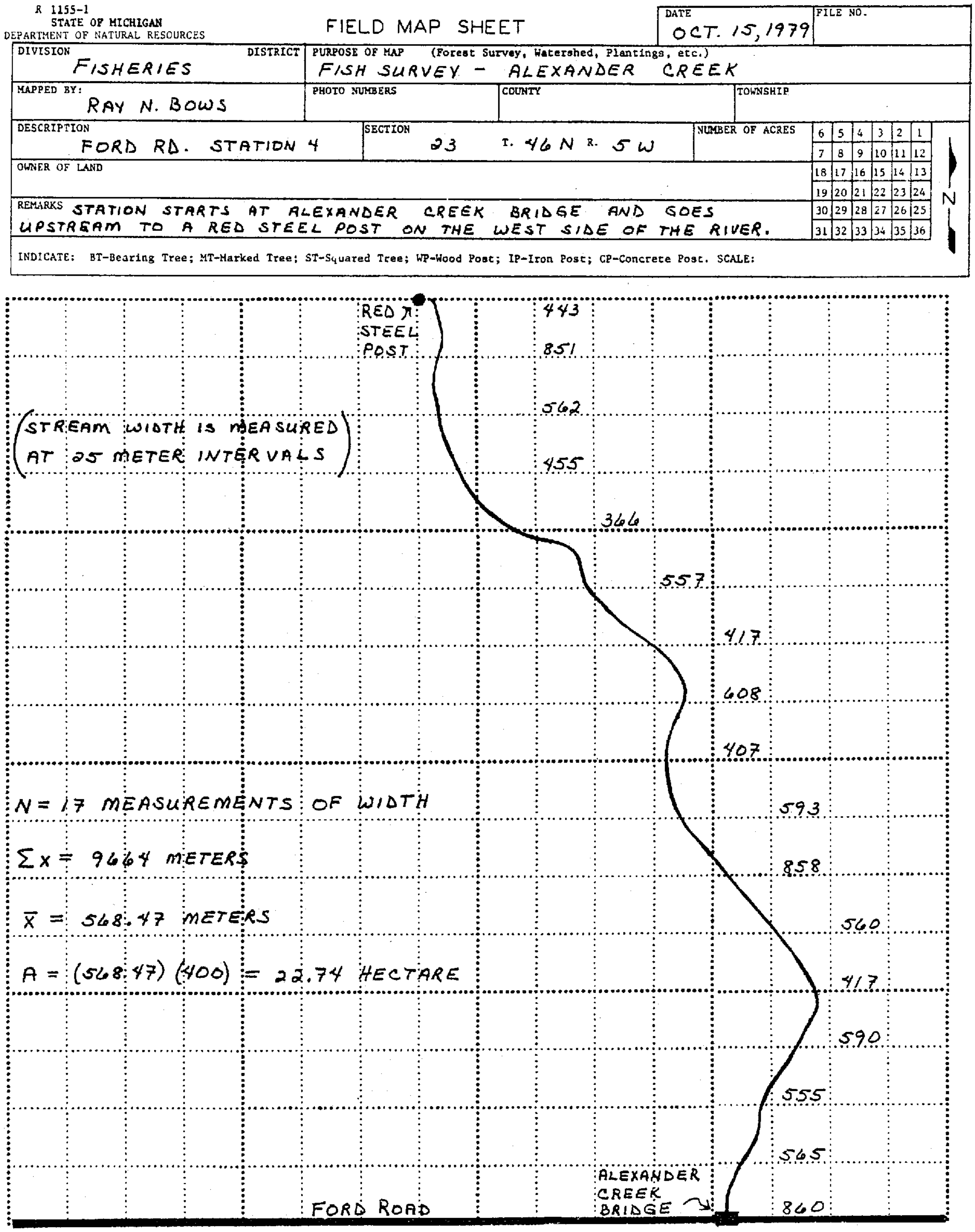


Figure 2.1.–A graphic view of the sampling zones and stations within the stream drainage.



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:

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:

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

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

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

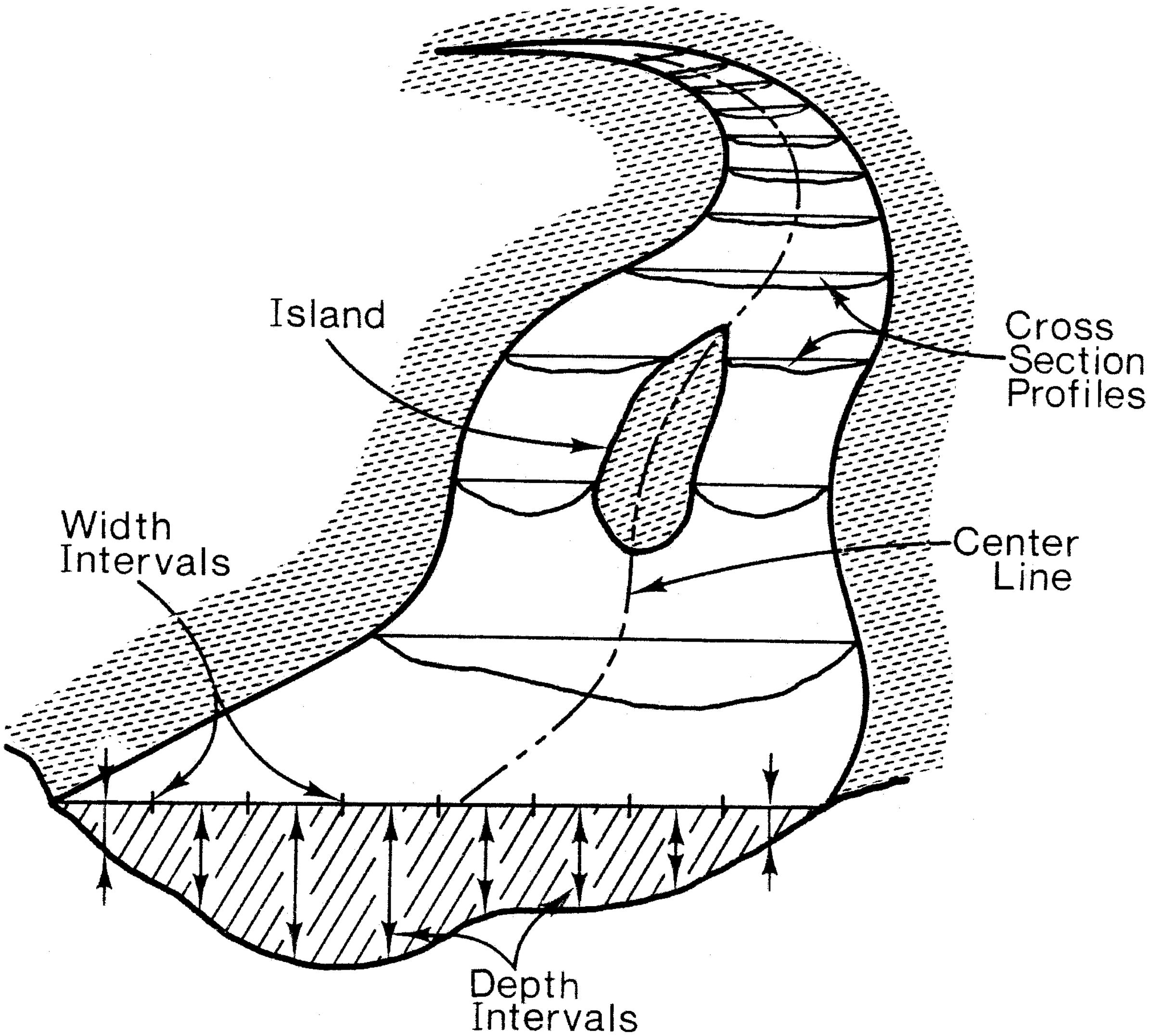


Figure 2.3–A stream sample station showing morphology measurements of length, widths, depths, and cross-section profiles.

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).

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

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.

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 $MnSO_4 \bullet 2\ H_2O$ or 364 g $MnSO_4 \bullet H_2O$ 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.

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

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.

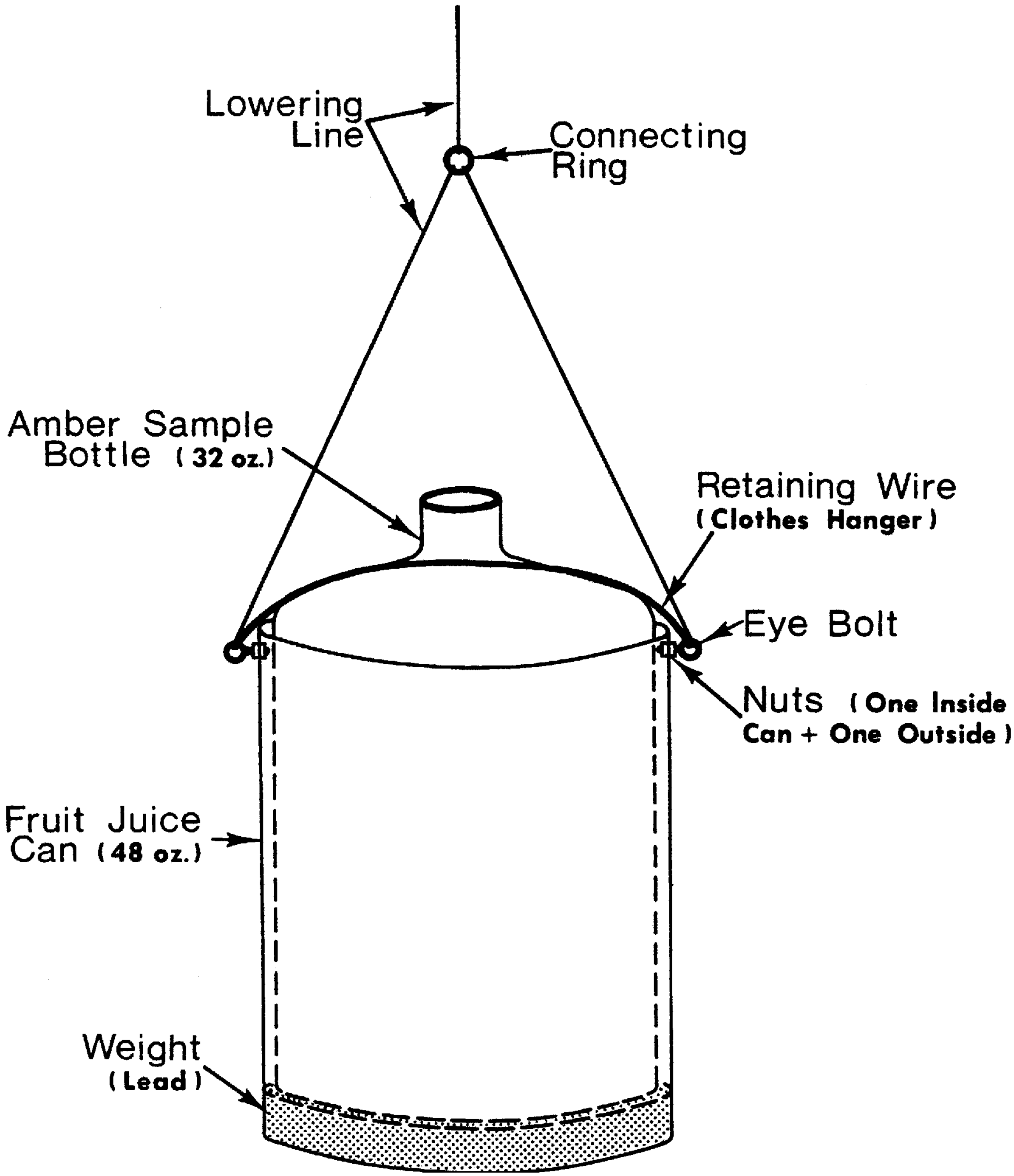


Figure 2.4–Phytoplankton (chlorophyll) sampler construction plans.

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.

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–

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.

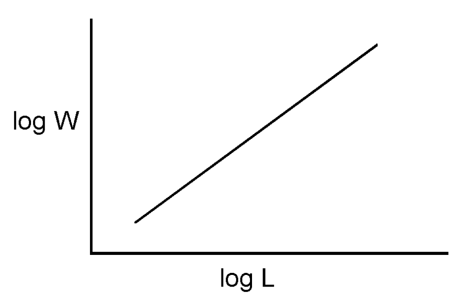
2.4.1.3 Age and growth (form R-8070; electronic version in Fish Collection System)–

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.

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	No.	Recapture run		Estimates			Estimates by age group				
group	marked	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.

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.

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.

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			

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
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								

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
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**		

Table 2.2–Continued.

Species, Size	Season and approximate temperature (F) 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.

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).

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.

***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).

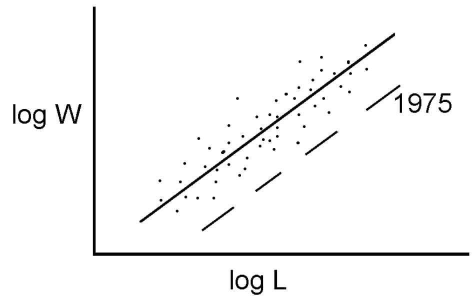
Methods for sampling and indexing the recruitment of walleye and muskie in lakes have been developed by Wisconsin biologists and verified by managers in Michigan (see Chapter 23). Basically, the methods involve electrofishing the edges of lakes during fall or spring, when young are inshore.

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^{o}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.

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

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).

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.

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.

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														

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									
		卌		卌									
		卌		|||									
		卌											
		卌											
		卌											
		卌											
		卌											
		卌											
		卌											
		卌											
		|||											

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		|||								
	||		||										

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	
<u>Mark-Recapture Population Estimates</u>.															
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	
<u>Age Composition of Scale Samples by Percents and Numbers of Fish ( ).</u>															
Age: 0		100 (28)	100 (28)	41.7 (10)											
I				58.3 (14)	100 (30)	100 (30)	36.4 (8)	7.7 (2)							
II							63.6 (14)	92.3 (24)	92.9 (26)	75.0 (18)	75.0 (16)	50.0 (4)	50.0 (2)		
III									7.1 (2)	25.0 (6)	25.0 (2)	50.0 (4)	50.0 (2)		
IV														100 (1)	
<u>Population Estimates per Hectare by Age Group and Inch Group = Pop/ha x %.</u>															
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

<u>Weighted Average Length of Age Group = Median Length x Age Est.</u>

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).

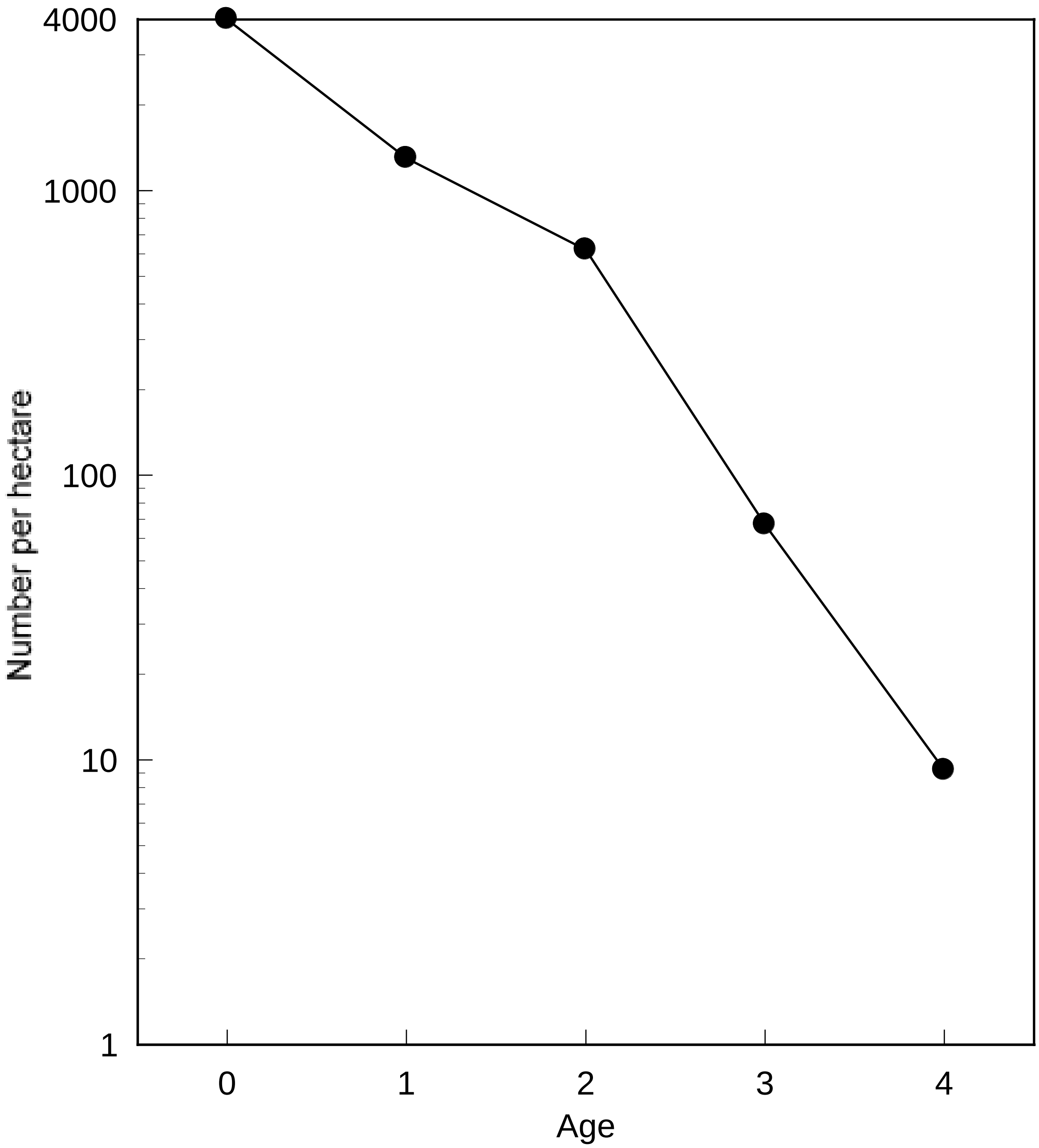


Figure 2.5.–Example of a survivorship curve for brook trout from a stream population estimate.

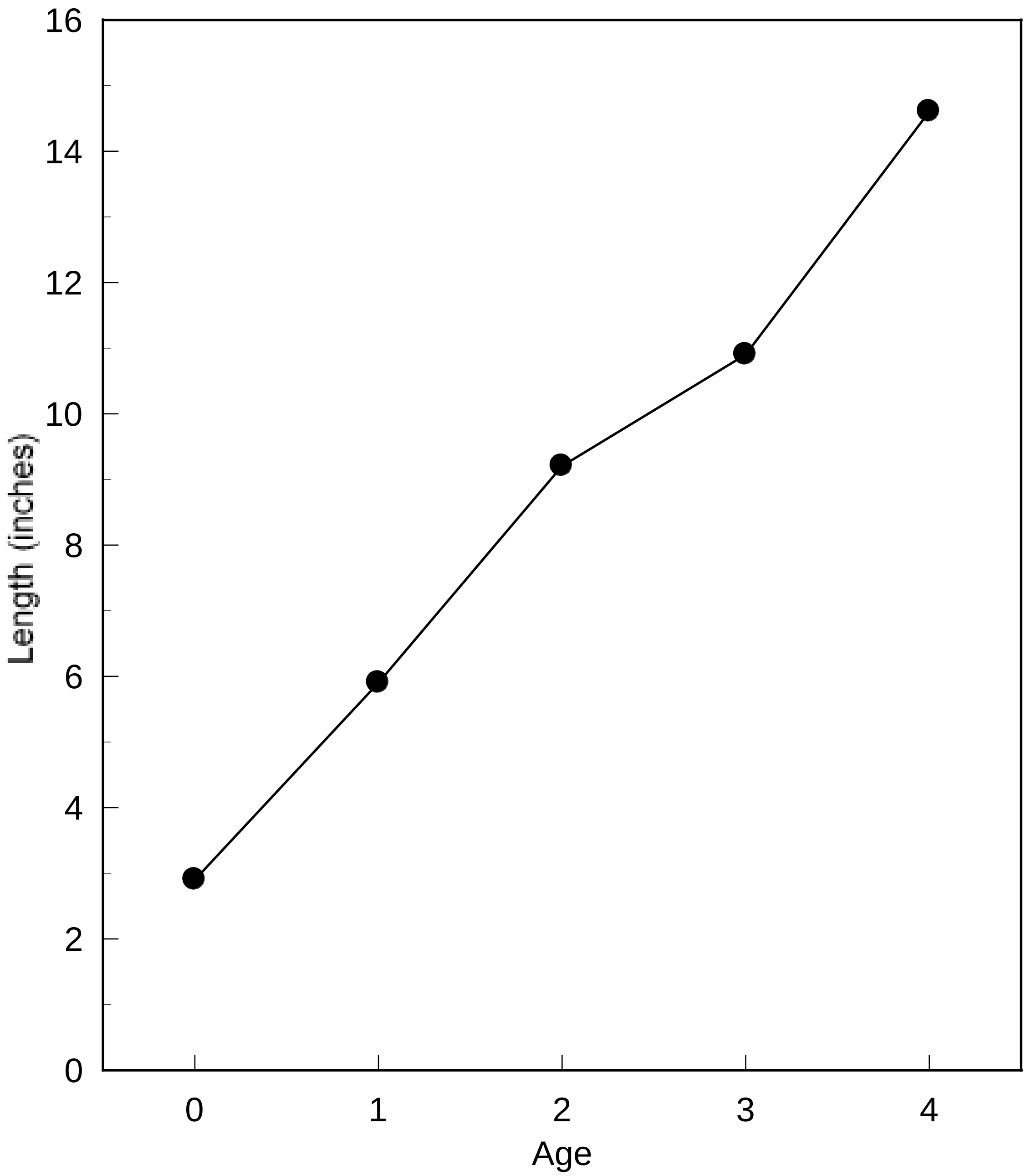


Figure 2.6.–Example of a growth curve for brook trout from a stream population estimate.

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).

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

Baker, E. A. and T. G. Coon. 1995. Development and evaluation of alternative habitat suitability criteria for brook trout *Salvelinus fontinalis*. Michigan Department of Natural Resources, Fisheries Research Report 2017, Ann Arbor.

Hay-Chmielewski, E. M., P. W. Seelbach, G. E. Whelan, and D. B. Jester, Jr. 1995. Huron River assessment. Michigan Department of Natural Resources, Fisheries Division Special Report 16, Ann Arbor.

Lagler, K. F. 1952. Freshwater fishery biology. W. C. Brown Company, Dubuque, Iowa.

Lyons, J. 1992. The length of stream to sample with a towed electrofishing unit when fish species richness is estimated. North American Journal of Fisheries Management 12: 198-203

Murphy, B. R., D. W. Willis, and T. A. Springer. 1991. The relative weight index in fisheries management: status and needs. Fisheries 16: 30-38

Ricker, W. E. (ed.). 1968. Methods for assessment of fish production in fresh waters. IBP Handbook No. 3, Blackwell Scientific Publishers, Oxford and Edinburgh.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Department of the Environment, Fisheries and Marine Service Bulletin 191, Ottawa, Canada.

Seelbach, P. W., M. J. Wiley, J. C. Kotanchik, and M. E. Baker. 1997. A landscape-based ecological classification system for river valley segments in lower Michigan (MI-VSEC Version 1.0). Michigan Department of Natural Resources, Fisheries Research Report 2036, Ann Arbor.

Schneider, J.C. In press. Evaluation of the effects of the herbicide Sonar on sport fish populations in Michigan lakes. Michigan Department of Natural Resources, Fisheries Technical Report, Ann Arbor.

Theiling, C H. 1990. The relationships between several limnological factors and bluegill growth in Michigan lakes Michigan Department of Natural Resources, Fisheries Research Report 1970, Ann Arbor.

Zorn, T. G. 1994. The effect of streamflow on the short-term carrying capacity of a stream for juvenile smallmouth bass: A test of the Instream Flow Incremental Methodology. Michigan Department of Natural Resources, Fisheries Research Report 1994, Ann Arbor.

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