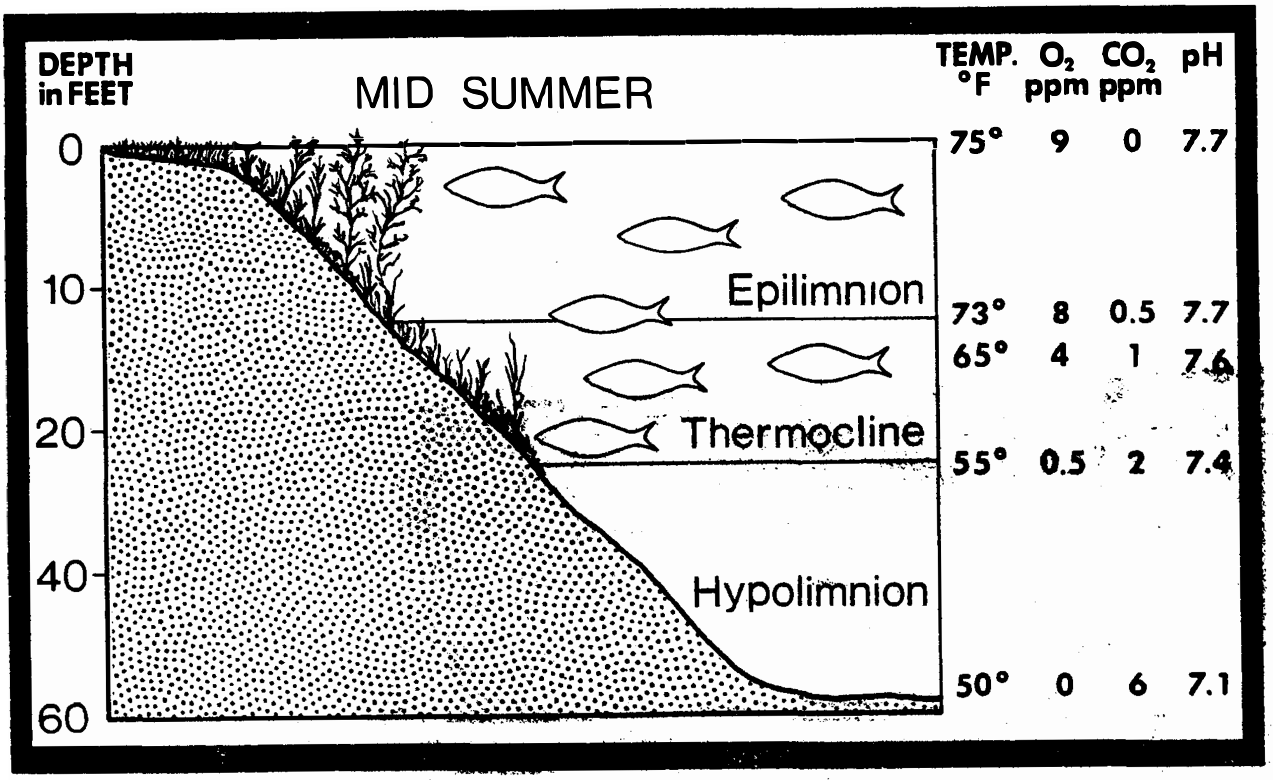
# *manual of....* FISHERIES SURVEY METHODS




**Michigan Department of Natural Resources Fisheries Division**

Fisheries Management Report No. 9 January 1981

# MANUAL OF FISHERIES SURVEY METHODS

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1. Introduction

# I. INTRODUCTION

## A. Perspective

Surveys are important. They (1) document the characteristics of the state's aquatic resources; (2) provide the factual basis for fisheries planning and management; and (3) supply data for other aquatic scientists and managers.

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

## B. Survey planning

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

## C. Objectives and description of survey modules

The objective of lake and stream studies is to develop a description of a body of water, its watershed, and the inhabiting biota which will be useful for fisheries management. This description will be developed by the summation of data from several survey modules. The objective of the individual modules is the description of one facet of either the water body, the watershed, or the biota. Descriptive techniques will obviously vary between lotic and lentic environments, and with size of the water mass. The biota will be characterized as either fish or supporting organisms, with considerably more effort devoted to delineation of the fish population.

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

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

1. Drainage and basin description

The objective of this study module is to develop a description of the complete watershed of the subject lake or stream. The description should include the immediate drainage area and the lake or stream basin. Observations in the drainage should delineate characteristics which potentially may affect the subject body of water.

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

Stream descriptions will include observations of bottom types, stream profiles, volumes of flow, depths and critical areas subject to abuse and damage.

2. Limnology

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

3. Plants and invertebrates

The objective of this study module is to describe the biota, other than fish, insofar as they serve as indicators of productivity. The organisms of interest include phytoplankton, macrophytes, zooplankton, and benthos. Seldom do we have the luxury of sufficient time to enumerate abundance of individual species or even to make reliable estimates of community biomass. However, qualitative estimates of abundance often serve as indicators of productivity. Since phytoplankton is usually the most significant constituent of the primary producers, a measure of chlorophyll serves as the most practical measure of primary production. Estimates of both density and range of macrophytes are important not only as indicators of productivity, but also because of their role in fish shelter, spawning substrates, shoreline erosion protection, nutrient absorption, and indicators of general lake quality.

Analyses of zooplankton and benthos are highly desirable whenever they are sampled with a specific goal in mind, such as trout lakes (see VI-A13).

4. Fish surveys

Fish populations are usually studied for one of two reasons: (a) to describe as completely as possible an unstudied population, or (b) to evaluate apparent problems or past management programs.

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

A basic description of the fish community will include (but not be limited to) species present, relative abundance, size frequencies, and if needed, growth rates.

More detailed analyses of fish populations should contain a measure of rates of recruitment, growth, production, and mortality. Additional data might include standing crop population measurements or observations on endangered and threatened species (VI-A11).

5. Fishery assessment

Local reports of fishing quality are worth recording if they are screened rather carefully. These might include reported catch or complaints in addition to estimates of fishing pressure, harvest, value of the fishery, or evaluation of management techniques. An accurate analysis of a fishery, however, requires a well planned and managed creel census. Methods of creel census can be found in VI-A9 and assistance is available at the Institute for Fisheries Research.

D. Forms and information systems

Many of the survey forms have been revised or replaced, and additional changes may yet occur. The main objectives were to require greater precision (e.g., more size intervals in the length-frequency records), simplify the recording of field data and its transfer to final forms, provide reminders and space for the taking of field notes, encourage and aid the analysis of survey results, and get the data into formats adaptable to computerization in the future. Paper files for summary-type forms will continue to be maintained at four locations (Lansing, region, district, Institute for Fisheries Research) even after computerization is completed. Certain types of computations--length-weight regressions, mark-and-recapture estimates, back-calculated growth--can now be submitted on designated forms for machine processing.

All forms are described in Section IV.

# II. SURVEY MODULES

## A. Drainage and basin descriptions

### 1. Lakes

The LAKE PHYSICAL DESCRIPTION form is to be used to record observations of the watershed and the lake basin. Comments on the drainage 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 Natural Resources enforcement personnel.

Several lake basin measurements (area, depth) can be taken from topographic maps, while others (flushing rate) must be calculated in the office and may not be determined until needed. Heating degree days is required mostly for research purposes, and will be recorded by research personnel from the literature cited. All other information requested on the LAKE PHYSICAL DESCRIPTION form should be completed.

Photographs of potential problem areas are valuable historical evidence, and can be filed with the report.

### 2. Streams

The STREAM SURVEY SUMMARY form will be used to record characteristics of streams and their watersheds. Even though the form is designed to describe a 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, outflows from ponds dredged adjacent to streams, (3) barriers such as dams, culverts, waterfalls, etc.; and (4) pollution which might involve chemical toxicants in the stream and/or aquifer, commercial fertilizers, sewer effluents (and seepage), sedimentation, temperature degradation, etc.

The quality of streams as 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 in order to constitute good fish habitat.

Pools should be judged by their size, type and frequency. The following classification is from Lagler's (1952) "Freshwater Fishery Biology" (W. C. Brown Co., Dubuque):

Size

1. Large: Pools having an average width greater than the average width of the stream.
2. Average: Pools having a width equal to the average width of the stream.
3. Small: Pools narrower than the average stream width.

Type

1. Deep: Pools exceeding 2 feet deep; exposed pools with luxuriant aquatic plants harboring a rich fauna; or deep pools with abundant cover of logs, roots, boulders or overhanging bank, much drift or detritus, and shaded by bank vegetation.
2. Moderate: Pools intermediate in depth, shelter and plant abundance.
3. Shallow: Shallow exposed pools without cover and without plants; scouring basins.

Frequency

1. Many: More or less continuous pools; ratio of pools to riffles about 75% to 25%.
2. Frequent: Rather close succession of pools and riffles in approximately a 50% to 50% ratio.

3. <u>Infrequent</u>: Long stretches of shallow riffles between pools; pools making up less than 25% of the entire stream area.

All streams have been classified by the Michigan Stream Classification System (VI-A15), and the classification should be listed on the STREAM SURVEY SUMMARY form. Streams are classified by the following system:

<u>Top Quality Trout Mainstream.</u>--Contain good self-sustaining trout or salmon populations and are readily fishable, typically over 15 feet wide.

<u>Top Quality Trout Feeder Stream.</u>--Contain good self-sustaining trout or salmon populations, but difficult to fish due to small size, typically less than 15 feet wide.

<u>Second Quality Trout Mainstream.</u>--Contain significant trout or salmon populations, but these populations are appreciably limited by such factors as inadequate natural reproduction, competition, siltation, or pollution. Readily fishable, typically over 15 feet wide.

<u>Second Quality Trout Feeder Stream.</u>--Contain significant trout or salmon populations, but these populations are appreciably limited by such factors as inadequate natural reproduction, competition, siltation, or pollution. Difficult to fish because of small size, typically less than 15 feet wide.

<u>Top Quality Warmwater Mainstream.</u>--Contain good self-sustaining populations of warmwater game fish and are readily fishable, typically over 15 feet wide.

<u>Top Quality Warmwater Feeder Stream.</u>--Contain good self-sustaining populations of warmwater game fish, but are difficult to fish because of small size, typically less than 15 feet wide.

<u>Second Quality Warmwater Mainstream.</u>--Contain significant populations of warmwater fish, but game fish populations are appreciably limited by such factors as pollution, competition, or inadequate natural reproduction. Readily fishable, typically over 15 feet wide.

Second Quality Warmwater Feeder Stream.--Contain significant populations of warmwater fish, but game fish populations are appreciably limited by such factors as pollution, competition, or inadequate natural reproduction. Difficult to fish because of small size, typically less than 15 feet wide.

Streams, or stream sections, which currently receive significant runs of anadromous trout or salmon are also to be designated as trout streams, regardless of whether they are "trout" or "warmwater" according to the above classification.

For a broader overview of the drainage characteristics, a narrative should be written describing the soils, topography, vegetation classification, land use, unique features, and problems. When more detail is desired and, to provide a better conceptual picture of the drainage, a topographic map may be prepared showing its principal features.

Streams are described by establishing habitat inventory sites which may be divided into zones and stations.

a. Zones.--First, partition the stream into segments (zones) about 8 km 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 mainstream to its source. Then number the tributary zones similarly beginning with the lowest tributary in the drainage (Fig. II-1).

b. 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.

c. Length.--A sketch of the sampling station should be made on the Field Map Sheet which is available for field use (Fig. II-2). The sketch should indicate directional orientation and note prominent features of the landscape (roads, bridges, etc.). The length of the station is measured down the center of the stream, and stream width is measured at 25-meter intervals. Determinations of average stream width and station area can

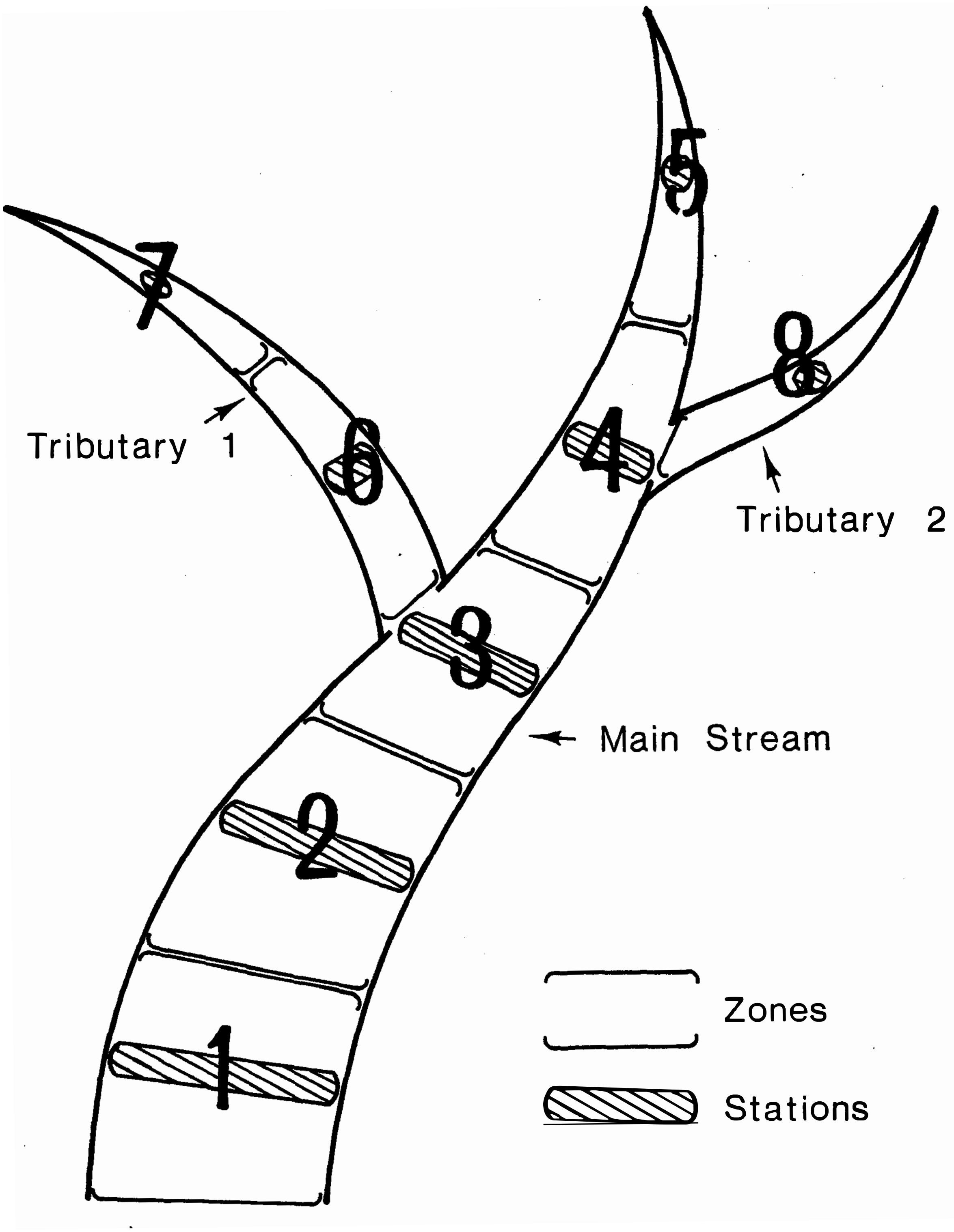



Figure II-1.--A graphic view of the sampling zones and stations within the stream drainage.

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. | | | |

| | | | | | |
|---|---|---|---|---|---|
| 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

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

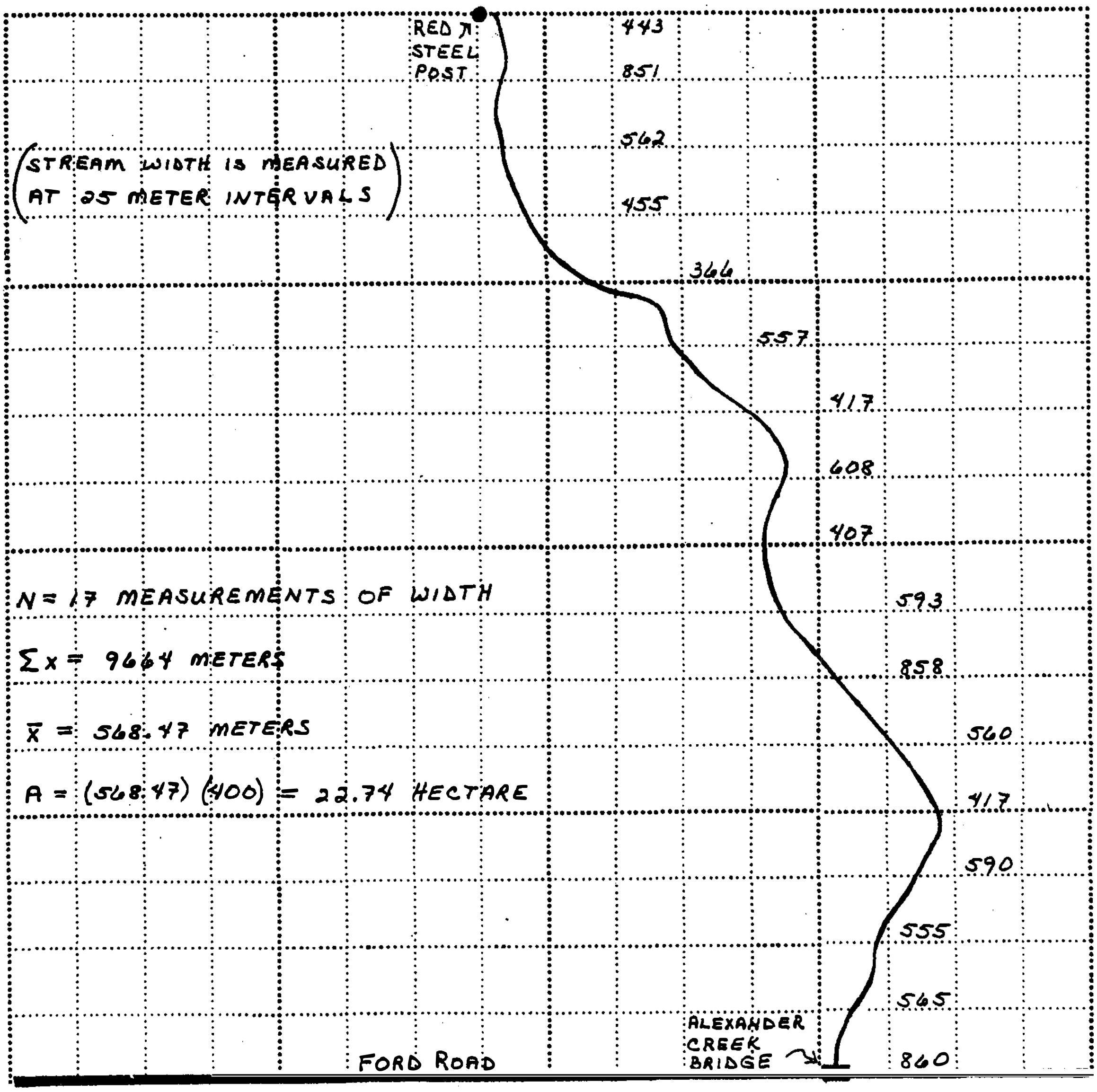



Figure II-2.--Example of use of Field Map Sheet to indicate length, width, area and orientation of stream study station.

be made on the Field Map sheet. The length of the station can vary depending on density of the fish to be censused and your efficiency in capturing them. A 400-meter 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 these streams generally have lower trout densities and lower electrofishing efficiency (due to lower conductivity). As a rule of thumb, for determining the length of a sampling station, electrofish until at least five fish 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. It is best to have the station terminate at a 50-m interval to minimize problems of calculation. Record these length intervals as in Table II-1. Both the 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 the location of markers in field notes.

d. 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 II-1. Area can be calculated by multiplying average width times the station length. When an island occurs in the stream, width measurements should be taken across the stream including the width of the island (Fig. II-3). Then subtract the area of islands to arrive at the water area only. A fairly accurate estimate of most islands in streams can be made with the following formula: island length $\times$ maximum width of island $\times$ 0.6. If the island is not of typical form (teardrop), then an array of width measurements should be taken. Area of the island is then calculated by multiplying the average width times length. Note that in the future we may wish to quantify certain measures of a fish population and express them in terms of the static water volume of a stream, its volume of flow per unit time, or even its total annual flow. These expressions may have a better biological basis for streams than the ones used at present--fish per unit length or fish per unit area.

Table II-1.--Example of field record of measurements of station length, width and water depth.

R1016-1

RIVER: ALEXANDER CREEK    DATE: OCT. 15, 1979

STATION: FORD RD. - STA. H    LOCATION: T. 46N, R. 5W, SEC. 23

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LENGTH (m) | 0 | 25 | 50 | 100 | 125 | 150 | 175 | 200 | 225 | 260 | 275 | 300 | 325 | 350 | 375 | 400 | 425 |
| WIDTH (cm) | 860 | 565 | 555 | 590 | 417 | 560 | 858 | 593 | 407 | 608 | 417 | 557 | 366 | 455 | 562 | 851 | 443 |
| DEPTH (cm)* (at following width intervals) | | | | | | | | | | | | | | | | | |
| 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 | 28 | 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 | 41 | 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 DEPTH: 0.3585 m

AVERAGE WIDTH: 5.68 m    AVERAGE CROSS SECTION AREA: 2.0457 $m^3$

AREA (water plus islands): 2272 $m^2$    VOLUME (static): 818.3 $m^3$

AREA (water only): 2272 $m^2$

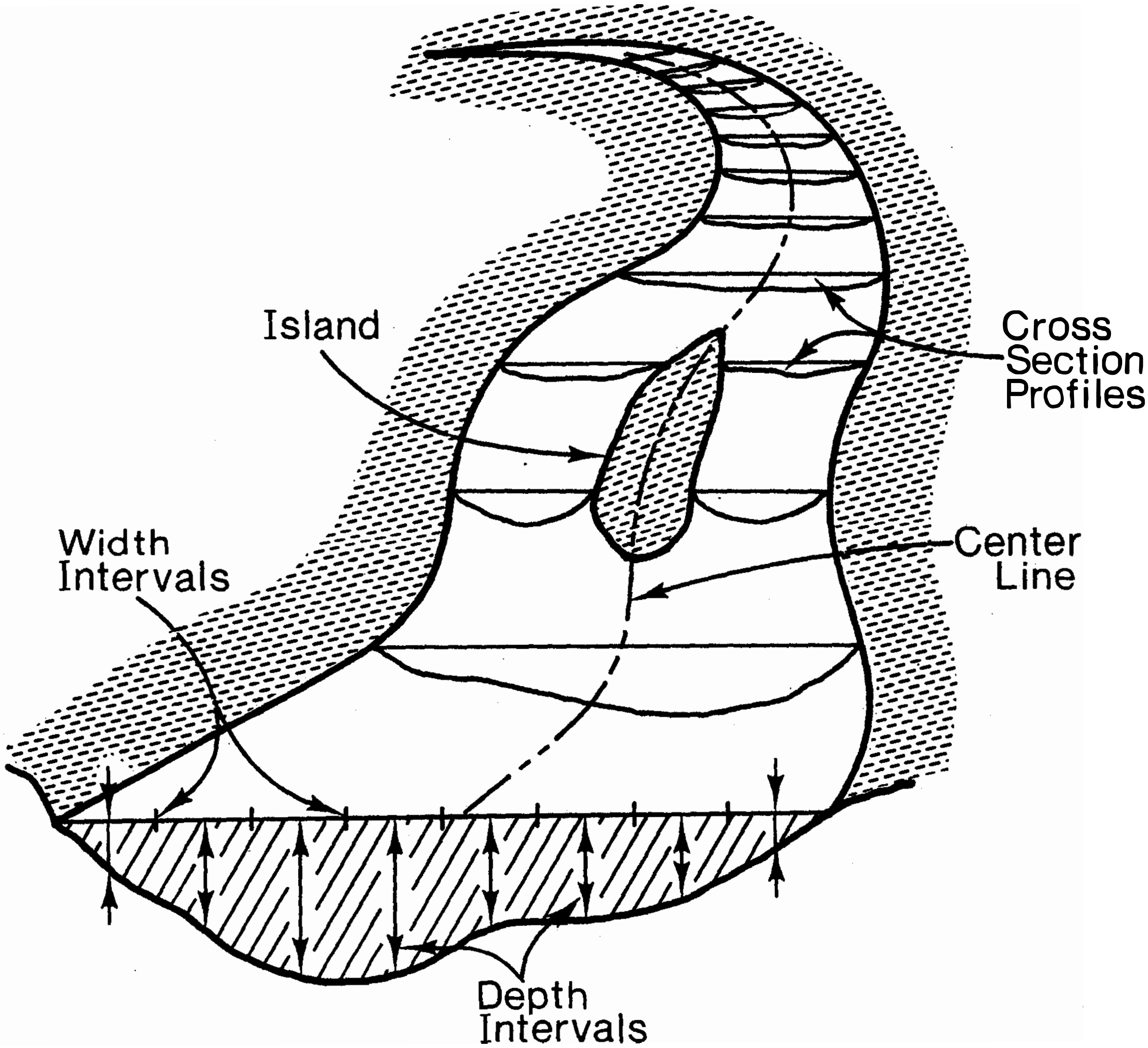



Figure II-3.--A stream sample station showing: morphology measurements of length, widths, depths, and cross-section profiles.

e. Depth.--Measure depth at 0.5-m intervals (0.25 m, 0.75 m, 1.25 m., etc.) along the stream width cross sections. Record depth measurements as on Table II-1. Measure from the water surface to the top of the substrate. Be careful not to disturb the top of soft bottom sediments.

f. 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.

g. 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 the static water volume by multiplying the average depth of the cross sections times the average width times the sample section length. This procedure gives an overestimate of water volume.

h. 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 (VI-14). Note, since the meters available at present are calibrated in English units, discharge will have to be calculated in these units, then transformed to metric units ($m^3$/sec). The best time of the year to measure discharge for our purpose is during October or November because the streams are generally in their most stable flow conditions and near their average seasonal flow. Take measurements 3 or 4 days after the last precipitation.

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

j. Annual stream discharge.--In the future we may want quantitative measurements of populations in terms of numbers, biomass, or production per 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 the 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 c.f.s.) during October or November equals the average discharge during the year and multiply it by 31,557,600 (the number of seconds in a year).

k. 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, the total river flow can be determined.

l. 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 measurements would require the use of surveying instruments (transects or dumpy levels along with measurement of drop below the line of sight).

m. 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 sieving the samples through standard Tyler sieves to determine the size distribution of the particles.

n. Spawning areas.--In the past many surveys have attempted to assess spawning areas for salmonids based upon the percent gravel in the streambed. 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 the salmonid species and their size. A more accurate assessment of spawning habitat can be made by walking or canoeing the stream during the spawning period and noting where redd building activity and spawning actually occurs.

o. 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 readily quantified. Subjective terms such as "good", "moderate", or "poor" are usually adequate for stream inventories.

## B. Limnology

1. Lakes

Routine limnological measurements will be made and recorded on the LIMNOLOGY form.

Two levels of intensity will be employed in limnological lake surveys, depending on the scope of other biological studies being conducted. A first level survey will be associated with routine fish collections or other sampling, short of a complete biological survey. A survey at this level will mostly be restricted to the measurement of parameters that will assist in fish sampling.

a. First level survey.--Measurements to be made in a first level survey include dissolved oxygen and temperature, depth profiles, alkalinity, Secchi disk, observations of water color, and influential weather conditions. Alkalinity measurements might be omitted if reliable data have been collected within the past 5 years indicating that the lake has a total alkalinity in excess of 80 ppm. Soft water lakes should be monitored at every convenient opportunity due to their lack of buffering capacity and consequent susceptibility to degradation by such phenomena as acid precipitation.

Temperature and oxygen depth profiles should be determined prior to fish sampling with any type of nets if the lake is stratified. Knowledge of these factors can prevent much wasted effort from fishing depth strata unsuitable for the target species of fish. A depth sounder should be used while setting nets, and the depth at each end of the net is to be recorded. The temperature range and the dissolved oxygen concentration within the strata fished can then be determined from temperature and oxygen depth profiles.

Complete temperature and oxygen depth profiles are not always necessary when netting during spring and fall circulation periods. However, sufficient temperature measurements must be made to assure that the lake is in a state of complete circulation. If circulation is not complete, anoxia may persist in the bottom strata.

Water transparency and color are valuable observations since they reflect the magnitude of plankton production. The Secchi disk is possibly our best available indicator of the basic productivity of a lake.

b. Second level survey.--A second level limnological study is to accompany a complete survey of a lake. In addition to the first level measurements, a second level study will include on-site observations of abundance of aquatic vegetation and the detection of pollution, or other water quality problems, which may need more study by the Water Quality Division. Water samples will also be collected and sent to the Environmental Services Laboratory for extensive chemical analysis. The results from these analyses will be incorporated in the data storage bank of the Inland Lake Management Unit of the Land Resource Programs Division as part of their intensive lake surveys. These data will be stored in STORET, but will also be available for our files. Sample and field information requirements are contained in VI-16.

The Environmental Services Laboratory will analyze the following parameters for all lake surveys:

| | |
|---|---|
| pH | Total phosphorus |
| Total alkalinity | Soluble ortho-phosphorus |
| Conductivity | Nitrate and Nitrite |
| Chlorides | Ammonia |
| Suspended solids | Organic nitrogen |
| Total solids | |

The following parameters may be measured also the first time a lake is surveyed. These will include:

| | |
|---|---|
| Hardness | Total iron |
| Turbidity | Magnesium |
| Silica | Potassium |
| Calcium | Sodium |
| Sulfate | Total organic carbon |

It is essential that both on-site measurements and collection of water for laboratory analysis take place during the time of maximum summer stratification--mid-July to mid-September. This is the only time that we can determine the maximum extent of oxygen depletion in the hypolimnion, and consequently, the suitability of the lake for cold water fish.

It is essential that a schedule of lakes to be included in the intensive surveys be sent to the Inland Lakes Management Unit during the December prior to the surveys. This enables the laboratory to schedule the analyses required. Laboratory services are allotted in January for the entire year.

2. Streams

a. Temperature.--A common procedure is to record air and water temperature and time of day at each survey outing. This meager information is of little value. Since seasonal and daily fluctuations in temperature are among the most important environmental factors affecting fish, we should make an effort to obtain good temperature data. Maximum-minimum thermometers should be placed at various locations along the stream drainage, including major tributaries. They should be read weekly for one full year, or for at least one summer. One year of data will usually provide a good picture of the temperature regimes within the stream drainage. Salmonids have highest populations in streams with the least amount of variation in seasonal and daily temperatures. Also these are the streams with the lowest average annual water temperature, particularly low average summer water temperatures. Undoubtedly, warmwater fish species also benefit greatly from relatively stable water temperature regimes, but, of course, on the warmwater side of the temperature scale.

b. Water chemistry.--Water analysis for 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 or some abnormal condition is suspected. For example, large daily fluctuations in the D.O. point up pollution problems. Many other chemical determinations, such as hardness, total solids, phosphorus, nitrogen, etc., might be of interest, but are too expensive for general surveys.

3. Limnological methods

a. Temperature.--In lakes, water temperature measurements should be made in °C with an electronic thermometer. A temperature reading should be taken, and recorded, at every meter of depth with the exception of the following conditions:

1. If, within the epilimnion or hypolimnion, there is no change from the reading of the previous depth.
2. 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.

In streams, or at lake surfaces, temperatures can be taken with a pocket thermometer. 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.

b. Dissolved oxygen.--Oxygen determinations must be made at sufficient depth intervals to accurately delineate stratification within the lake. Temperature stratification should be determined prior to conducting oxygen analysis. Samples for oxygen analysis should then be collected at the surface, top, middle, and bottom of the thermocline, 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 describe oxygen depletion. You should look also for an oxygen maximum in the thermocline, since this is an indication of high phytoplankton abundance.

If oxygen samples cannot be titrated on the lake, then additional samples must be taken initially. Samples should then be collected at the surface and bottom of the epilimnion, and every 2 m of depth from the top of the thermocline to the bottom of the lake.

The oxygen content of water can be measured either by an oxygen probe and meter or by 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 standardized in a water sample previously analyzed by a chemical method. Standardization must be repeated daily. 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 used. 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 method. Water is collected from a desired depth with a Kemmerer water sampler, and transferred to a 250-ml BOD 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 not to retain air bubbles when inserting the ground glass stoppers.

1. Fixing: Three reagents are added to the sample with automatic pipets, as follows:
   a. 2 ml manganous sulfate ($MnSO_4$); deliver below the surface of the water so as not to introduce air bubbles.
   b. 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.
   c. Replace stopper and mix thoroughly by inverting bottle repeatedly. Allow precipitate to settle until top half of bottle is clear.
   d. 2 ml concentrated sulfuric acid ($H_2SO_4$); deliver carefully below the surface of the sample. Restopper and shake until precipitate dissolves. If precipitate does not dissolve immediately, allow to stand for several minutes.
2. Titrating: The sample is now ready to titrate with 0.025 N sodium thiosulfate ($Na_2S_2O_3$) 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:
   a. Transfer 200 ml of sample to a 250-ml Erlenmeyer flask.
   b. Titrate with $Na_2S_2O_3$ until pale yellow color.
   c. Add a "pinch" of Thyodene (starch substitute) for pale blue color.
   d. Continue titration until colorless. The number of ml of $Na_2S_2O_3$ 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 $MnSO_4 . 4H_2O$ or 400 g $MnSO_4 . 2H_2O$ or 364 g $MnSO_4 . H_2O$ in distilled water, filter and dilute to 1 liter.

Alkaline-iodide reagent: Dissolve 500 g sodium hydroxide (NaOH) or 700 g potassium hydroxide (KOH), and 135 g sodium iodide (NaI), or 150 g potassium iodide (KI), in distilled water and dilute to 1 liter.

Sulfuric acid: Purchase concentrated solution.

Sodium thiosulfate: Purchase Acculute brand (Anachemia Chemicals Ltd., P.O. Box 87, Champlain, New York 12919) of standard volumetric solution. This comes in a small bottle which is emptied into a 1-liter volumetric flask. The bottle is filled with distilled water and emptied into the flask three times, to assure complete rinsing, and the flask is then filled with distilled water. The liter of solution will be exactly 0.025N, and will not need to be standardized as required in the past. The solution will keep for at least 6 months if refrigerated.

Thyodene: Purchase (Fisher Scientific Co.) and use as supplied.

c. Alkalinity: Samples should be collected from the surface, middle of the thermocline, and within 1 m of the bottom. Phenolphthalein and methyl orange, or total alkalinity, are to be determined by the chemical method, as follows:

1. Water is collected with a Kemmerer sampler, and 100 ml is transferred to an Erlenmeyer flask.

2. Add 4-5 drops of ph-th indicator. If the sample remains clear, record 0.0 ph-th alkalinity. If the sample becomes pink, titrate with 0.02N sulfuric acid until clear. Ten times the number of ml of acid used equals the ph-th alkalinity.
3. To the same sample add 3-5 drops M.O. indicator, and, without refilling buret, continue titration until yellow color changes to salmon pink. Record total alkalinity (M.O. alkalinity) as 10 times the total number of ml $H_2SO_4$ used in both titrations.
4. Reagents: The reagents used in the alkalinity determination are prepared as follows:

   Phenolphthalein (ph-th) indicator: Dissolve 5 g phenolphthalein in 500 ml of isopropyl alcohol and add 500 ml distilled water. If necessary, add 0.02N sodium hydroxide (NaOH) dropwise 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, 0.02N: Purchase Acculute solution and dilute to 1 liter. See instructions for sodium thiosulfate in dissolved oxygen methods.

d. Secchi disk depth.--The transparency of 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 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, 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.

e. 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.

f. Environmental Services Laboratory analysis.--Water samples for laboratory analysis must be received at the lab within 48 hours, and must be kept cold until delivered. From most areas of the state, this can be accomplished by either DNR aircraft or commercial bus. Fisheries Division personnel will pick up samples at the Lansing airport or bus depot if arranged by telephone. The Inland Lake Management Unit will furnish station location sheets and three laboratory analysis sheets. These forms should accompany the samples to the laboratory. Detailed instructions for handling samples and forms are contained in appendix VI-A-16.

Samples for nutrient analysis should be collected at the surface, mid-depth (thermocline area if one exists), and within 1 meter of the bottom. Three 500-ml plastic bottles of water from each depth are required. One bottle from each depth is to be preserved as directed.

g. pH.--Despite the fact that biologists have been recording the pH of water for many years, there still seems to be no satisfactory 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 wil do pH analysis upon request.

## C. Plants and invertebrates

1. Lakes

a. Macrophytes.--Abundance of littoral vegetation is to be recorded on the LIMNOLOGY form. Abundance estimates are to be made for various forms of aquatic plants including submergent, emergent, floating, and *Chara*.

Aquatic plants are good indicators of lake eutrophy. Traditionally biologists have made a single statement evaluation of macrophyte abundance throughout an entire water body. Plant abundance has the potential of giving us more information than we have utilized if we can be more precise in recording our observations. This may prove to be one of our most significant historical observations for evaluating cultural eutrophication.

The recorded observations for each form of vegetation should consist of one or more percentage figures representing the percent of the littoral area where that growth form is common (C), abundant (A), excessive (E), etc. For example, if emergent vegetation is sparse in 60% of the littoral, common in 20% and excessive in 10% the recorded notation should read: Emergent 60 S, 30 C, 10 E. The recorded percentages should always total 100% of the littoral.

b. Chlorophyll.--Chlorophyll analysis is the easiest and most practical method of recording phytoplankton abundance. This is also a useful historical measure of eutrophication.

Chlorophyll analysis will be conducted by the Inland Lake Management Unit. These samples must be scheduled in advance of collection.

Chlorophyll requires special collection and handling techniques. A special composite sampler (Fig. II-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.

c. Fish food.--The sampling of zooplankton and benthos is a time consuming task and is not recommended for routine lake surveys.

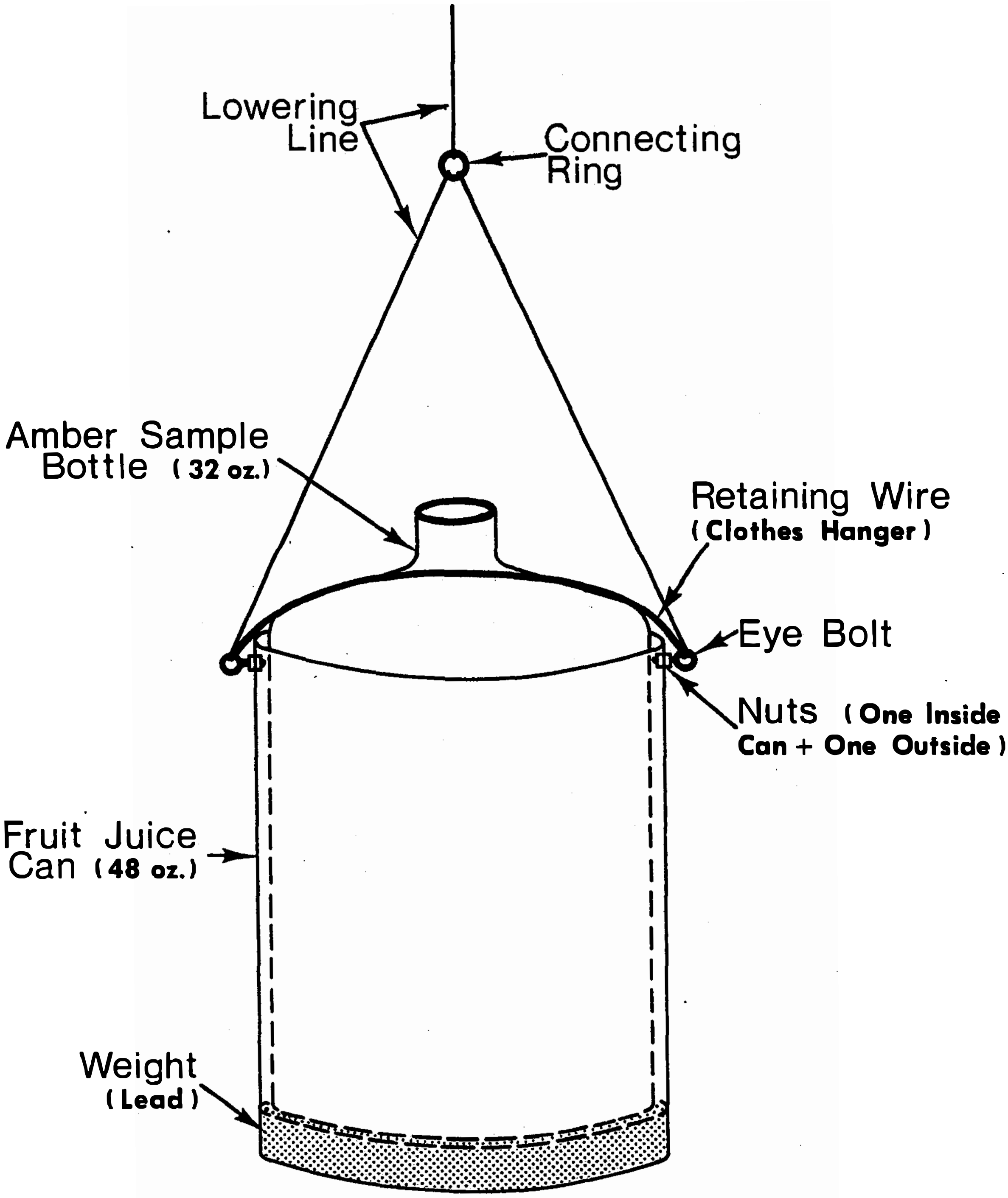



Figure II-4.--Phytoplankton (chlorophyll) sampler construction plans.

However, sampling for large zooplankters, as described in Appendix VI-A13, is recommended for special surveys of lakes in which (1) stocked trout are not providing satisfactory returns and (2) survival of walleye or other young game fish is poor.

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 LAKE SURVEY SUMMARY form or on a NOTES AND REFERENCE form.

2. Streams

a. Vegetation.--To assess the standing crop (or production) of plants growing in streams is extremely difficult. For most surveys, the best we can afford to do is to subjectively estimate the percent of the channel in which vegetation is "abundant", "moderate", or "sparse".

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

b. Fish food.--An estimate of the relative abundance of fish food can be made from two square-foot samples of bottom fauna--one from the middle of the stream and one midway between the center and a stream bank. Take the samples with a 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 abundance of benthos.

Use the mean numbers and volume (or weight) of fauna from the two square-foot samples to classify the stream for food richness as follows:

Exceptional richness: Volume greater than 2 ml, or 2 g, and number of organisms greater than 50.

Average richness: Volume from 1 to 2 ml, or 1 to 2 g, more than 50 organisms.

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

In order to qualify in any richness category both the numerical and weight or volume requirements must be met by the mean square-foot sample.

## D. Fish surveys

### 1. Discussion

Samples of fish may be desired for studies at one, or all, of three levels: (a) community (species diversity and relative abundance of species), (b) population (abundance, distribution, length-frequency, age frequency, growth, etc. of a species population), or (c) individual (specimens). 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 subsampled for length-frequency, age and growth, survival rate, etc.

Usually, our aim in field surveys is to obtain a representative sample of the 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.

The objective(s) of the survey, the target species, and the types of information needed must be defined in advance. Types of surveys include (a) a basic inventory of all species, (b) an inventory of principal (target) species, and (3) a check on a specific problem or management procedure. The purpose of the survey is to be recorded on the completed 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. A SURVEY PLANNING form can be used to plan surveys. The purpose of this form is to assist in review of past surveys, setting an objective for the proposed survey, and communicating this information to others. Dispose of the form after the survey report is completed.

Other forms aid in the recording and analysis of 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 which 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.

a. CATCH SUMMARY, by gear type:

Species
Length
Avg. Wt.

| | No. | Lb. |
|---|---|---|
| Total | | |
| % | | |
| CPE | | |
| % L-A | | |

This table records the species taken, average length and weight, the actual catch by number and weight, the percentage contribution of the species to the sampled portion of the fish community (total % by number and by weight), an index of population abundance (CPE), and the proportion 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 the status of the community and its species populations and are useful for detecting changes through time. At some future date, statewide averages or standards will be available for making comparisons.

b. LENGTH-FREQUENCY and LENGTH-BIOMASS, by gear type:

| | Species | |
|---|---|---|
| Inches | No. | Lb. |
| 1 | | |
| 2 | | |
| 3 | | |
| . | | |
| . | | |
| . | | |

This table, derived from a random sample of the catch, shows the size structure of the 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 type of gear.

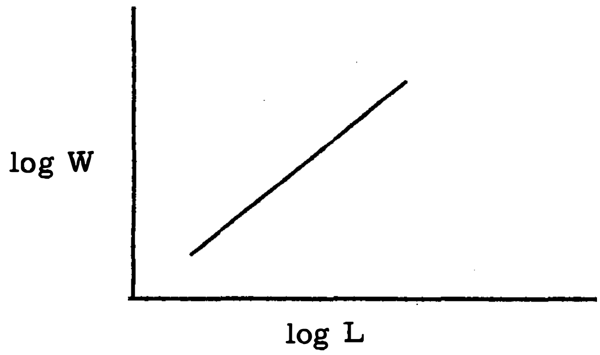
The CATCH SUMMARY, LENGTH-FREQUENCY, and LENGTH-BIOMASS tables are on the FISH COLLECTION form. Some space is provided on this form for analysis and interpretation. Other parameters are recorded and interpreted on the forms that follow.

c. FISH GROWTH, by gear type (form 8070):

| Species | Age group | Number of fish | Length range in inches | Average length in inches | State avg. length | Growth index by age group | Avg. growth index for species |
|---|---|---|---|---|---|---|---|

This table records the statistics of the growth sample and compares the average length of the sample to the state average. In the analysis section of the form it is appropriate to also indicate how the growth indices compare to previous samples. Growth rate is a most useful measure of a population's well being. Slow growth commonly indicates that recruitment is not properly balanced by mortality--within the constraints of the food supply. Conversely, fast growth suggests that recruitment and overall production could be improved.

d. LENGTH-WEIGHT REGRESSION (form ):




This figure, or its equivalent equation:

$$\log W = \log c + n \log L,$$

is a measure of the well being (plumpness) of individuals in the population and is handy for converting length-frequency data to biomass-frequency data. Some state-average data are available now, and additional research is being conducted to develop useful standards.

e. POPULATION ESTIMATES (form ):

Species________Estimated:No./acre____Lb./acre____ % L-A: By No.___ By Lb.____

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

More sophisticated management problems at the population and community levels require absolute, rather than relative, measures of population abundance and size frequency. Mark-and-recapture methods, stratified by size groups to eliminate bias caused by size selectivity of gear, are practical in some situations--especially in wadable streams.

While the population is being estimated, it is usually wise to take a large number of scale samples so that the 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 over fishing or excessive natural mortality.

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 customed tailored to the survey 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 to design efficient sampling plans as the need arises.

a. Planning.--Review I-B and II-E1. The survey objectives, and the types of summaries 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 the location of sampling stations, net sets, transects, and electrofishing areas, and 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 the FISH COLLECTION form or a NOTES AND REFERENCE form.

b. Forms and records.--The quality of our records reflects our degree of professionalism. In the field, use FISH COLLECTION forms to tabulate the catch and the length-frequency data (or plain waterproof data paper) and as a guide for recording the appropriate information about habitat. 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 II-4 and II-5 are recommended. Keep separate records of catch and effort for each gear type, collection site, and index site. In the office, as soon as possible afterwards, summarize the data, combine records for collection sites (if there is no reason to report them separately) and carefully prepare the appropriate summary forms for distribution and filing according to the instructions below and in Section IV. Store the field sheets also, if they contain potentially useful data not on the summary version.

c. Fish identification.--All fish must be identified accurately. If there is any question on identity save a sample for later examination. The I.F.R. 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 VI-A11).

d. Measuring fish.--Standard units of measurement are inches and pounds (decimal).

Length. Measure total length of fish to 0.1 inch 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. Carefully measure weights of individual fish (panfish to 0.002 pound). Very small fish may be weighed in small groups to obtain an average weight for the inch group. Make measurements on a stable platform, out of the wind. Extremely large catches of fish may be estimated from bulk weights and subsample counts and weights.

e. 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.

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 among species.

Lakes.--Data required to complete the LIMNOLOGY form should be collected just prior to the fish survey if the lake is stratified. Use the temperature, DO, and depth information to aid in the defining of habitats and the selecting of 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 is the ultimate management unit, thus the main survey unit (see II-B2). 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 the assessment of fish populations and angling.

f. 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 abundance and distribution within the 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 10 to 100 hectares and ten stations for larger lakes.

Record the location of index stations on maps and, if feasible, on fish collection records. 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.

g. Selection of gear.--All types of fishing gear (including poisons) are selective by size of fish and by species. Furthermore, their efficiency varies according to habitat.

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, the sampling gear should be adequate and diverse enough to sample all habitat types and all species in rough proportion to their abundance. Basic lake surveys require the use of gill nets, trap nets or fyke nets, plus seines or 220-volt 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.

Non-wadable streams are difficult to sample. Boom shockers with 220-volt AC or 220-volt DC are usually the best types of gear. In sluggish current, fyke nets or seines may be useful. Rotenone may be used to sample river populations (e.g., Grand River in 1978). The fish are collected in a blocking seine at the lower end of the sample areas. The rotenone is detoxified with potassium permanganate as it leaves the sample areas.

h. 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 species. This goal may not be feasible if the fish prove to be difficult to catch (e.g., mid-summer netting in lakes).

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 (hectares) | Net nights |
|---|---|
| 1-10 | 6 |
| 10-100 | 6-20 |
| 100-1000 | 20-50 |
| 1000+ | 1 per 25 ha |

i. 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 and effort are prerequisite. For all fish surveys catch and effort are to be recorded for each gear type, and corresponding CPE's 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. Catch per effort is expressed as both number and weight caught per unit of effort.

Catch per effort information should be part of final reports and should be used for comparisons with past surveys (Table II-2). It should be understood that CPE is a highly variable statistic and that only major increases or decreases or clear trends through time should be interpreted as reflecting real changes in fish abundance.

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 II-2.--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.

| Species | Trap nets 1975 (38) | Trap nets 1969 (16) | Trap nets 1940 (560) | Gill nets 1975 (16) | Gill nets 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 | - | - |

Table II-3.--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 )<br>Inland experimental gill net)<br>Great Lakes gill net ) | Catch per net lift (with overnight sets)[a] |
| 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 |
| Set hooks | Catch per set hook per lift |
| Electrofishing | |
| Lakes and non-wadable streams | Catch per hour of actual fishing time (15 minutes minimum effort) |
| Wadable streams | Catch per mile or catch per acre |

Part B

| Number of nets | Number of nights between lifts | Number of CPE units: 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 a 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 1-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.

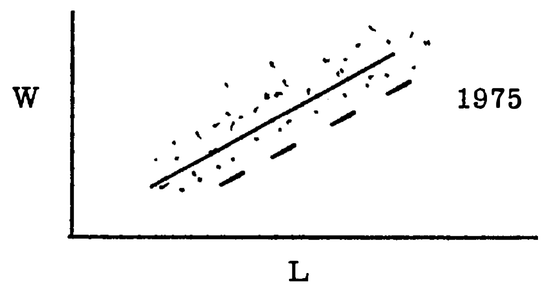
More precise measures of fish community structure require actual population estimates of each species, or CPE's adjusted for gear selectivity.

Table II-3 presents units of effort required to calculate CPE for various types of gear.

j. Length-weight relationship.--Individual lengths and weights of important species should be obtained during inventories so that length-weight regressions can be computed. Use the regressions to determine relative plumpness, and (see II-Eh) to expand length-frequency data to length-biomass data and total biomass of the catch.

Obtain the individual lengths and weights on a sample of about 10 fish per inch group per species. For small fish which are difficult to weigh individually, weigh all 10 fish together to obtain an average. Weigh panfish to 0.002 pound (1 gram), if possible. Take the weights carefully, on stable footing, out of the wind. Record lengths and weights on scale envelopes, if scale samples are being taken, or on LENGTH-WEIGHT FIELD DATA forms. Later, transfer data from the scale envelopes to SCALE SAMPLE ANALYSIS forms. Computer analysis of these forms is available, saving step 1 below:

1. Calculate: $\log W = \log c + n \log L$
   or plot W and L on log-log graph paper:




2. Fill out the LENGTH-WEIGHT REGRESSION form. Evaluate relative plumpness by comparing the regression slopes (n), or the displacement of the lines 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 (VI-A12) may also be used for comparison. Keep seasonal changes in mind (e.g., spawning) when making comparisons.

k. 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 or the smallest specimen may be added to the length-frequency table if it was 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 on the FISH COLLECTION form. A rough draft of the form may be used for tabulating data in the field.

l. Length-biomass and total biomass.--Biomass of fish is a better measure of productivity and of 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 the average lengths of the species.

Obtain length-biomass data for the random sample of fish used for the length-frequency table either directly by weighing all the fish in each inch group, or indirectly (usually the most practical under field conditions) by multiplying the number of fish caught per inch group by an average weight for fish in each group. For the indirect method, obtain an average weight for each inch group by one of the following:

1. Adding the empirical weights taken for the length-weight relationship and dividing by the number of fish weighed (LENGTH-WEIGHT FIELD DATA form);
2. Calculating from the length-weight regression equation (or simply reading from the graph), by assuming the average length of fish in the inch group was the mid-point (e.g., 6.5, 7.5, etc.);
3. Using the state average length-weight tables (VI-A12).

After the length-biomass table has been completed, calculate for each species an average weight and the total pounds caught, then the other statistics required for completion of the 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 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 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 lb./12.08 lb. = 81.4
CPE No. = 80/2 = 40
CPE Lb. = 14.24/2 = 7.12

Note the rounding off in the table.

| | | |
|---|---|---|
| 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 |

m. Average length and weight.--Designated as "size, no." and "size, lb." on the FISH COLLECTION form. Calculate from a random or systematic sample, usually from the 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 which were made to 0.1 inch. A satisfactory estimate of average length may be computed from a large length-frequency sample by a weighted formula which assumes that the 0-inch group fish average 0.5 inch long, the 1-inch group fish average 1.5 inches long, etc. Each median length is multiplied by the number of fish in the inch group, the products summed, then divided by the total number of fish. Below is calculated the average length of the 68 perch in the preceding example (II-E2n).

$$\text{avg. length} = \frac{(5.5\times 12) + (6.5\times 15) + (7.5\times 8) + (8.5\times 20) + (9.5\times 13)}{68} = 7.6 \text{ inches}$$

The best estimate of average weight is obtained by dividing the total biomass in the biomass-frequency table by the number of fish in the length-frequency table. See the example in II-E21. Alternatively, divide the empirical weight of the total catch by the total number of fish.

n. Growth.--Samples taken for age and growth analysis should fairly represent the ages and growth rates within a species population. Subsamples 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 (see II-Ep). Appendix VI-A1 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.

The techniques of scale sampling, aging, and back calculation are discussed in VI-A4. There are two methods for calculating the average length of an age group of fish. If the sample was taken systematically or randomly, then a simple average of the data is appropriate. However, if a stratified subsample 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, as illustrated in VI-A10. 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 VI-A4) may be used as standards for comparing the growth of one population with others. However, in judging if the observed growth is satisfactory or meets expectations, other factors such as the productivity of the water and the 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-III 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-III 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).

o. Population estimates.--Estimates of the actual density of fish may be obtained by (1) a complete census of the entire water body or a portion of it, e.g., draining or poisoning followed by complete recovery; (2) catch per unit of effort adjusted for gear efficiency, e.g., catch per area seined, trawled, or electrofished; or (3) by one of the variations of the mark-and-recapture technique. Because complete recovery of fish is rarely possible and the efficiency of gear is difficult to assess, the mark-and-recapture method is usually the best.

Mark-and-recapture data of the Petersen type (e.g., trout in streams) may be submitted for machine computation by entering the raw data on the left-hand side of the POPULATION ESTIMATE form. After the estimates are computed, the rest of the table is to be completed and distributed. Estimates derived from other types of formulas (e.g., Schnabel) should be summarized on the same form, if possible.

For details on mark-and-recaptured methodology refer to VI-A2 (streams) and VI-A3 (lakes) and to standard references such as W. E. Ricker's (1975) "Computation and Interpretation of Biological Statistics of Fish Populations," Bulletin 191, Department of the Environment, Fisheries and Marine Service, Ottawa, Canada.

Several points about mark-and-recapture estimates merit emphasis:

1. It is usually wise to collect scale samples during population estimates so that age-frequency and survival can be studied concurrently (see II-E1e and II-E2k).

2. 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 II-B2c for specifics on length of stations.

3. 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.

4. 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.

5. The most critical underlying assumption is that marked fish have the same probability of recapture as any other fish in the population in the recapture sample.

6. 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 the fish are mixing freely and are equally vulnerable to capture. Such mixing occurs on the shoals of lakes during spring and fall.

7. Valid estimates can be obtained even after a long lapse of time between marking and recovery (e.g., fall to spring), provided:

a. Marks are not "lost".

b. Marked and unmarked fish have the same survival rate.

c. Fish are not subtracted or added to the population because of movement or recruitment.

8. Concentrate sampling effort on the target species. For example, in 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 DeLury-type estimate (see Ricker [1975] for methods) in a short section of the 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 II-4 and II-5.

In the office, the data were tallied, and population estimates were made by inch group using the Bailey modification of the Petersen formula (Table II-6, see also VI-A2). 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 number of marked fish to the population estimate for every other size group, plotted these ratios versus size groups, fit a line or a curve to these points, read the ratio off the graph for the size group

Table II-4.--Example of stream fish population estimate:

MARKING RUN - BROOK TROUT
ALEXANDER CREEK 8/30/80

R1016-1

(length 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 | | 5.5 | | 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 | 2.4 | 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 | 2.8 | 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 | | | 5.7 | | 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 | 2.2 | | 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 II-5.--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 |
| \| | | 𝍸 | 𝍸 | 𝍸 | 𝍸 | 𝍸 | \|\|\|\| | 𝍸 | 𝍸 | 𝍸 | 𝍸 | 𝍸 | 𝍸 |
| | | 𝍸 | 𝍸 | 𝍸 | 𝍸 | 𝍸 | | 𝍸 | 𝍸 | 𝍸 | 𝍸 | 𝍸 | 𝍸 |
| | | 𝍸 | 𝍸 | 𝍸 | \|\|\|\| | | | 𝍸 | \|\| | 𝍸 | \|\| | | |
| | | 𝍸 | 𝍸 | 𝍸 | | | | 𝍸 | | \|\| | | | |
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| | | 𝍸 | | 𝍸 | | | | | | | | | |
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| 8.0 - 8.9 | | 9.0 - 9.9 | | 10.0 - 10.9 | | 11.0 - 11.9 | | 12.0 - 12.9 | | 13.0 - 13.9 | | 14.0 - 14.9 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| U | M | U | M | U | M | U | M | U | M | U | M | U | M |
| 𝍸 | 𝍸 | 𝍸 | 𝍸 | \|\|\|\| | 𝍸 | \|\| | \|\|\| | | | | \| | | \| |
| 𝍸 | 𝍸 | \|\|\|\| | 𝍸 | | \|\|\| | | | | | | | | |
| | \|\| | | \|\| | | | | | | | | | | |

Table II-6.--Example of stream fish (brook trout) population analysis.

BROOK TROUT
ALEXANDER CREEK
SECTION A (AREA = 0.227 HA.)

R1016-1

| INCH GROUP | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **MARK-RECAPTURE POPULATION ESTIMATES.** | | | | | | | | | | | | | | | |
| NUMBER MARKED | 2 | 131 | 70 | 24 | 47 | 51 | 17 | 31 | 32 | 14 | 9 | 3 | 3 | 2 | |
| NUMBER RECAPTURED | 0 | 20 | 14 | 4 | 12 | 12 | 10 | 12 | 12 | 8 | 3 | 0 | 1 | 1 | |
| TOTAL CATCH | 1 | 103 | 52 | 14 | 36 | 29 | 20 | 22 | 21 | 12 | 5 | 0 | 1 | 1 | |
| EST. = $m(c+1)/(R+1)$ | | 665 | 247 | 72 | 134 | 118 | 32 | 55 | 54 | 20 | 14 | 3* | 3 | 2 | |
| POP/HA. | | 2930 | 1088 | 317 | 590 | 520 | 141 | 242 | 238 | 88 | 62 | 13* | 13 | 9 | |
| **AGE COMPOSITION OF SCALE SAMPLES BY PERCENTS AND NUMBERS OF FISH ( ).** | | | | | | | | | | | | | | | |
| AGE: 0 | | 100 | 100 | 41.7 | | | | | | | | | | | |
| | | (28) | (28) | (10) | | | | | | | | | | | |
| I | | | | 58.3 | 100 | 100 | 36.4 | 7.7 | | | | | | | |
| | | | | (14) | (30) | (30) | (8) | (2) | | | | | | | |
| II | | | | | | | 63.6 | 92.3 | 92.9 | 75.0 | 75.0 | 50.0 | 50.0 | | |
| | | | | | | | (14) | (24) | (26) | (18) | (6) | (4) | (2) | | |
| III | | | | | | | | | 7.1 | 25.0 | 25.0 | 50.0 | 50.0 | | |
| | | | | | | | | | (2) | (6) | (2) | (4) | (2) | | |
| IV | | | | | | | | | | | | | | 100 | |
| | | | | | | | | | | | | | | (1) | |
| **POPULATION ESTIMATES PER HECTARE BY AGE GROUP AND INCH GROUP = POP/HA x %.** | | | | | | | | | | | | | | | |
| AGE: 0 | | 2930 | 1088 | 132 | | | | | | | | | | | TOTALS: 4150 |
| I | | | | 185 | 590 | 520 | 51 | 19 | | | | | | | 1365 |
| II | | | | | | | 90 | 223 | 221 | 66 | 46 | 6 | 6 | | 658 |
| III | | | | | | | | | 17 | 22 | 16 | 6 | 6 | | 67 |
| IV | | | | | | | | | | | | | | 9 | 9 |

**WEIGHTED AVERAGE LENGTH OF AGE GROUP = MEDIAN LENGTH x AGE EST.**

AGE: 0 $\dfrac{(2.5 \times 2930) + (3.5 \times 1088) + (4.5 \times 132)}{4150} = 2.83$ inches

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

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

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

IV $\dfrac{(14.5 \times 9)}{9} = 14.5$ inches

*Estimated indirectly (see text).

with insufficient data, then expanded the number of fish marked by this ratio. Population estimates should be expressed in fish per acre, fish per mile, or fish per unit of discharge (Table II-6). Biomass of the population should also be computed if the length-weight relationship is known.

Using the age composition of the scale sample collection, the estimates by inch groups were converted to partial estimates by inch groups and age groups as shown in Table II-6. For example, of the 317 4-inch trout per hectare, 41.7% were age 0 (132 fish) and 58.3% were age I (185 fish). The total estimate for the age group is then the sum of these 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% for age 0-I, 48.4% for age I-II, 10.2% for age II-III, 13.3% for age III-IV. A plot of the abundance of each age class on semi-log paper gives a graphic picture of survival rate (Fig. II-5). Note the term "apparent" survival rate. This is because one cannot be sure whether decreases in numbers at a particular station are due to mortality or to movement out of the station which is why it is best to look at the population on a drainage basis.

Good population estimates at all the sample stations of the 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 the population per acre found within the station, times the number of acres in the zone. To arrive at the population of the drainage, the populations of all zones are summed.

From the data on numbers of fish in each age and size class, a weighted estimate of growth rate was made (Table II-6). 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 the total estimated number of age-0 fish to get the

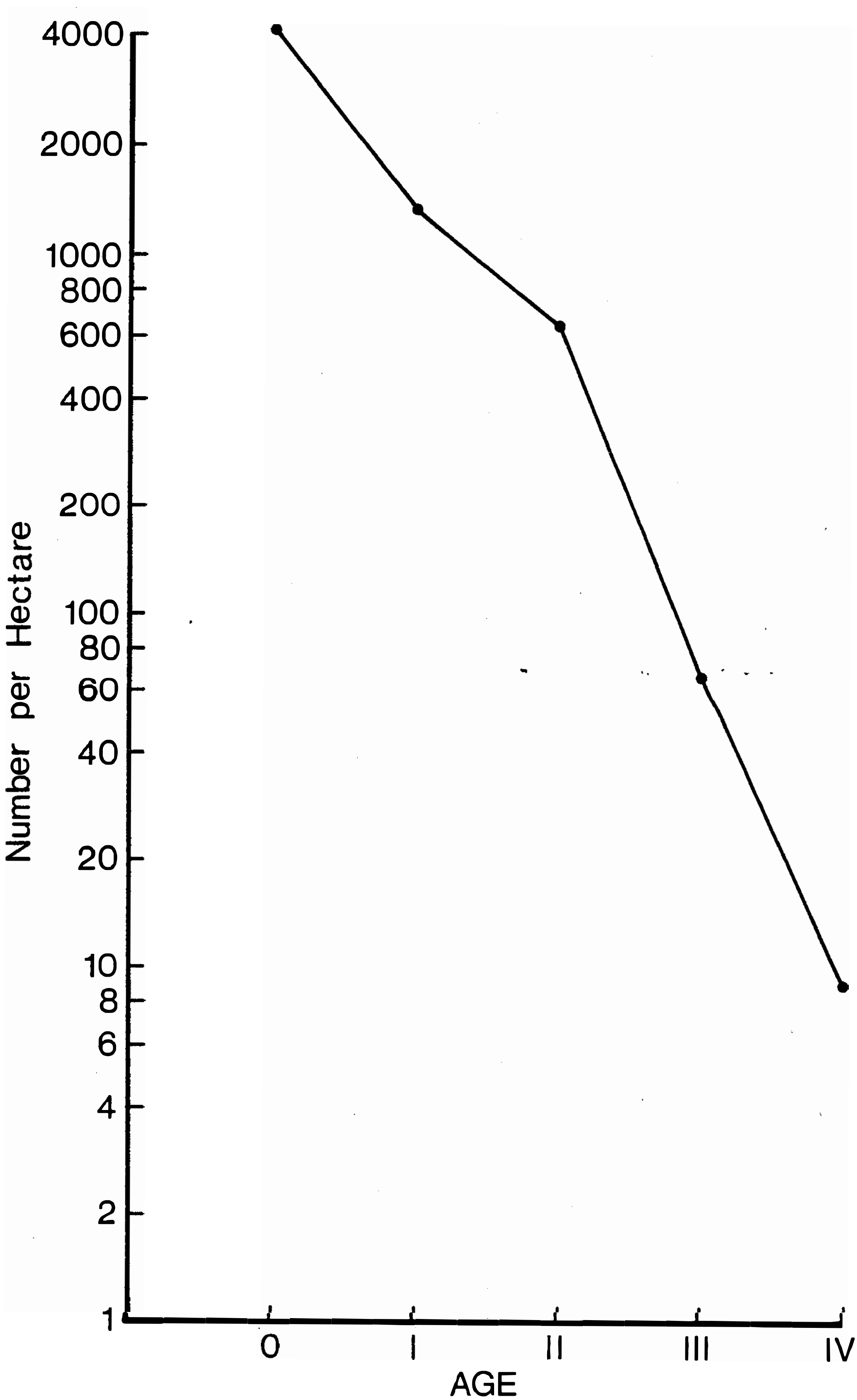



Figure II-5.--Example of a survivorship curve for brook trout from a stream population estimate.

average size of age-0 fish. The procedure was repeated for each age group. Another example is provided in VI-A10. This method reduces most sampling bias but has limitations in that it requires rather extensive data. A graphic picture of the growth rate is in Fig. II-6.

p. 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 subsamples must be weighted as in VI-A10), 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 II-E3o and VI-A10. The computations are to be summarized on the POPULATION ESTIMATES form.

Survival may also be estimated from simple "catch curves" by substituting catch frequencies for mark-and-recapture population estimates. See textbooks for discussions of methods and limitations. This method is not as reliable because catch frequencies are biased by gear selectivity.

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 the number alive in year 2 divided by the number alive in year 1.

For an example of the computation of survival rate see the trout data in the preceding section (II-E3o).

q. 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 the instantaneous rate of increase in

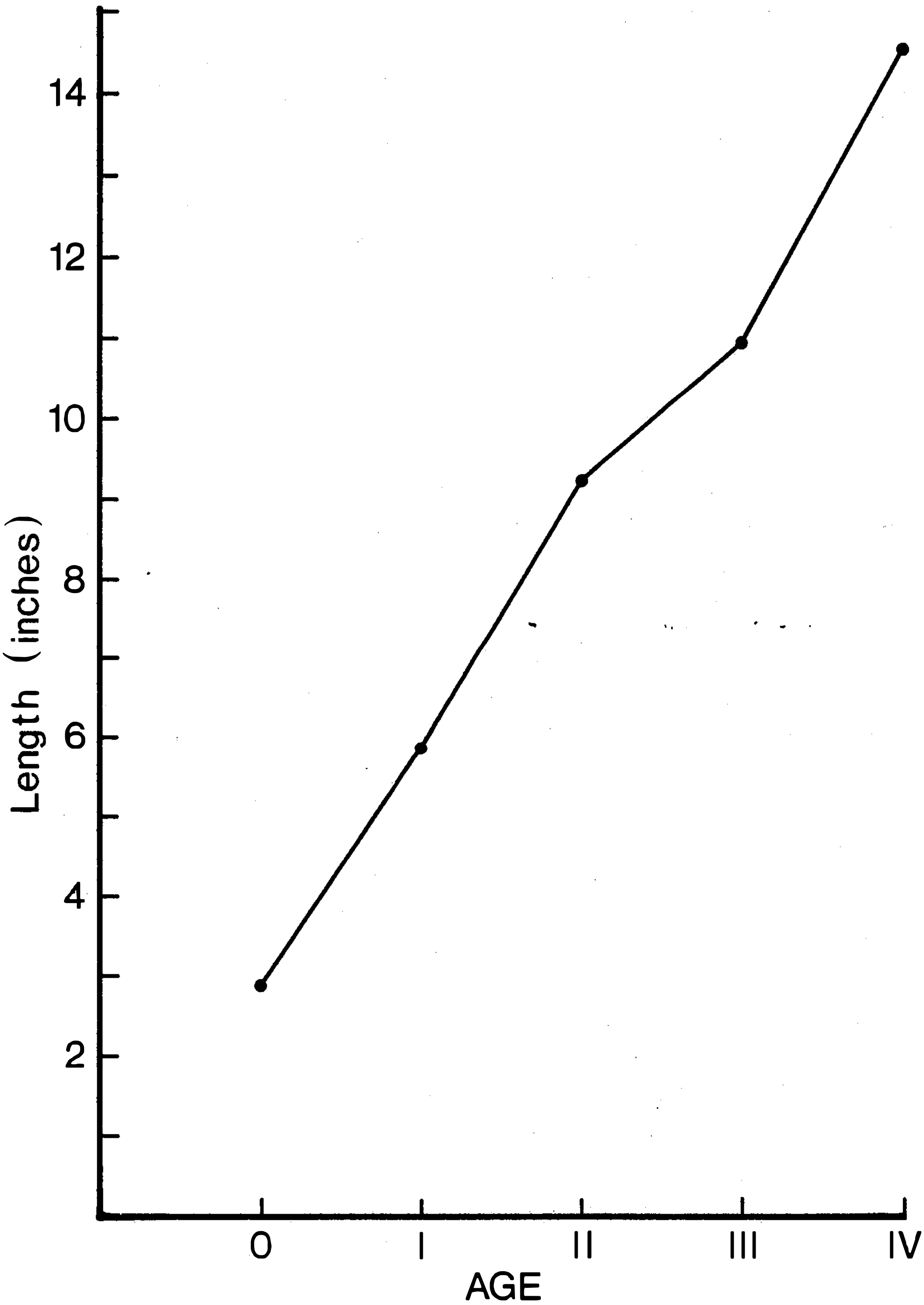



Figure II-6.--Example of a growth curve for brook trout from a stream population estimate.

individual weight by the average biomass of the population during the time interval. Thus, the basic data required are growth, survival, and the biomass of the population. Production can be determined by means of a graph (Allen method), equation, or computational table. See references such as: W. E. Ricker (ed.) 1968. Methods for assessment of fish production in fresh waters. IBP Handbook No. 3. Blackwell Scientific Publ., Oxford and Edinburgh.

r. 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.

### E. Fishery assessment

Observations on the fishery should be recorded on the FISH COLLECTION or NOTES AND REFERENCES form. Recorded observations should usually be limited to fish observed; however, local reports of success or complaints may be recorded if the biologist feels the account is reliable.

Creel census should be used to document the success of significant management programs. Creel census methods are contained in VI-A9. Assistance in conducting a creel census is also available at the Institute for Fisheries Research in Ann Arbor.

# III. GEAR

Gear for collection of fish samples continues to develop. The most common types of gear are described in the following sections. Consider these descriptions as standards--gear with other features must be more fully described on the FISH COLLECTION form. Whenever you collect samples make sure the gear is adequately described so the biological information will continue to be useful and collections can be duplicated later.

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

## A. Trap nets

Description

There are two types of trap nets in use for inland surveys; the "3-foot trap" and the "6/3-foot trap." Walter Crowe developed the 3-foot trap and Dave Havens the 6/3-foot trap. Figures III-1 and III-2 describe these traps.

Use

Trap nets are effective in lakes. They readily take most of the warmwater species and trout if they are actively moving. Size selectivity is determined by mesh size and size of the funnel opening. Trap nets usually allow return of fish to the water unharmed.

Trap nets fish best when set off points, weed beds or other obstructions to fish movements which act as natural leads. Nets are usually set perpendicular to shore, on a gently sloping bottom, with the pot end deeper than the inshore lead. They do not fish as effectively on steeply sloping bottoms or in depths greater than about 10 m. Trap nets should be fished one night between lifts.

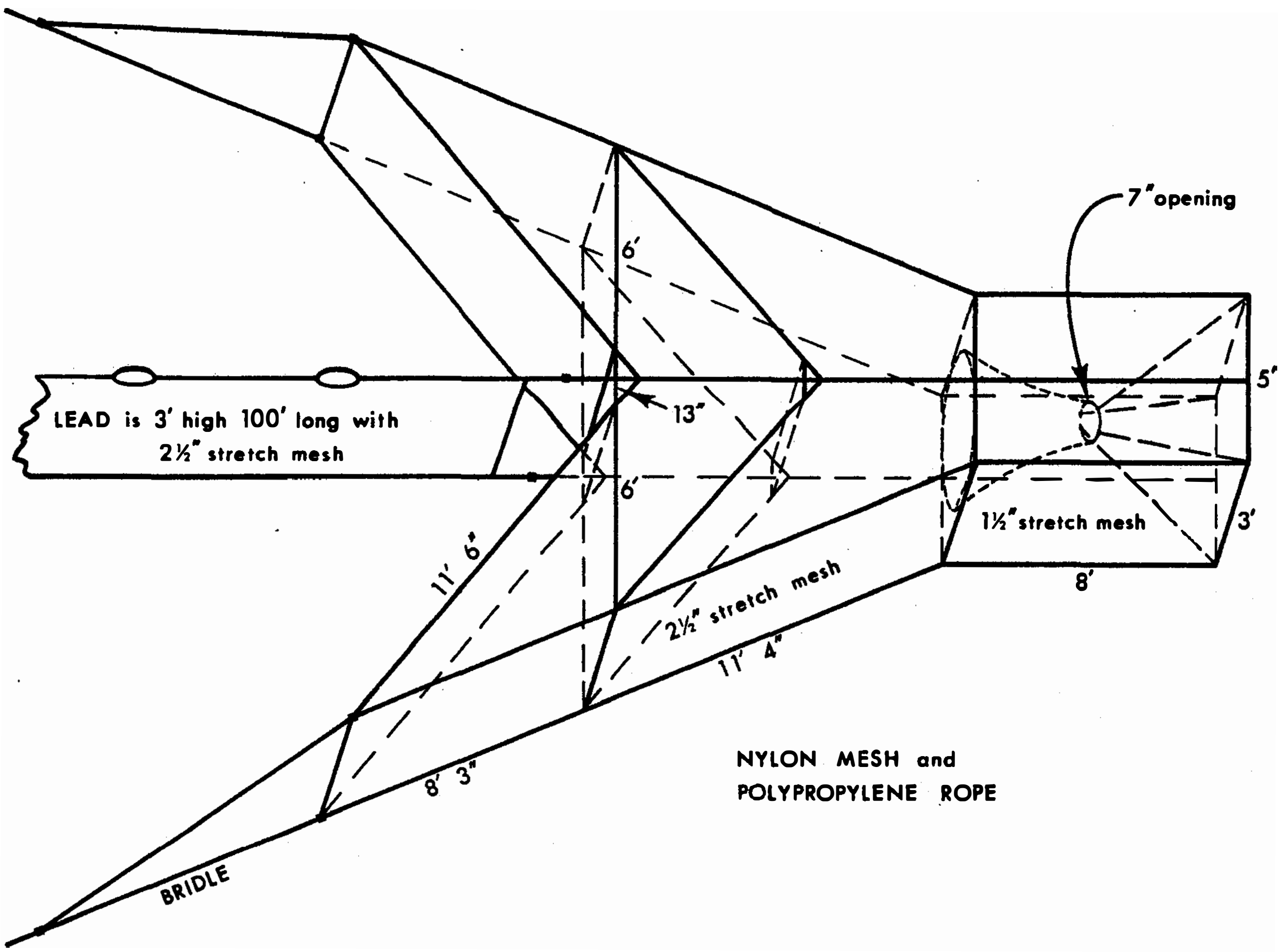



Figure III-1. --Construction details of a 3-foot trap net.

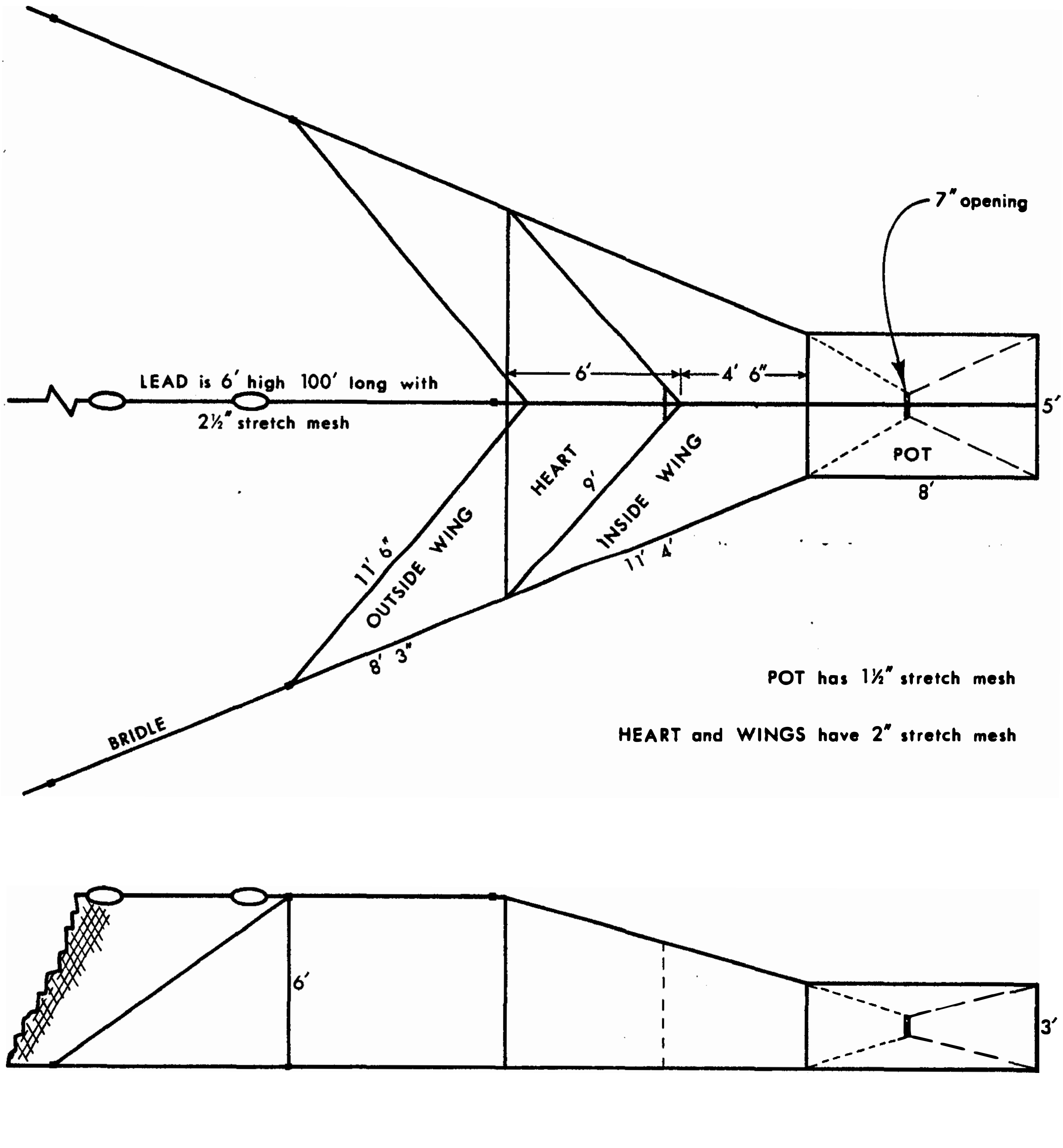



Figure III-2.--Construction details of a 6/3-foot trap net (6-foot lead tapering to a 3-foot pot).

## B. Fyke nets

Description

The original design has 2-inch stretch mesh, is 4-feet high, and has a 150-foot lead (Fig. III-3). The same frames are sometimes hung with either 1 1/2-inch or 1-inch mesh, and fitted with shorter leads. A fourth variation has 1/2-inch mesh, a 25-foot lead, and a half-scale frame (2 feet high × 3 feet wide). In describing fyke nets on forms, record stretched mesh size and frame height.

Use

Fykes are easier to handle than trap nets, especially in water less than 2 m deep. They are effective in lakes and in sluggish rivers. Selectivity is influenced by mesh size and fish movements.

Fyke nets should be set perpendicular to shore or with the current. They fish better than trap nets on steep slopes.

Fykes should fish one night between lifts. They can be substituted in place of some trap net sets.

## C. Inland experimental gill nets

Description

This net is 125 feet long and 6 feet deep. It consists of five 25-foot sections of different mesh sizes. The mesh sizes (stretch measure) are 1 1/2 inches, 2 inches, 2 1/2 inches, 3 inches, and 4 inches, and are hung in that order on a 1:2 basis (2 feet of stretch mesh per foot of lead or float line). The mesh is made of nylon multifilament. Weight of the solid core lead line should be sufficient to sink the net.

Use

Gill nets are used in lakes or (very carefully) in sluggish streams. Gill nets are very selective, but effective in catching many fish, especially yellow perch, northern pike, and trout. Centrarchids are usually under-sampled.

Gill nets are to be fished one night between lifts for standard CPE. Set each net as an individual unit.

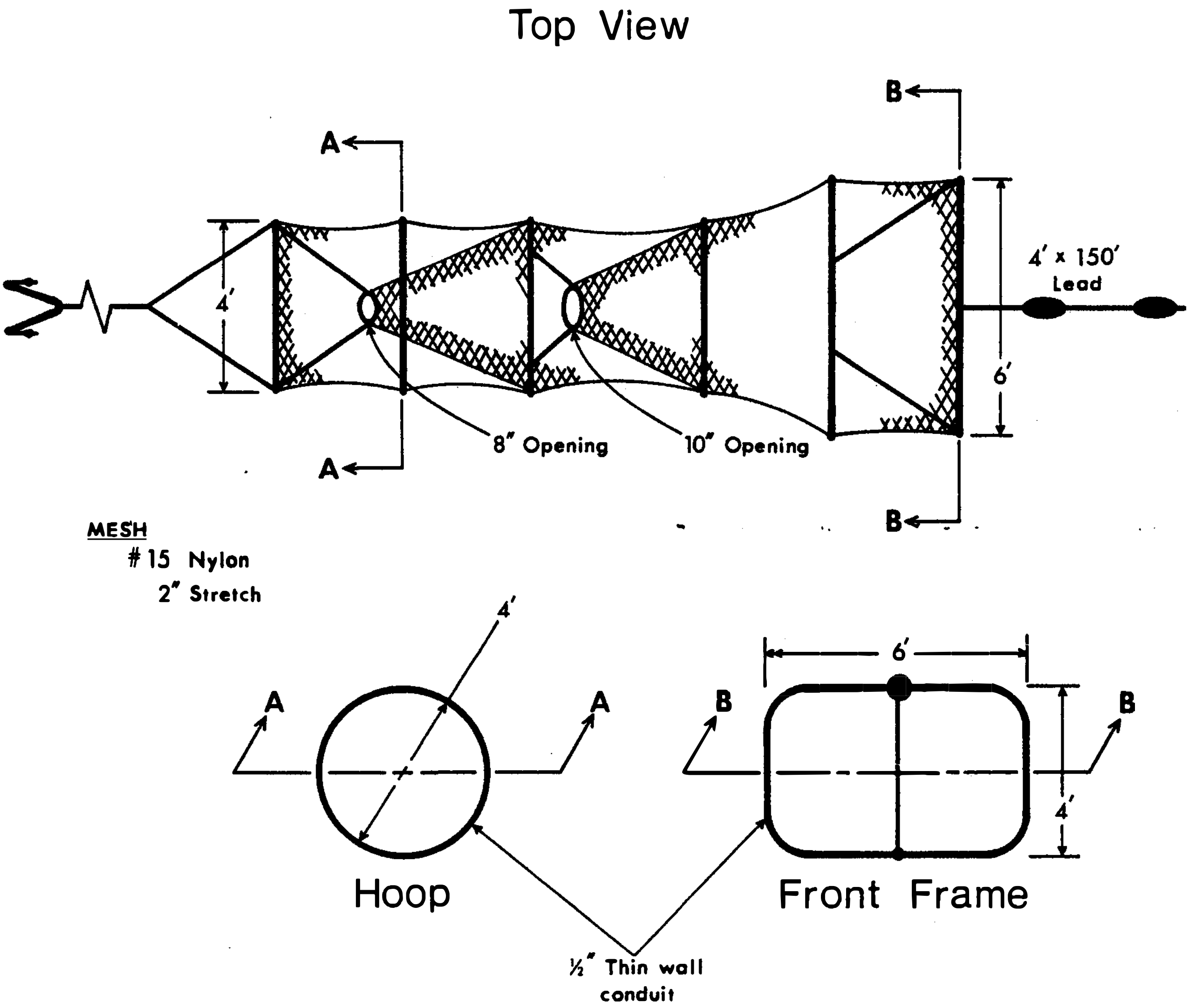



Figure III-3.--Construction detail of a fyke net.

## D. Modified Great Lakes gill nets

### Description

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

### Use

This net has been used in larger lakes where a large sample is needed or where larger individual fish are found.

Gill nets are to be fished one night between lifts. Set each net as an individual unit. Number of sets must be tailored to the survey needs.

## E. Seines

### Description

Various seines are in use. There seems to be no "standard" seine.

### Use

Generally, seines are effective on small fish, especially minnows. Larger seines are effective in sampling most species which occur in habitats within "reach" of shore if the habitat is free of snags.

Enough effort should be expended to obtain a representative sample of fish. Sample sites should be widely scattered.

## F. Toxicant sampling

### Description

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

Various methods can be used. A description of the procedure used for cove sampling by the Texas Parks and Wildlife Department follows:

Place a barrier net of 1 1/2-inch stretch mesh across the cove one day prior to treatment. Bundle the net along the float line to permit free passage of fish. Release the net sometime between 2 hours after sunset and 2 hours before sunrise during the night before treatment.

Place marked fish, similar to the species in the lake, into the area. Use enough toxicant for a total kill. Begin treatment on or before 8 AM. Recover fish on the day of treatment and the following day.

### Use

Sampling with a toxicant has been a valuable tool in many states and has been used on large rivers in Michigan. When marked fish are present, more accurate estimates of the composition of the fish community and of standing crop can be made by means of size-stratified mark-and-recapture methods. Toxicants sample all sizes and species of fish but not all sizes and species are recovered with the same degree of effectiveness.

Enough effort should be expended to obtain a representative sample.

## G. Electrofishing

Description

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

"Boom" shocking equipment, used on lakes and large rivers, consists of a boat rigged with booms out front. From two to five electrodes are suspended from the booms. IF DC current is used, the positive electrodes (usually two) are out front and the negative electrodes trail along the sides (see Novotny and Priegel 1974, Wisconsin Tech. Bull. 73). Common types are 220-volt, AD, DC, or pulsed DC. Working output is normally 4 to 10 amperes, but it should be adjusted to water conductivity, size of fish, and fish recovery time to avoid injury to the spine or to the gills.

"Stream" shocking equipment, used on wadable streams, may be either of the pulsed DC "back-pack" battery type, or the type which requires the use of a small boat to transport the 220-volt DC generator. The latter supplies more power and is much more effective. The positive electrode (1, 2, or 3 may be used) is hand-held; the negative electrode may be attached to the bottom of the boat or to a separate float.

Use

Electrofishing gear is less size selective than fyke, trap, or gill nets and obtains a more representative sample of the size structure, age structure, and growth of the population. However, its use is restricted to shallow habitats less than about 1.5 m deep, and that may result in a sample which is unrepresentative of the water body as a whole.

Electrofishing is the most effective gear for sampling stream and river fish. It can be effective in lakes for routine sampling, or for special projects such as sampling bass in the spring or trout in the spring or fall. Some fish, such as northern pike, often escape from the electric field. In lakes, usually a larger and more representative sample of fish is obtained after dark. Catch may vary greatly seasonally, and from night to night, depending on fish movements. For boom shocking rivers, it is usually best to fish downstream, motoring slightly faster than the current, but pausing occasionally to allow fish stunned on the bottom to drift to the surface.

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

Water conductivity should be measured for each survey.

## H. Trawl

### Description

A 16-foot head rope otter bottom trawl is standard for inland sampling. The trawl is 16 feet across the front opening and has 1 1/2-inch stretch nylon mesh on the main part. The cod end has a liner of 1/4-inch mesh.

Otter boards with adjustable chains are used to hold out the sides. The foot line is weighted with chain and the head line is fitted with styrofoam floats.

The net is fished with a boat with at least a 20-hp motor and pulled by hand or winch.

Towing speed is measured using a simple trolling meter.

Towing lines must be long enough to maintain the trawl on the bottom.

### Use

Trawling is similar to bag seining, but more mobile and can be used in deeper water. Minnows and young fish are the main targets, but fish as large as adult perch are sampled.

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

## I. Visual observations

Description

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

Use

Observations may pinpoint the optimum time for population control or spawning habitats.

# IV. FORMS--USES AND POINTS OF CLARIFICATION

Forms dealing with surveys are listed and briefly described in this section. Only items which are new or likely to be confusing to users are discussed in detail. For additional clarification, refer to related sections of the manual and to the examples provided.

One new item, appearing on several forms, is "Id.______." This item is to aid computer storage of information in the future and need not be filled in at present. For lakes, the identifying county and lake number are given by Humphrys and Green in the "Michigan Lake Inventory Bulletin." For example, Houghton Lake's Id. is 7278. For streams, the Ids. will be designated in the Watershed Management Plan.

SURVEY PLANNING FORM (R-8060). Use to plan all surveys. The purpose of this form is to assist in review of past surveys, setting an objective for the proposed survey and communicating this information to others. Dispose of the form after the survey report is completed.

LIMNOLOGY (R-8056). Use to record the results of water analyses and observations on vegetation and weather conditions. Most requirements are self explanatory. Two columns are available for temperature-oxygen depth profiles. These can be used for two stations if desired or one station if the lake is exceptionally deep. One station located in the deepest part of the lake is adequate unless the lake consists of two or more distinctly separate basins.

Wave condition--recorded as calm, choppy, rough or white caps. These designations give a better indication of the effect of wind on the lake than simply recording wind velocity.

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

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

Chlorophyll a--and nutrient concentrations--will be analyzed by the Environmental Services Laboratory from our water samples. The data should be recorded on the LIMNOLOGY form as they are made available by the lab. Record the depth at which "mid-depth" samples were collected for nutrient analysis.

Pollution--record any pollution observed. The "comments" should include a statement as to remedial steps being taken or whether a report has been made through proper channels.

Vegetation--aquatic vegetation will be classified as to type (submergent, emergent, floating, Chara), and ranked in abundance as: none, sparse, common, abundant, or excessive. A designation of excessive should indicate nuisance conditions that interfere with recreational uses of the lake. It would also be probable that there had been frequent public complaints and requests for control programs. The observations required here will give an evaluation of the abundance of various types of vegetation throughout the entire littoral area. For each type of vegetation, list a combination of percentage and abundance designations to equal 100% of the littoral area. For example, submergent weeds might be excessive throughout 50% of the littoral (50E), common in 20% (20C), and sparse in 30% (30S).

The entire designation for "submergent" would thus be: 50E, 20C, 30S. Give similar designations for all other vegetation types, even if some types are absent in the lake (Example: Floating 100N).

Additional comments--observations worthy of comment might include (but not be limited to):

1. Sensitive areas to be protected: marshes, spawning shoals, etc.
2. Evidence of dredge or fill or other perturbation.
3. Residential development; percent developed, whether septic tanks or sewers, etc.
4. Immediate watershed; percent in agriculture, forest, old field, residential, urban, etc.
5. Existing or potential erosion problems.
6. Potential for water quality management or rehabilitation.

INLAND LAKE MANAGEMENT UNIT FORMS. FIELD SHEET. This form is used by the Inland Lake Management Unit for their intensive lake surveys. It is imperative that they have all required field information. If water analysis data are not accompanied by precise field information (station locations, etc.), none of the data will be accepted by STORET.

ENVIRONMENTAL LABORATORY ANALYSIS--BIOLOGICAL (ESD-02602)
ENVIRONMENTAL LABORATORY ANALYSIS--INORGANICS (ESD-04000)
ENVIRONMENTAL LABORATORY ANALYSIS--ENVIRONMENTAL QUALITY (ESD-01403)

At the present time the Environmental Services Laboratory is divided into several units, each requiring separate samples and analysis forms. Analysis required for a second level limnological survey will utilize the services of three units of the laboratory, and thus require three water samples and the completion of three laboratory analysis forms.

Changing analytical methodologies frequently result in changes in required sample size, preservation, etc. Appendix VI-A-16 contains information concerning sampling requirements, and completion of forms required by the Inland Lake Management Unit. The laboratory may also be contacted by phone for additional information.

LAKE PHYSICAL DESCRIPTION (R-8057). Summarizes information from various sources on the physical characteristics of lakes. Line items 1-5 are to be completed from available maps and reference materials listed on the form (data for lakes larger than 100 acres are available now), other lines are to be completed by on-site surveys. Update form every 20 years or when new information becomes available.

LAKE AREA AND VOLUME ANALYSIS (R-8069). Use for calculating the area and volume of lake from its hydrographic map. See appendix VIA6.

FISH COLLECTION (R-8058) and FISH COLLECTION (CONT) (R-8058-1). Intended primarily for distribution and permanent file storage, but may be adopted for use in the field as well. Use for fish collections from lakes, rivers, or streams. Summarizes information on sample site(s), year, catch, CPE, LENGTH-FREQUENCY, and LENGTH-BIOMASS. Extensive space is provided for maps, analysis, and comments. Not every item of information requested is relevant to each survey. These forms may be used in four ways to summarize catch:

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

Side 1

Summary of--indicate source of the information on this form, i.e., site and gear.

Sample site(s)--indicate number of locations, range in depth at which the gear was fished and (if the water was thermally stratified and contained dissolved oxygen) the temperature range where the gear was fished. If water temperature was uniform from surface to bottom, record only the surface temperature.

Sample location(s)--describe, or use space given for sketching a map.

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

Fish foods--comment on foods observed in the habitat or in fish stomachs.

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

Conductivity--express in micro ohms per $cm^2$. Record temperature elsewhere on form.

Electrofishing efficiency--either rank as poor, satisfactory, or good; or for mark-and-recapture studies, give the recapture percentage on the second "run" i.e., number recaptures divided by number of recaptures plus unmarked.

Stream physical data--it is recommended that length, average width, average depth, average velocity and discharge be determined by the methods in Section IIB2. If those methods are not followed, prefix the estimates with "approx.", as illustrated. When a current meter is not available for the proper determination of average velocity, use "the wood chip method" and record the result as "surface velocity."

Bottom type--primarily intended for stream surveys but may be used to describe lake sample sites too. Estimate the percentage of bottom comprised of bedrock, boulder (greater than 10 inches), cobble (3 to 10 inches), gravel (1/8 to 3 inches), sand, silt, clay, muck, detritus.
Gear--list the number of units used, types, unusual features (see description of standard gear in Section III) and, for trap and fyke nets,

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

Effort--standard units of effort are given in Table II-3. For net lifts, record the total number of lifts which were fished one or more nights (e.g., four nets lifted once a day for 3 days = 12 net lifts; four nets lifted every third day = 4 net lifts). For net nights, record the total number of lifts which were fished one night (net nights = net lifts if the nets were lifted once a day; net nights = 0 if four nets were lifted every third day). For area covered, record the acres seined, trawled, or electrofished (for streams). For hours shocked, record actual fishing time in lake or stream (optional) electrofishing.

Non-standard types of effort, such as nets lifted more than once a day, should not be recorded here but may be noted under Analysis, map, remarks, fishing reports.

Standard effort which is not representative (for example a torn net) should be footnoted and explained and CPE should not be calculated from it.

Purpose of collection--state the survey objectives or why it was done (e.g., reports of poor fishing, basic inventory, survey of walleye recruitment) to aid in the interpretation of sampling methods and results.

Data collected--indicate the types of data gathered during this collection and the resulting summaries which were prepared. The CATCH SUMMARY and LENGTH-FREQUENCY and LENGTH-BIOMASS summaries are on the FISH COLLECTION form; the other summaries appear on other forms.

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

Side 2 (*See Section II, pages 25-26 and 27-39*).

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

Avg. Wt.—Total lb ÷ No., or from LENGTH-BIOMASS sample. Round to 0.001 lb.

Total—Total catch, by species and gear, in both numbers and pounds. Total pounds may be obtained by weighing all fish, or calculated from the LENGTH-BIOMASS sample. Round pounds to nearest 0.1 when <50; to whole pound when >50.

Total %—For each type of gear: total number (and pounds) caught of each species ÷ ALL SPECIES TOTAL x 100. Round to whole number when >1%.

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

Percent L-A—Percentages of the LENGTH-FREQUENCY and LENGTH-BIOMASS samples which were of legal or acceptable size. See footnote on form for definitions. Space is provided on the bottom of the form for alternative definitions. Round to whole number when >1%.

LENGTH-FREQUENCY—Measure to inch group all fish caught, or sample the first 200. Record numbers of fish in each group in "No." column and total number in sample at bottom of column.

LENGTH-BIOMASS—Determine the weight of fish in each inch group of the LENGTH-FREQUENCY (see II, page 37 and Appendix 12). Record as pounds under "Lb" column, rounding to 0.1 when <50 and to nearest pound when >50. Sum to obtain sample total pounds and divide by sample total numbers to get an average weight for the fish collected.

ALL SPECIES TOTAL—Grand total for the gear in numbers and pounds.

LENGTH-WEIGHT FIELD DATA (R-8059). Intended primarily for field use for recording the lengths and weights of individual fish, or of small lots of fish. Add appropriate headings and calibrate as needed. Space is provided for computing average weight by inch group, as an aid in calculating biomass estimates for the FISH COLLECTION form. Data recorded on scale envelopes in the field may be added to the form. The form may be submitted for computer analysis of the length-weight relationship. The information recorded on this sheet is to be summarized on FISH COLLECTION and LENGTH-WEIGHT REGRESSION forms for distribution and permanent storage. The field sheet may be stored by the collector.

LENGTH-WEIGHT REGRESSION (R-8059-1). A summary form for distribution and permanent storage of the length-weight relationships of species taken in a fish collection. The conventional units of measurement at present are inches and pounds. Give the regression equation on the front of the form, or plot the relationship on the log-log graph on the back of the form. The regression equation may be calculated by hand, or by computer from the LENGTH-WEIGHT FIELD DATA form (R-8059) or the SCALE SAMPLE ANALYSIS form (R-8055).

SCALE SAMPLE ANALYSIS (R-8055). A work form for computer analysis; not intended for distribution and filing. To use, transfer data from scale envelope, add age and, if desired, scale measurements for back calculation. The computer will compute length-weight regressions, scale radius-fish length regressions, and will back calculate length of fish at each annulus. These data are to then be transferred to appropriate summary forms, distributed, and filed.

FISH GROWTH (R-8070). Summarizes the ages of fish taken in a FISH COLLECTION and compares them to statewide averages. Give a terse description of the collecting gear (more detailed information will be on the FISH COLLECTION form) and <u>unusual</u> methods. Examples: a random or complete sample of the catch instead of the usual stratified random size-selective sample; ages determined from otoliths, fins, etc., instead of scales; selection of key scales or scales from areas of the body other than the recommended areas; weighted mean lengths (see VIA10) instead of simple averages; etc. See VIA4 for the state average growth rates and the method for calculating growth indices. Note that space is provided for analysis of results.

POPULATION ESTIMATES (R-8073). Use to summarize for distribution and filing, data derived from mark-and-recapture population estimates of fish. The left-hand table of raw data may be submitted first for computer computation of Petersen-type estimates, then a final summary prepared. As a summary, the form provides space for (1) raw data, (2) estimates by inch groups, (3) estimates by age groups, and (4) survival rates. Items 3 and 4 should not be attempted unless the data are adequate (see IIE2j and IIE2k). The form is set up for one species per side but more could be inserted.

Sum--the sum total of the inch group estimates, except that the 95% limits on the sum of the estimates is not simply the sum of the limits on the inch group estimates. See appendix VIA2.

Survival--round off to 0.1% (e.g., 47.3)

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

NOTES AND REFERENCES (R-8077). Use to record any valuable information not contained on other forms.

LAKE SURVEY SUMMARY (R-8063). Use for summarizing physical, biological, and fishery information about lakes. Most items on form are self explanatory; items 20 and 23 are explained below.

20. Oxygen-thermal types are based on mid-late summer oxygen-temperature profiles and history of winterkill:
    1. Stratified lakes with at least 2 ppm DO at all depths.
    2. Stratified lakes in which DO falls from a high level to 2 ppm in the hypolimnion.

3. Stratified lakes in which DO falls from a high level to 2 ppm between the 2-meter level of the thermocline and the top of the hypolimnion.
4. Stratified lakes in which DO falls from a high level to 2 ppm between the bottom of the epilimnion and the 2-meter level of the thermocline.
5. Unstratified lakes in which surface temperatures exceed 22° C.
6. Unstratified lakes in which surface temperatures do not exceed 22° C.
7. Lakes subject to frequent, severe, fish kills (DO falls to near zero throughout the lake).

23. Vegetation--use ranking system for LIMNOLOGY form.

STREAM SURVEY SUMMARY (R-8064). Use for summarizing physical, biological, and fishery information about streams. Most items on form are self explanatory or are explained in the text (IIA2). Items 2 and 3 are explained below.

2. Stream--name the stream on which the study station is located.

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

   Example: Stream--Butternut Creek

   Drainage system--Butternut Creek, Fish Creek, Maple River, Grand River.

MANAGEMENT RECORD (R-8076). Summarizes management recommendations and actions.

# V. REPORTS

A final report is required for extensive surveys in addition to properly prepared forms. It will be used for departmental and public information. Make and distribute a NOTE AND REFERENCE form referring to reports not stored in the lake or stream filing system. Refer to Fisheries Division Policies and Procedures for additional information about report policies, and review and editing procedures.

## A. Style

Reports can take the following forms:

1. Technical Report series -- for information of statewide interest. River rotenone surveys will be included in the this series, with contents as outlined in B. See Policies and Procedures for Reports and Publications.
2. Status of the Fishery Resource Report series -- similar to Technical Reports, but less extensive distribution, including District, Region, Division Office, and Research. Narrative style, as outlined in C.
3. Notes -- on FISH COLLECTION form or NOTES AND REFERENCE form.

## B. Content of River Rotenone Survey Reports

Use the style and format of Towns (1987), Technical Report 87-3. The following outline, based on that document, is recommended:

I. Summary.

II. Introduction.

III. Methods.

IV. Results.

 A. Overview.

 B. Fishery description, by station.

V. Discussion.

 A. General.

 B. Management considerations.

VI. Literature Cited.

VII. Tables.

 Table 1. Locations of sampling stations.

 Table 2. List of species captured at each station.

 Table 3. Percent of catch by weight, number and species. Chubs, shiners, minnows, darters, and individuals less than 3 inches long are excluded.

 Table 4. Catch results.

 Table 5. Numbers of common fish per surface acre collected at each station.

VIII. Figures.

 Figure 1. Map showing locations of sampling stations.

 Figure 2. Weight of gamefish, redhorses and suckers, carp, and all fish captured at each station.

C. Content of Status of the Fishery Resource Reports

Use the style and format of Dexter (1991), Status of the Fishery Resource Report 91-1 for Deep Lake, with the associated Management Plan (copy follows page V-12). Framework software is available to simplify the preparation of report outlines and tables.

**Outline**

The following outline is recommended. A description of the suggested contents of each item appears after this outline.

I. Environment.
   A. Location.
   B. Geology and geography.
   C. Watershed description (inlets, outlets, connecting waters, basin and the associated Great Lake).
   D. Chemical and physical characteristics.
   E. Development, public ownership, and access.

II. Fishery Resource.
   A. History of the fishery.
   B. Current status of the fish community.
      1. Summary tables.
   C. Analysis and discussion.

III. Management direction.
   A. Current.
   B. Goals and expectations.
   C. Obstacles to attainment of goals.

IV. References

V. Hydrographic Map.

VI. Management Plan.
   A. Objectives
   B. Proposed management action.
   C. Expected results.
   D. Evaluation plan.

**Comments on Preparing Status of the Fishery Resource Reports**

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

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

Formulation of the management goals will require some additional thoughtful consideration of the water body and the fish community. The logic leading to the management goals should be clear, and the supporting facts and observations should appear in the previous sections of the report. The management goals must be consistent with the goals of the Fisheries Division.

These reports should be updated following all surveys of the fish community.

The year of the fish survey should appear in the title; the date of the report's preparation should appear following the text of the report, just before the tables.

Reports may be cited as follows:

Dexter. J. L. 1991. Deep Lake (T3N, R10W, SECTION 26), Barry County, Surveyed September and October 1988. Michigan Department of Natural Resources, Status of the Fishery Resource Report 91-1, Ann Arbor.

The common names of fishes should follow the guidelines of the American Fisheries Society (AFS); see AFS Special Publication No. 12, A List of Common and Scientific Names of Fishes from the United States and Canada, Fourth Edition.

**Outline Contents**

Here follows the recommended outline, with a description of the suggested contents of each item in the outline.

I. Environment.

Most of this information may be found on the following survey forms: Lake (or Stream) Survey Summary, Lake Physical Description, Lake Area and Volume, and Limnology. These forms are descibed in the Manual of Fisheries Survey Methods.

A. Location.

Be sure to mention the distance to the nearest town.

B. Geology and geography.

Briefly relate the information on geology and geography to aquatic systems. For example, the presence of sandy soils suggests a potentially large influence of groundwater on the water temperature and chemistry of a lake or stream.

C. Watershed description (inlets, outlets, connecting waters, basin, and the associated Great Lake).

D. Chemical and physical characteristics.

E. Development, public ownership and access.

II. Fishery Resource.

A. History of the fishery.

Describe the fish stocks and the fishery as they were in earlier years along with known problems and management history.

B. Current status of the fish community.

Describe status of the fish community and the fishery, environmental conditions, and resource uses including conflicting ones. Most of this information should be found on the following forms descibed in the Manual of Fisheries Survey Methods: Fish Collection, Fish Growth Analysis, and Population Estimates.

1. Summary tables.

   These tables summarize the species of gamefish present, their size, growth, relative abundance, and ages.

C. Analysis and discussion.

Analyze the fish stocks, the fishery, and the physical/chemical environment. Compare their current status with what they were in the past. All major species should be mentioned, including species which require no current actions. Also, this water should be compared with similar waters, and these fish stocks with others in the state (or with statewide averages). This discussion places the known information about the water in perspective and lays the groundwork for long-range goals and expectations.

III. Management direction.

A. Current.

In addition to stocking or other actions, management will generally involve attention to habitat and water quality, and continued monitoring of fish population status.

B. Goals and expectations.

Describe what the status of the fishery could and should be in the far future (next 25 years). The success of all future management efforts will be measured by how much they move the fishery toward the goals set down here. Use the history of this water and performance of similar waters and comparable state waters as a guide to setting long-range goals for the fish stocks, the fishery, and the environment. Consider natural reproduction, growth, standing stocks (by age and size), species mix, access, and public use as factors in making a goal statement. Note that the relative health of the fish stocks and the fishery can be measured by how close the current status is to the long-term goals and expectations. On many of our best waters our long-term goal (or a major part of it) will be to maintain the excellent health of the fish community and the environment.

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

IV. References.

Cite references in the usual scientific report format.

V. Hydrographic Map.

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

VI. Management Plan.

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

A. Objective.

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

B. Proposed management action.

Give a more detailed description of proposal. For example: "Delay opening day on bass until the last Saturday in June and raise the size limit to 14 inches."

C. Expected results.

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

D. Evaluation.

State how you plan to evaluate the management action. For example,: "We will evaluate trout fishing from voluntary angler reports and will evaluate trout survival and growth via a tagging study beginning in 1994."

Tables

The format for each table is shown in the example status report for Deep Lake. Table 1 is included to show the species collected, their relative numbers and weights, and information about fish sizes. Table 2 indicates the growth rate for important species, with the corresponding Michigan growth index for comparison. Table 3 shows the estimated age composition of the population. If the sample is large enough, the mortality rate of the older fish can be estimated from this table. It should be apparent from this table whether or not strong and weak year classes are present in a population. Note that table entries are not simply the age frequency of the aged fish, but are values calculated for the entire population. Age frequency is computed by multiplying the number caught in each inch group by the proportion of each age class found in that inch group, and summing over inch groups to get the total number of fish of each age; the number in each age class is then converted to a percent of the total number of that species. See Mamual of Fisheries Survey Methods, Appendix VI-A-10, for an example.

Framework software is available to aid in table preparation. Starting with a computerized version of the FISH COLLECTION FORM and scale sample data, rough drafts of Tables 1, 2, and 3 can be easily generated. Alternatively, use spreadsheets outliSR1.FW3, outliSR2.FW3, or outliSR3.FW3 as typing tables.

*Michigan Department of Natural Resources*
*Status of the Fishery Resource Report 91-1, 1991*

# DEEP LAKE

*Barry County (T3N, R10W, Section 26)*
*Surveyed September and October 1988*

**James L. Dexter, Jr.**

## Environment

Deep Lake is a kettle lake of glacial origin located in west-central Barry County within the Yankee Springs Recreation Area (see map). It lies about 10 miles west of Hastings, Michigan.

Rolling hills and sandy soils characterize the geography of the area. The watershed is predominantly a mixture of mature oak and red pine forest, with a large amount of old fallow farmland returning to forest. The immediate area surrounding the lake is primarily scrub-shrub and wetland underlaid with well-drained loamy sand soils. One small unnamed inlet (top quality coldwater) is at the southern end of the lake and drains through Houghton muck soils. A small outlet, Turner Creek (top quality warmwater), is on the north end; its water flows to the Thornapple River in the Grand River watershed of Lake Michigan.

Deep Lake is 32.4 acres in size and up to 35 feet deep. Shoals, comprised primarily of sand and marl, cover 30-40% of the area. Vegetation is sparse except for cattails and rushes.

Water quality conditions were last surveyed on August 18, 1986. The water was colorless, and quite clear with a Secchi disk reading of 13 feet. Within the water column, alkalinity ranged from 134 ppm to 145 ppm and pH ranged from 7.4 to 8.4. These indicate the water is hard and well-buffered. Temperature varied from 77°F at the surface to 48°F at the bottom, with the thermocline occurring between 10 and 20 feet. Typically, summer oxygen levels are sufficient for fish down to a depth of 25 feet. Dissolved oxygen in the thermocline ranged from 5-10 ppm. Overall water quality is excellent and presents a very good environment for a two-story fishery, with a combination of warmwater fish in the upper layer and trout in mid-water.

Development around Deep Lake is very limited. The Yankee Springs Recreation Area maintains a campground (120 sites) and a public launch site on the northeast shore. There are a total of five buildings on the lake, but three of these are scheduled to be demolished in 1990, as the state has purchased this land recently.

## Fishery Resource

According to historical records, Deep Lake has been actively managed by the state since 1934, when largemouth bass were stocked. Bluegills, yellow perch, and more largemouth bass were stocked in varying numbers over the next 7 years. Rainbow trout fingerlings were stocked for the first time in 1942 and 1943 to try to create a two-story fishery.

In 1944, gill nets were used to evaluate the rainbow trout plants. No rainbows were found, but four large brown trout were captured. Hazzard (1944) suggested that brown trout had not been stocked for at least 10 years, and that these fish were presumably the result of natural reproduction (from the inlet). We have no records, however, of stocking prior to 1934.

The fish community in the 1930s and 1940s consisted mainly of bluegills, largemouth bass, and yellow perch. Ciscoes were reported by fishermen, but their presence has never been verified. Rock bass, black crappie, and pumpkinseeds were also available to the angler.

The fish community was most recently surveyed on September 29-30 and October 20-21, 1988. The netting effort entailed an overnight set of two trap nets and six gill nets and a second overnight set of the gill nets.

Today's fish community is similar to that of 50 years ago (Table 1). Large bluegills and perch remain the mainstay of the fishery. Other warmwater species are limited by the small amount of shoal habitat. Largemouth bass are not very abundant.

Northern pike are new to the lake. We netted a 40-inch pike in 1988, and in May 1989, a 43-inch pike weighing 20 pounds was caught by an angler and entered in the Master Angler Award program. Pike may have entered Deep Lake either through Turner Creek (which drains into the Thornapple River) or by an unapproved private introduction.

It is interesting to note that rainbow trout yearlings, stocked in the spring since 1966 at 43 per acre, formerly provided a very good fishery. In the mid-1980s, however, survival of stocked rainbows may have declined: catches dwindled, and fishing pressure dropped off. The 1988 survey revealed practically the same results as the 1944 survey—no rainbows but five wild brown trout. The decline in the rainbow fishery could be linked to the presence of northern pike. Just a few large pike could decimate the rainbow stockings. Beginning in 1989, management direction changed to stocking brown trout to supplement their low level of natural reproduction.

Growth rates of important game fish species are good (Table 2). Yellow perch are growing above state average, and bluegill are growing at state average. Wild brown trout are growing very rapidly.

Age composition and survival characteristics of sport fish appear to be normal, considering that relatively few fish were sampled and that the survey nets were not effective for small fish (Table 3). For perch and bluegill, young fish have been regularly recruited to the populations and the longevity of adults is satisfactory. Presence of age-II and age-III brown trout indicates that environmental conditions will be good for the carry-over of stocked trout from year to year.

Deep Lake produces larger bluegill and perch than many southern Michigan lakes due to a favorable combination of growth and survival. On a scale of 1 to 7 (Schneider 1990), the quality of the bluegill population ranked 4.8, "good". Bluegills as large as 8.4 inches, perch up to 11.1 inches, and brown trout up to 19.9 inches were taken during the 1988 survey.

Fishing on Deep Lake is a very pleasurable experience. It does not receive intense fishing pressure, and the water is clear and inviting. Water quality will be preserved because the state owns almost all the land surrounding the lake. Access is assured through the campground. Bluegills and yellow perch should continue to provide good fishing. Hopefully fishermen will key in on the brown trout now stocked. With only a few buildings visible from any point on the lake, and the good fishing available, the lake provides a high quality experience.

### Management Direction

This lake will continue to be managed as a two-story fishery. Currently the only special management practiced on Deep Lake is the annual stocking of 1,300 yearling brown trout. As very few lakes in southern Michigan are stocked with browns, we are not sure how good a fishery they will provide at Deep Lake. The possibility exists that a very high quality fishery will develop, as evidenced by the lake's history of large brown trout.

Our goals for the next 6 years will be to (1) maintain the bluegill and yellow perch fishery, and (2) develop the brown trout fishery.

No problems are expected to develop with goal Number 1; however, goal Number 2 may be difficult to reach. Brown trout are notoriously more difficult to catch than rainbows. We will rely heavily on reports from park personnel to determine if anglers are fishing for browns and their success rate. In addition, we may evaluate the brown trout fishery by tagging fish and soliciting tag returns from anglers.

Report completed: February 16, 1990.

**References**


Hazzard, A. S. 1944. Management check on Deep Lake, Barry County. Michigan Department of Conservation, Fisheries Research Report 970, Ann Arbor.

Schneider, J. C. 1990. Classifying bluegill populations from lake survey data. Michigan Department of Natural Resources, Fisheries Technical Report 90-10, Ann Arbor.


Table 1.—Number, weight, and length indices of fish collected from Deep Lake with gill and trap nets, September 29-30 and October 20-21, 1988.

| Species | Number | Percent by number | Weight (pounds) | Percent by weight | Length range (inches)[1] | Average length | Percent legal size[2] |
|---|---|---|---|---|---|---|---|
| Bullhead spp. | 84 | 38.9 | 34.8 | 36.4 | 5-12 | 8.9 | 92 |
| Bluegill | 53 | 24.5 | 8.9 | 9.3 | 5.2-8.4 | 6.4 | 55 |
| Yellow perch | 30 | 13.9 | 9.0 | 9.4 | 6.6-11.1 | 9.1 | 97 |
| Lake chubsucker | 15 | 6.9 | 3.5 | 3.7 | 6-8 | 7.5 | — |
| Pumpkinseed | 6 | 2.8 | 1.6 | 1.7 | 9-11 | 5.5 | 17 |
| Grass pickerel | 6 | 2.8 | 1.6 | 1.7 | 9-11 | 10.5 | — |
| Brown trout | 5 | 2.3 | 7.7 | 8.1 | 12.8-19.9 | 15.9 | 100 |
| Largemouth bass | 5 | 2.3 | 0.7 | 0.7 | 6.3-9.3 | 8.1 | 0 |
| Rock bass | 3 | 1.4 | 0.7 | 0.7 | 5-6 | 5.8 | 33 |
| Warmouth | 3 | 1.4 | 0.1 | 0.1 | 4 | 4.5 | 0 |
| Bowfin | 2 | 0.9 | 8.9 | 9.3 | 11-29 | 20.5 | — |
| Golden shiner | 2 | 0.9 | 0.3 | 0.3 | 7-8 | 8.0 | — |
| Northern pike | 1 | 0.5 | 16.2 | 17.0 | — | 40.2 | 100 |
| White sucker | 1 | 0.5 | 1.5 | 1.6 | — | 14.5 | — |
| Total | 216 | 100.0 | 95.5 | 100.0 | | | |

[1]Note some fish were measured to 0.1 inch, others to inch group: e.g., "5" = 5.0 to 5.9 inches; "12" = 12.0 to 12.9 inches; etc.

[2]Percent legal size or acceptable size for angling.

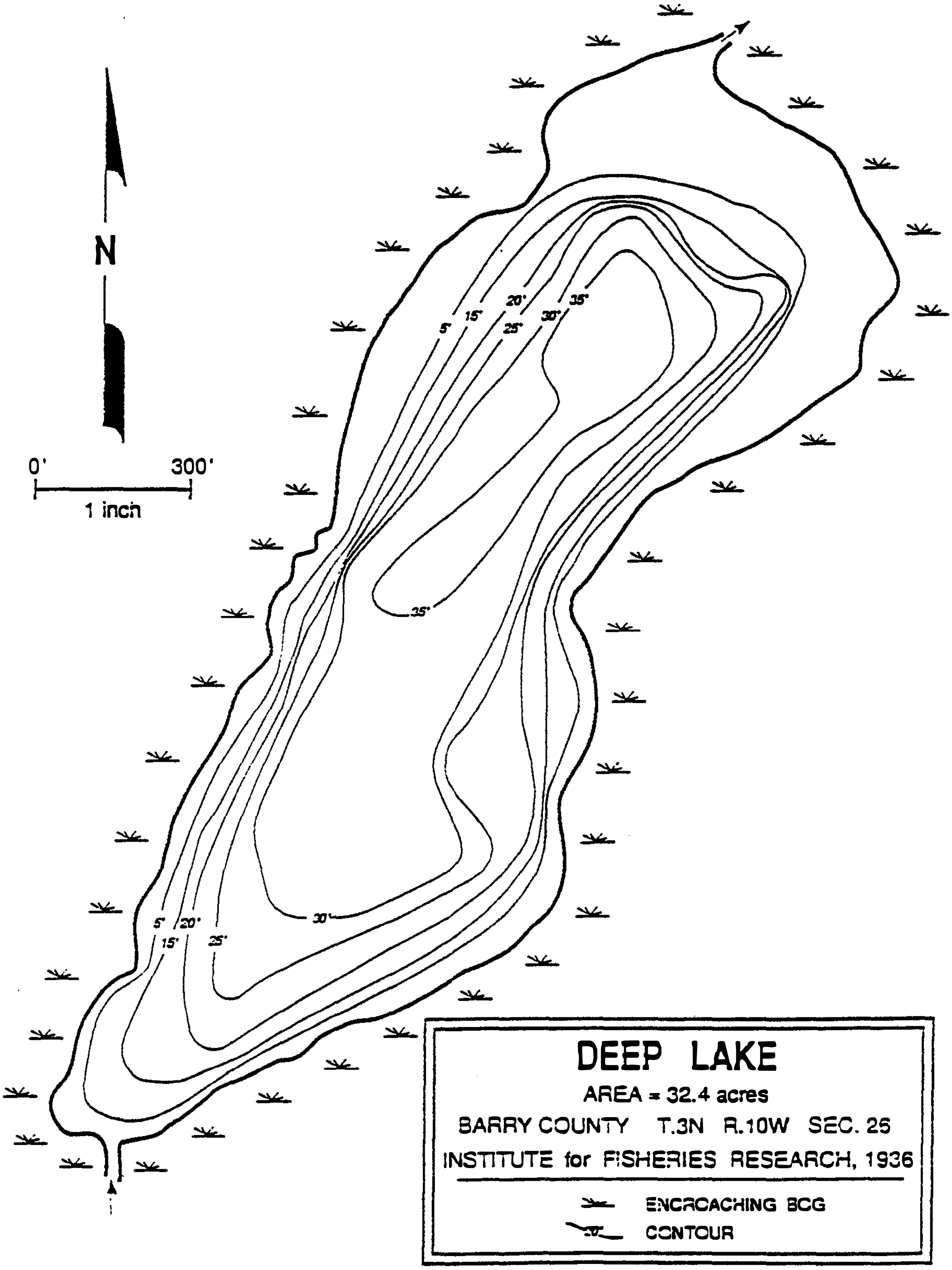
Table 2.—Average total length (inches) at age, and growth relative to the state average, for five species of fish sampled from Deep Lake with gill and trap nets, September 29-30 and October 20-21, 1988. Number of fish aged is given in parentheses.

| Species | Age | | | | | | | | Mean growth index[1] |
|---|---|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | VII | VIII | |
| Brown trout | — | 15.2 | 19.9 | — | — | — | — | — | — |
| | — | (4) | (1) | — | — | — | — | — | |
| Bluegill | — | 5.4 | 5.9 | 7.0 | 7.8 | 8.3 | — | — | +0.3 |
| | — | (3) | (9) | (13) | (3) | (3) | — | — | |
| Yellow perch | 6.6 | 8.0 | 8.7 | 9.7 | 11.1 | — | — | — | +1.2 |
| | (1) | (3) | (15) | (7) | (1) | — | — | — | |
| Largemouth bass | — | 7.4 | 9.3 | — | — | — | — | — | — |
| | — | (4) | (1) | — | — | — | — | — | |
| Northern pike | — | — | — | — | — | — | — | 40.2 | — |
| | — | — | — | — | — | — | — | (1) | |

[1]Mean growth index is the average deviation from the state average length at age.

Table 3.—Estimated age frequency (percent) of five species of fish caught from Deep Lake with gill and trap nets, September 29-30 and October 20-21, 1988.

| Species | Age | | | | | | | | Number caught |
|---|---|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | VII | VIII | |
| Brown trout | — | 80 | 20 | — | — | — | — | — | 5 |
| Bluegill | — | 15 | 40 | 32 | 8 | 5 | — | — | 53 |
| Yellow perch | 4 | 11 | 56 | 26 | 3 | — | — | — | 30 |
| Largemouth bass | — | 80 | 20 | — | — | — | — | — | 5 |
| Northern pike | — | — | — | — | — | — | — | 100 | 1 |


N
0'
300'
1 inch
5'
15'
20'
25'
30'
35'
35'
30'
5'
20'
15'
25'
DEEP LAKE
AREA = 32.4 acres
BARRY COUNTY T.3N R.10W SEC. 25
INSTITUTE for FISHERIES RESEARCH, 1936
ENCROACHING BOG
CONTOUR

# DEEP LAKE

*Barry County (T3N, R10W, Section 26)*

**MANAGEMENT PLAN**

*based on*

*Status of the Fishery Resource Report 91-1*

**James L. Dexter, Jr.**

Management goals based on the 1988 survey are twofold. Goal number one is to maintain the good bluegill and yellow perch populations and fisheries. No active management is proposed to achieve this goal. A possible obstacle to it is that heavy stocking of brown trout (goal number 2) may have a negative effect on panfish. This effect, and overall progress towards goal number 1, will be monitored by conducting another fish survey in fall 1994. Specifically, length-frequencies, growth rates, and catch rates of bluegill and yellow perch will be compared to data obtained in previous surveys.

Goal number two is to develop a high-quality brown trout fishery. Steps to achieve this goal include: (a) stocking of yearling brown trout at the rate of 40 per acre per year from 1989 to 1994; (b) public notification, through press releases, of the stocking change from rainbow trout to brown trout; (c) maintaining contact with park personnel to monitor angler results; and (d) resurveying the fish populations in fall 1994 to evaluate success. Some portion of the stocked brown trout may also be tagged to determine angler utilization via voluntary tag returns. The tagging phase will be implemented if similar projects now underway at other lakes indicate this type of tagging is a suitable evaluation tool.

We see few obstacles to the success of brown trout stocking. Water quality is good and trout have grown and survived well in Deep Lake in the past. A serious threat to success would be a buildup of northern pike, either from additional immigration or from the establishment of natural reproduction. Status of trout survival and growth, and of northern pike abundance, will be evaluated in the 1994 fish survey.

The expected yield to the fishery at Deep Lake is uncertain because brown trout are hard for anglers to catch and few other small lakes have been intensively managed for brown trout. Optimistically, perhaps 25% of the stocked fingerlings will eventually be harvested by anglers, an average of about 300 per year. Most will be harvested when they reach 10-14 inches in length, but a relatively large number may provide high-quality fishing at lengths of 18-22 inches.

Plan completed: February 1991
Approved: David Johnson, District Biologist, March, 1991
Donald Reynolds, Regional Biologist, March, 1991

# VI. APPENDICES

# Sample Size for Biological Studies

By G. P. Cooper and J. R. Ryckman

In a review of the subject of sample size, one must first make the decision of how precise an answer he wants. Here we deal with both non-discrete variables such as length and weight of fish which are measured along a continuous scale, and with discrete variables which are counted in units such as number of fin rays or number of lateral-line scales. Of more importance here is that we are dealing with characters which have a "normal" distribution, or a distribution which can be transformed to normal, and for which we can compute mean, standard deviation, and other parametric statistics.

In confronting the question of how large a sample is needed (how many fish must be measured), the starting questions are: (1) what level of confidence--95%, 99%, etc. -- do you want that your conclusion will be correct, and (2) how precisely do you want to estimate the true population mean? For example, for the latter question, if you measure a number of 3-year-old bluegills and their mean length figures out to be 6.3 inches, how narrow do you want your confidence limits to be about your sample mean, and at the same time be 95% confident that the population mean lies within these limits. In short, you need first to decide just how precise you want your sample mean to be, and what odds do you want that you are correct. The second bit of information one needs is a measure of the size variability in the population you are studying--how much do 3-year-olds in this lake vary in length? The statistical measure used is standard deviation(s). You must measure a few fish in advance, to get a prior figure on standard deviation; or you estimate standard deviation from your prior knowledge of length of 3-year-old bluegills in other waters. In practice, one often measures a "reasonable" number of fish and then computes the precision of his sampling after-the-fact; he can then decide on how much larger a sample he needs for the desired degree of precision.

Sample size (n) from formula $n = t^2 \frac{s^2}{L^2}$ for mean ± L, for 95% confidence limits

| L | L | Standard deviation (s) = $\sqrt{s^2}$ | | | | | | | | | | | | | | | | L | L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1.0 | 1.25 | 1.5 | 1.75 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 6.0 | 7.0 | 8.0 | 9.0 | 10.0 | | |
| | | .10 | .125 | .15 | .175 | .20 | .25 | .30 | .35 | .40 | .45 | .5 | .6 | .7 | .8 | .9 | 1.0 | | |
| 0.10 | 0.010 | 400 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 0.010 | 0.10 |
| 0.125 | 0.0125 | 250 | 400 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 0.0125 | 0.125 |
| 0.15 | 0.015 | 175 | 270 | 400 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 0.015 | 0.15 |
| 0.175 | 0.0175 | 130 | 200 | 290 | 400 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 0.0175 | 0.175 |
| 0.20 | 0.020 | 99 | 155 | 220 | 300 | 400 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 0.020 | 0.20 |
| 0.25 | 0.025 | 64 | 99 | 145 | 195 | 250 | 400 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 0.025 | 0.25 |
| 0.30 | 0.030 | 46 | 70 | 99 | 135 | 175 | 270 | 400 | .. | .. | .. | .. | .. | .. | .. | .. | .. | 0.030 | 0.30 |
| 0.35 | 0.035 | 34 | 49 | 73 | 99 | 130 | 195 | 290 | 400 | .. | .. | .. | .. | .. | .. | .. | .. | 0.035 | 0.35 |
| 0.40 | 0.040 | 27 | 40 | 57 | 76 | 99 | 155 | 220 | 300 | 400 | .. | .. | .. | .. | .. | .. | .. | 0.040 | 0.40 |
| 0.45 | 0.045 | 22 | 33 | 46 | 61 | 79 | 121 | 175 | 240 | 320 | 400 | .. | .. | .. | .. | .. | .. | 0.045 | 0.45 |
| 0.5 | 0.05 | 18 | 27 | 38 | 50 | 64 | 99 | 145 | 195 | 250 | 320 | 400 | .. | .. | .. | .. | .. | 0.05 | 0.5 |
| 0.6 | 0.06 | 14 | 20 | 27 | 36 | 46 | 70 | 99 | 135 | 175 | 220 | 270 | 400 | .. | .. | .. | .. | 0.06 | 0.6 |
| 0.7 | 0.07 | 11 | 15 | 21 | 27 | 34 | 52 | 73 | 99 | 130 | 165 | 200 | 290 | 400 | .. | .. | .. | 0.07 | 0.7 |
| 0.8 | 0.08 | 9 | 12 | 16 | 21 | 27 | 40 | 57 | 76 | 99 | 124 | 155 | 220 | 300 | 400 | .. | .. | 0.08 | 0.8 |
| 0.9 | 0.09 | 8 | 10 | 14 | 17 | 22 | 33 | 46 | 61 | 79 | 99 | 121 | 175 | 240 | 320 | 400 | .. | 0.09 | 0.9 |
| 1.0 | 0.10 | 7 | 9 | 12 | 15 | 18 | 27 | 38 | 50 | 64 | 81 | 99 | 145 | 195 | 250 | 320 | 400 | 0.10 | 1.0 |
| 1.25 | 0.125 | 5 | 7 | 9 | 11 | 13 | 18 | 25 | 33 | 42 | 53 | 64 | 91 | 123 | 160 | 210 | 250 | 0.125 | 1.25 |
| 1.5 | 0.15 | 5 | 6 | 7 | 8 | 10 | 14 | 18 | 24 | 30 | 38 | 46 | 64 | 87 | 112 | 145 | 175 | 0.15 | 1.50 |
| 1.75 | 0.175 | 4 | 5 | 6 | 7 | 8 | 11 | 14 | 18 | 23 | 28 | 34 | 48 | 64 | 83 | 105 | 130 | 0.175 | 1.75 |
| 2.0 | 0.20 | 4 | 4 | 5 | 6 | 7 | 9 | 12 | 15 | 18 | 22 | 27 | 38 | 50 | 64 | 81 | 99 | 0.20 | 2.0 |
| 2.5 | 0.25 | 3 | 4 | 4 | 5 | 5 | 7 | 9 | 11 | 13 | 15 | 18 | 25 | 33 | 42 | 53 | 64 | 0.25 | 2.5 |
| 3.0 | 0.30 | 2 | 4 | 4 | 4 | 5 | 6 | 7 | 8 | 10 | 12 | 14 | 18 | 24 | 30 | 38 | 46 | 0.30 | 3.0 |
| 3.5 | 0.35 | 2 | 3 | 4 | 4 | 4 | 5 | 6 | 7 | 8 | 9 | 11 | 14 | 18 | 23 | 28 | 34 | 0.35 | 3.5 |
| 4.0 | 0.40 | 2 | 3 | 3 | 4 | 4 | 4 | 5 | 6 | 7 | 8 | 9 | 12 | 15 | 18 | 22 | 27 | 0.40 | 4.0 |
| 4.5 | 0.45 | 2 | 3 | 3 | 3 | 4 | 4 | 5 | 5 | 6 | 7 | 8 | 10 | 12 | 16 | 18 | 22 | 0.45 | 4.5 |
| 5.0 | 0.5 | 2 | 3 | 3 | 3 | 3 | 4 | 4 | 5 | 5 | 6 | 7 | 9 | 11 | 13 | 15 | 18 | 0.5 | 5.0 |
| 6.0 | 0.6 | 2 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 5 | 5 | 6 | 7 | 8 | 10 | 12 | 14 | 0.6 | 6.0 |
| 7.0 | 0.7 | 2 | 3 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 5 | 5 | 6 | 7 | 8 | 9 | 11 | 0.7 | 7.0 |
| 8.0 | 0.8 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 5 | 6 | 7 | 8 | 9 | 0.8 | 8.0 |
| 9.0 | 0.9 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 5 | 5 | 6 | 7 | 8 | 0.9 | 9.0 |
| 10.0 | 1.0 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 5 | 5 | 6 | 7 | 1.0 | 10.0 |

Determination of sample size requires a preliminary estimate of <u>s</u> , and a decision as to an acceptable value of <u>L</u> .

(Footnotes to table on reverse side apply to the above table also.)

Sample size (n) from formula $n = t^2 \frac{s^2}{L^2}$ or mean ± L, for 99% confidence limits

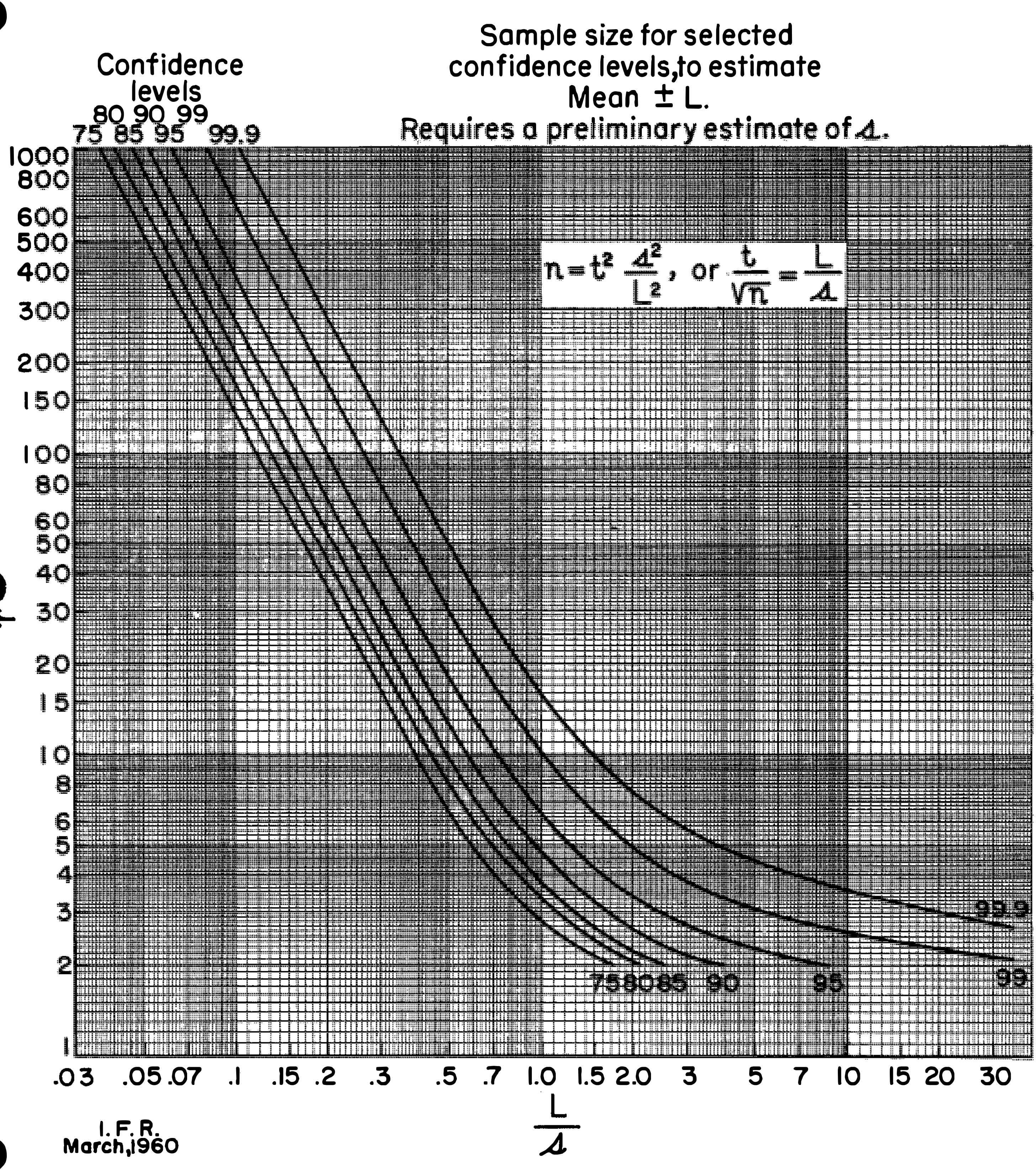
| L | L | Standard deviation (s) = $\sqrt{s^2}$ | | | | | | | | | | | | | | | | L | L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1.0 | 1.25 | 1.5 | 1.75 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 6.0 | 7.0 | 8.0 | 9.0 | 10.0 | | |
| | | .10 | .125 | .15 | .175 | .20 | .25 | .30 | .35 | .40 | .45 | .5 | .6 | .7 | .8 | .9 | 1.0 | | |
| 0.10 | 0.010 | 675 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 0.010 | 0.10 |
| 0.125 | 0.0125 | 450 | 675 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 0.0125 | 0.125 |
| 0.15 | 0.015 | 300 | 475 | 675 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 0.015 | 0.15 |
| 0.175 | 0.0175 | 230 | 360 | 500 | 675 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 0.0175 | 0.175 |
| 0.20 | 0.020 | 170 | 270 | 380 | 525 | 675 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 0.020 | 0.20 |
| 0.25 | 0.025 | 109 | 170 | 250 | 340 | 450 | 675 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 0.025 | 0.25 |
| 0.30 | 0.030 | 77 | 118 | 170 | 230 | 300 | 475 | 675 | .. | .. | .. | .. | .. | .. | .. | .. | .. | 0.030 | 0.30 |
| 0.35 | 0.035 | 57 | 88 | 125 | 170 | 230 | 340 | 500 | 675 | .. | .. | .. | .. | .. | .. | .. | .. | 0.035 | 0.35 |
| 0.40 | 0.040 | 45 | 68 | 97 | 135 | 170 | 270 | 380 | 500 | 675 | .. | .. | .. | .. | .. | .. | .. | 0.040 | 0.40 |
| 0.45 | 0.045 | 36 | 54 | 77 | 104 | 135 | 210 | 300 | 425 | 550 | 675 | .. | .. | .. | .. | .. | .. | 0.045 | 0.45 |
| 0.5 | 0.05 | 31 | 45 | 63 | 85 | 109 | 170 | 250 | 340 | 450 | 550 | 675 | .. | .. | .. | .. | .. | 0.05 | 0.5 |
| 0.6 | 0.06 | 23 | 32 | 45 | 60 | 77 | 118 | 170 | 230 | 300 | 380 | 475 | 675 | .. | .. | .. | .. | 0.06 | 0.6 |
| 0.7 | 0.07 | 18 | 25 | 34 | 45 | 57 | 88 | 125 | 170 | 230 | 280 | 360 | 500 | 675 | .. | .. | .. | 0.07 | 0.7 |
| 0.8 | 0.08 | 15 | 20 | 28 | 35 | 45 | 68 | 97 | 135 | 170 | 220 | 270 | 380 | 525 | 675 | .. | .. | 0.08 | 0.8 |
| 0.9 | 0.09 | 12 | 17 | 23 | 29 | 36 | 54 | 77 | 104 | 135 | 170 | 210 | 300 | 425 | 550 | 675 | .. | 0.09 | 0.9 |
| 1.0 | 0.10 | 11 | 15 | 19 | 25 | 31 | 45 | 63 | 85 | 109 | 145 | 170 | 250 | 340 | 450 | 550 | 675 | 0.10 | 1.0 |
| 1.25 | 0.125 | 8 | 11 | 14 | 17 | 21 | 31 | 41 | 55 | 71 | 89 | 109 | 150 | 220 | 280 | 360 | 450 | 0.125 | 1.25 |
| 1.50 | 0.15 | 7 | 9 | 11 | 13 | 16 | 23 | 31 | 39 | 50 | 63 | 77 | 109 | 150 | 195 | 250 | 300 | 0.15 | 1.50 |
| 1.75 | 0.175 | 6 | 8 | 9 | 11 | 13 | 18 | 24 | 31 | 38 | 47 | 57 | 81 | 109 | 145 | 180 | 230 | 0.175 | 1.75 |
| 2.0 | 0.20 | 6 | 7 | 8 | 9 | 11 | 15 | 19 | 25 | 31 | 37 | 45 | 63 | 85 | 109 | 145 | 170 | 0.20 | 2.0 |
| 2.5 | 0.25 | 5 | 6 | 6 | 7 | 8 | 11 | 14 | 17 | 21 | 26 | 31 | 42 | 55 | 71 | 89 | 109 | 0.25 | 2.5 |
| 3.0 | 0.30 | 4 | 5 | 6 | 6 | 7 | 9 | 11 | 13 | 16 | 19 | 23 | 31 | 39 | 50 | 63 | 77 | 0.30 | 3.0 |
| 3.5 | 0.35 | 4 | 5 | 5 | 6 | 6 | 7 | 9 | 11 | 13 | 15 | 18 | 24 | 31 | 38 | 47 | 57 | 0.35 | 3.5 |
| 4.0 | 0.40 | 4 | 4 | 5 | 5 | 6 | 7 | 8 | 9 | 11 | 13 | 15 | 19 | 25 | 31 | 37 | 45 | 0.40 | 4.0 |
| 4.5 | 0.45 | 4 | 4 | 4 | 5 | 5 | 6 | 7 | 8 | 9 | 11 | 12 | 16 | 20 | 27 | 31 | 36 | 0.45 | 4.5 |
| 5.0 | 0.5 | 4 | 4 | 4 | 5 | 5 | 6 | 6 | 7 | 8 | 10 | 11 | 14 | 17 | 21 | 26 | 31 | 0.5 | 5.0 |
| 6.0 | 0.6 | 3 | 4 | 4 | 4 | 4 | 5 | 6 | 6 | 7 | 8 | 9 | 11 | 13 | 16 | 19 | 23 | 0.6 | 6.0 |
| 7.0 | 0.7 | 3 | 4 | 4 | 4 | 4 | 5 | 5 | 6 | 6 | 7 | 8 | 9 | 11 | 13 | 15 | 18 | 0.7 | 7.0 |
| 8.0 | 0.8 | 3 | 3 | 4 | 4 | 4 | 4 | 5 | 5 | 6 | 6 | 7 | 8 | 9 | 11 | 13 | 15 | 0.8 | 8.0 |
| 9.0 | 0.9 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 5 | 5 | 6 | 6 | 7 | 8 | 9 | 11 | 12 | 0.9 | 9.0 |
| 10.0 | 1.0 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 5 | 5 | 5 | 6 | 6 | 7 | 8 | 10 | 11 | 1.0 | 10.0 |

Values of n computed to the nearest higher:
1 for n = 2-125
5 for n = 125-200
10 for n = 200-300
20 for n = 300-400
25 for n = 400-500

For values of t not given in Snedecor, t computed from:

$$t = K\left[1 + \frac{K^2 + 1}{4f} + \frac{(K^2 + 3)(5K^2 + 1)}{96f^2}\right]$$

where: f = n-1
$K(t_{.05}) = 1.9600$
$K(t_{.01}) = 2.5758$


Sample size for selected
confidence levels, to estimate
Mean ± L.
Requires a preliminary estimate of Δ.
Confidence levels
80 90 99
75 85 95 99.9
n = t² Δ²/L², or t/√n = L/Δ
n
L/Δ
75 80 85 90 95 99 99.9
I. F. R.
March, 1960

The formula for determining sample size (n) is given at the head of the accompanying tables; t is a statistic (from standard texts) which is related to the confidence level desired; L is 1/2 of your confidence interval about your sample mean. Attached tables give sample size for two confidence limits (95% and 99%) for specified values of L and standard deviation(s); the reader will have to familiarize himself on the computation of standard deviation:

$$s = \sqrt{\frac{\Sigma X^2 - \frac{(\Sigma X)^2}{n}}{n - 1}}$$

As a guide for the use of the attached tables, see the table for 95% confidence limits: under L run down to 1.0, and for standard deviation run along the top to the column head s = 2.0. Match the two, and you have a sample size of 18; that is, if you are dealing with measurements which have a standard deviation of 2.0, and you want to be 95% sure that your sample mean will be within 1.0 inch of the true population mean, you need a sample size of at least 18 measurements.

Supposing you were measuring something large, and you have a sample standard deviation of 10.0 units; now if you want to be 95% certain that your sample mean is within 1.0 unit of the true mean, you need the very large sample of 400 measurements.

The accompanying figure also presents the data on sample size for the confidence levels of 95% and 99%, and in addition for other confidence levels ranging from 75% to 99.9%. In the figure the fraction, L divided by s, is used for the horizontal (log) scale, and sample size (n) is read from the vertical (log) scale. Try applying to the figure, the example illustrated above (s = 2.0, L = 1.0, conf. lim. 95%), you will confirm the (same) sample size of 18.

I.F.R., 1960
Revised 3/11/76

# Population Estimates by Mark-and-Recapture

(for shocker runs, in streams)

By G. P. Cooper and J. R. Ryckman

Data from mark-and-recapture population estimates by the Petersen Method (simple proportion) are binomial data, since they deal with a certain proportion (p) of marked fish and another proportion ($q = 1 - p$) of unmarked fish. Where:

$N_1$ = number of fish caught, marked and released in first sample.

$N_2$ = total number of fish caught in second sample (including recaptures).

$N_{12}$ = number of recaptures in the second sample (of fish marked and released in the first sample).

$p = \frac{N_{12}}{N_2}$ (Note that p is estimated from the proportion of marked fish in the $N_2$ sample.)

$q = 1 - p = 1 - \frac{N_{12}}{N_2}$

Population estimate (Pop.) $= \frac{N_1 N_2}{N_{12}} = \frac{N_1}{p}$ Formula (1)

Variance of p $= \frac{pq}{n} = \frac{pq}{N_2}$ Formula (2)

Example: If the second sample contained 80 fish of which 10 were marked recaptures, p = 0.125.

$$\text{Var. of } p = \frac{(.125)(.875)}{80} = .001367$$

$$\text{Standard error of } p = \sqrt{.001367} = .037$$

Standard error of p $= s_{\bar{x}} = \sqrt{\frac{pq}{n}} = \sqrt{\frac{pq}{N_2}}$

For 95% confidence limits (Pop. ± L), $L = ts_{\bar{x}} = 2s_{\bar{x}} = 2\sqrt{\frac{pq}{n}}$

(where 2 is taken as the approximate value of t).

Thus $p \pm 2\sqrt{\frac{pq}{n}}$ is used to compute Pop. ± 95% confidence limits.

$$\text{Upper limit} = \frac{N_1}{p - 2\sqrt{\frac{pq}{N_2}}} \times \text{Lower limit} = \frac{N_1}{p + 2\sqrt{\frac{pq}{N_2}}} \qquad \text{Formula (3)}$$

The binomial theory for computing standard error of $p = \frac{pq}{n}$ requires that $npq > 9$. In the previous example, $N_2 = 80$, $p = .125$, and $q = .875$. Thus $npq = 8.75$ which falls somewhat short of the requirement, and in such an instance the confidence limits should be stated with the qualification that npq is slightly less than 9. If the values had been, say: $N_2 = 80$, $p = .25$, and $q = .75$, then $npq = 15$ and the requirement would be met.

Bailey (1951, Biometrika, 38: 293-306) gave a formula for the variance of the population estimate by the simple Petersen formula:

$$\text{Pop. est.} = \frac{N_1 \; N_2}{N_{12}}$$

$$\text{Variance} = \frac{N_1^2 \; N_2 \; (N_2 - N_{12})}{N_{12}^3} \qquad \text{Formula (4)}$$

He then pointed out that the above formula for Pop. is applicable where Pop., $N_1$, $N_2$ and $N_{12}$ all tend to be infinitely large; whereas with a population, say, of 1,000 and $N_1$ and $N_2$ about 100, the formula $\frac{N_1 \; N_2}{N_{12}}$ gives a biased estimate which is too large. Bailey gives an adjusted formula for population estimate, which should be used in most of our fish population estimates because such estimates generally involve populations numbering in the thousands or less, and $N_1$ and $N_2$ samples numbering in the hundreds. The adjusted formula, and its variance, are:

$$\text{Pop. est.} = \frac{N_1 \; (N_2 + 1)}{(N_{12} + 1)} \qquad \text{Formula (5)}$$

$$\text{Variance of pop.} = \frac{(\text{Pop. est.})^2 \; (N_2 - N_{12})}{(N_2 + 1) \; (N_{12} + 2)} \qquad \text{Formula (6)}$$

See Ricker (1958, Fish. Res. Bd. Canada Bull. 119, p. 84) for comments on Bailey's variance formula (6). Ricker states that, rather than use Bailey's formula for variance, it is better to obtain approximate confidence intervals from charts or tables of binomial distribution, such as the charts in Clopper and Pearson (1934, Biometrika, 26: 404-413). Photographic copies of the two charts of interest in Clopper and Pearson are attached to the present outline. See Ricker (pp. 85-86) for an example in determining confidence limits. The Clopper and Pearson charts give the same results as obtained by the use of Formulas (2) and (3) in the present outline.

To illustrate the use of the accompanying Clopper and Pearson charts (e.g., the one for 95% confidence), assume an $N_2$ sample of 50 fish of which 20 were marked recaptures. In this example, $p = \frac{x}{n}$ (in the chart) $= \frac{20}{50} = 0.40$. The confidence limits of p are read along the vertical line which ends at $\frac{x}{n} = 0.4$. For p = 0.4 and a sample size of 50, the 95% confidence limits of p are 0.27 and 0.55, and the confidence limits for the number of recaptures in a sample of 50 are $(0.27 \times 50 =)$ 13.5 and $(0.55 \times 50 =)$ 27.5 fish. Confidence limits for the population estimate are obtained by substituting 13.5 and 27.5 for $N_{12} + 1$ in the formula

$$\text{Pop. est.} = \frac{N_1 (N_2 + 1)}{(N_{12} + 1)}$$

In certain studies the investigator may desire to add several population estimates and have confidence limits for the total population. For example, one might have separate population estimates for 7-, 8-, 9- and 10-inch trout which could be added to give the total number of legal-size trout. Formulas (4) and (6) give variances in terms of numbers of fish, which can be pooled and can be used to determine confidence limits for the total population where separate estimates have been added. On the other hand, variances obtained from Formula (2) cannot be pooled, and therefore do not provide a method of determining confidence limits for total population where separate estimates are added.

In studies where population estimates are not to be added, the recommended procedure is to compute the population estimate by Formula (5), and compute its variance and confidence limits by Formulas (2) and (3) or by the Clopper and Pearson charts and the method described by Ricker (1958, pp. 84-86).

Where population estimates are to be added, and confidence limits for the total are desired, compute population estimates by Formula (5), and compute the variance of each estimate [1] by Formula (6). The variances can then be pooled.

Where confidence limits are computed from variance = $\frac{pq}{N_2}$, and where $p < 0.50$, which is usual in fish population studies, the lower "half" of the confidence interval is smaller than the upper "half" (see charts and the accompanying table). When the Bailey formulas (4) or (6) are used for variance, the confidence limits are equidistant from the estimate. Where variances from the Bailey formulas are used (either singly or pooled), allowance should be made for the fact that there is some error involved in the symmetry of confidence limits. Also, where variance is computed by the Bailey formulas, it would be safe to hold to the requirement that $N_2 pq > 9$.

The accompanying table is based on mark-and-recapture data for trout in Section E of the Pigeon River, 1955. Formulas (1), (2) and (3) are used in the upper part of the table; Formulas (5) and (6) in the lower part. The trout are grouped by 1-inch size classes because recapture rate with the electric shocker varies greatly with size of fish.

July 29, 1960
Revised 3/9/76

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[1] At an in-service session on statistics at Higgins Lake in January, 1960, Institute biologists worked out the sample problem in the accompanying table. Estimates were computed by Formulas (1) and (5), and variances by Formulas (2) and (4) but not by Formula (6). Formula (6) is the one recommended by Bailey, however.

Population estimates by mark-and-recapture, trout in Section E of Pigeon River, 1955

| Statistical function | Length of fish (inches) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 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+ |
| $N_1$ | 145 | 133 | 38 | 152 | 146 | 33 | 4 | 6 | 3 |
| $N_2$ | 143 | 176 | 45 | 136 | 119 | 28 | 7 | 2 | 4 |
| $N_{12}$ | 33 | 45 | 19 | 42 | 48 | 16 | 2 | 1 | 3 |
| $p = N_{12}/N_2$ | .231 | .256 | .422 | .309 | .403 | .571 | .286 | .500 | .750 |
| $q = 1 - p$ | .769 | .744 | .578 | .691 | .597 | .429 | .714 | .500 | .250 |
| $N_2pq$ | 25.4 | 33.5 | 11.0 | 29.0 | 28.6 | 6.9 | 1.4 | .5 | .75 |
| Pop. $= \frac{N_1 N_2}{N_{12}}$ | 628 | 520 | 90 | 492 | 362 | 58 | 14 | 12 | 4 |
| $s_{\bar{x}}^2 = \frac{pq}{N_2}$ | .00124 | .00108 | .00542 | .00156 | .00202 | .00875 | .02917 | .12500 | .04688 |
| $s_{\bar{x}} = \sqrt{\frac{pq}{N_2}}$ | .0352 | .0329 | .0736 | .0395 | .0449 | .0935 | .1708 | .3536 | .2165 |
| $L = 2s_{\bar{x}}$ | .070 | .066 | .147 | .079 | .090 | .187 | .342 | .707 | .433 |
| p + L | .301 | .322 | .569 | .388 | .493 | .758 | .628 | 1.207 | 1.183 |
| p - L | .161 | .190 | .275 | .230 | .313 | .384 | 0 | 0 | .317 |
| Pop. limits: | | | | | | | | | |
| $N_1/p + L$ | 482 | 413 | 67 | 392 | 296 | 44 | 6 | 5 | 2 |
| $N_1/p - L$ | 901 | 700 | 138 | 661 | 466 | 86 | ... | ... | 9 |
| Pop. $= \frac{N_1(N_2 + 1)}{N_{12} + 1}$ | 614 | 512 | 87 | 484 | 358 | 56 | 11 | 9 | 4 |
| Var. = $\frac{(\text{pop. est.})^2 (N_2 - N_{12})}{(N_2 + 1)(N_{12} + 2)}$ | 8228 | 4128 | 204 | 3653 | 1517 | 72 | 19 | 9 | 1 |
| $s_{\bar{x}} = \sqrt{\text{Var.}}$ | 90.7 | 64.3 | 14.3 | 60.4 | 38.9 | 8.5 | 4.4 | 3.0 | 1.0 |
| $L = 2s_{\bar{x}}$ | 182 | 129 | 29 | 121 | 78 | 17 | 9 | 6 | 2 |
| Pop. - L | 432 | 383 | 58 | 363 | 280 | 39 | 2 | 3 | 2 |
| Pop. + L | 796 | 641 | 116 | 605 | 436 | 73 | 20 | 15 | 6 |

In adding population estimates, as 56 + 11 + 9 + 4 = 80 fish over 7 inches, the pooled variance is 72 + 19 + 9 + 1 = 101, $s_{\bar{x}} = \sqrt{101} = 10$, L = 20, and 95% confidence limits are 80 ± 20.

## CONFIDENCE BELTS FOR p (CONFIDENCE COEFFICIENT ·95)

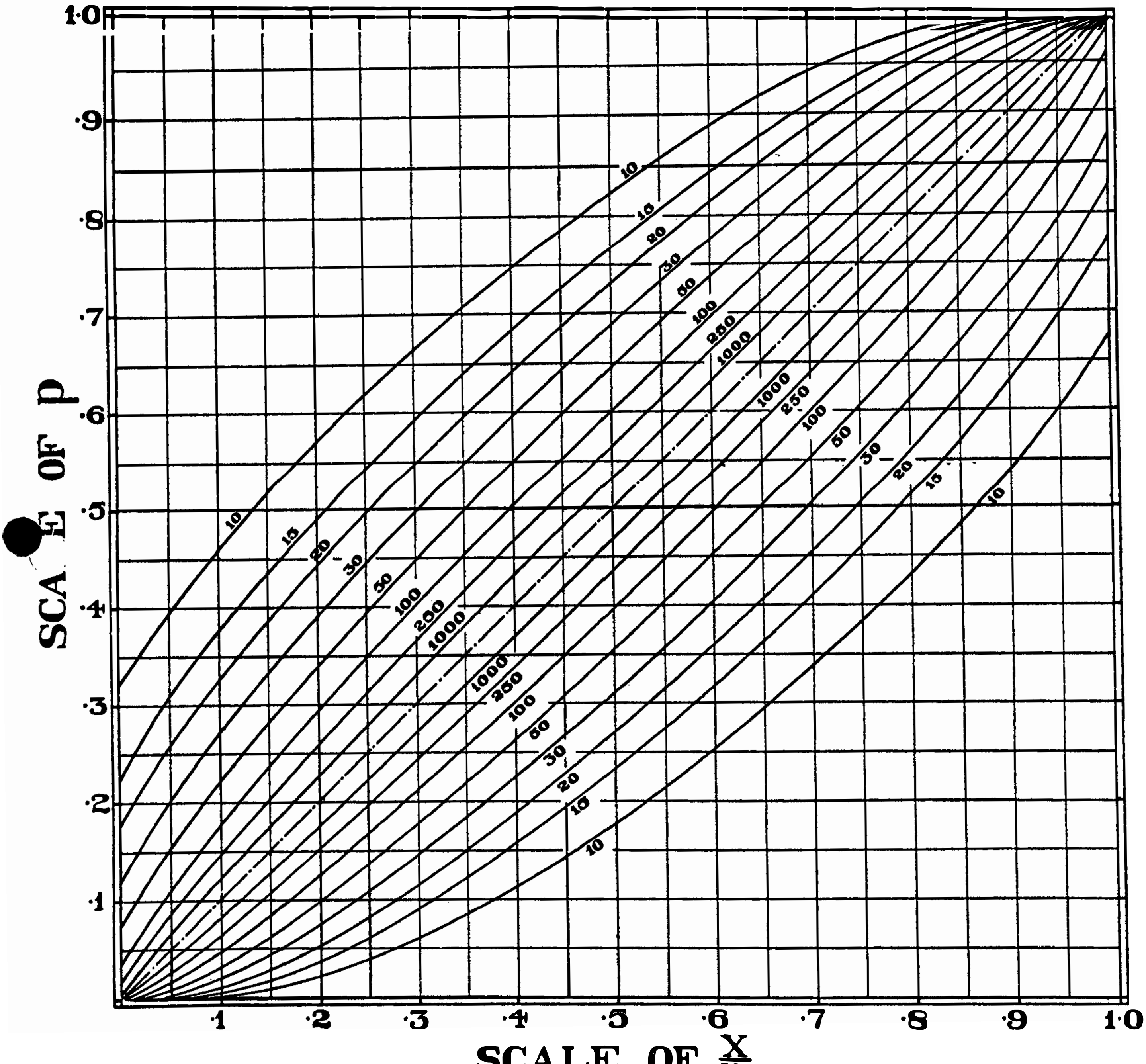


FIG. 4.

FROM: CLOPPER AND PEARSON (1934) IN BIOMETRIKA, 26: 404-413.

# CONFIDENCE BELTS FOR p (CONFIDENCE COEFFICIENT ·99)

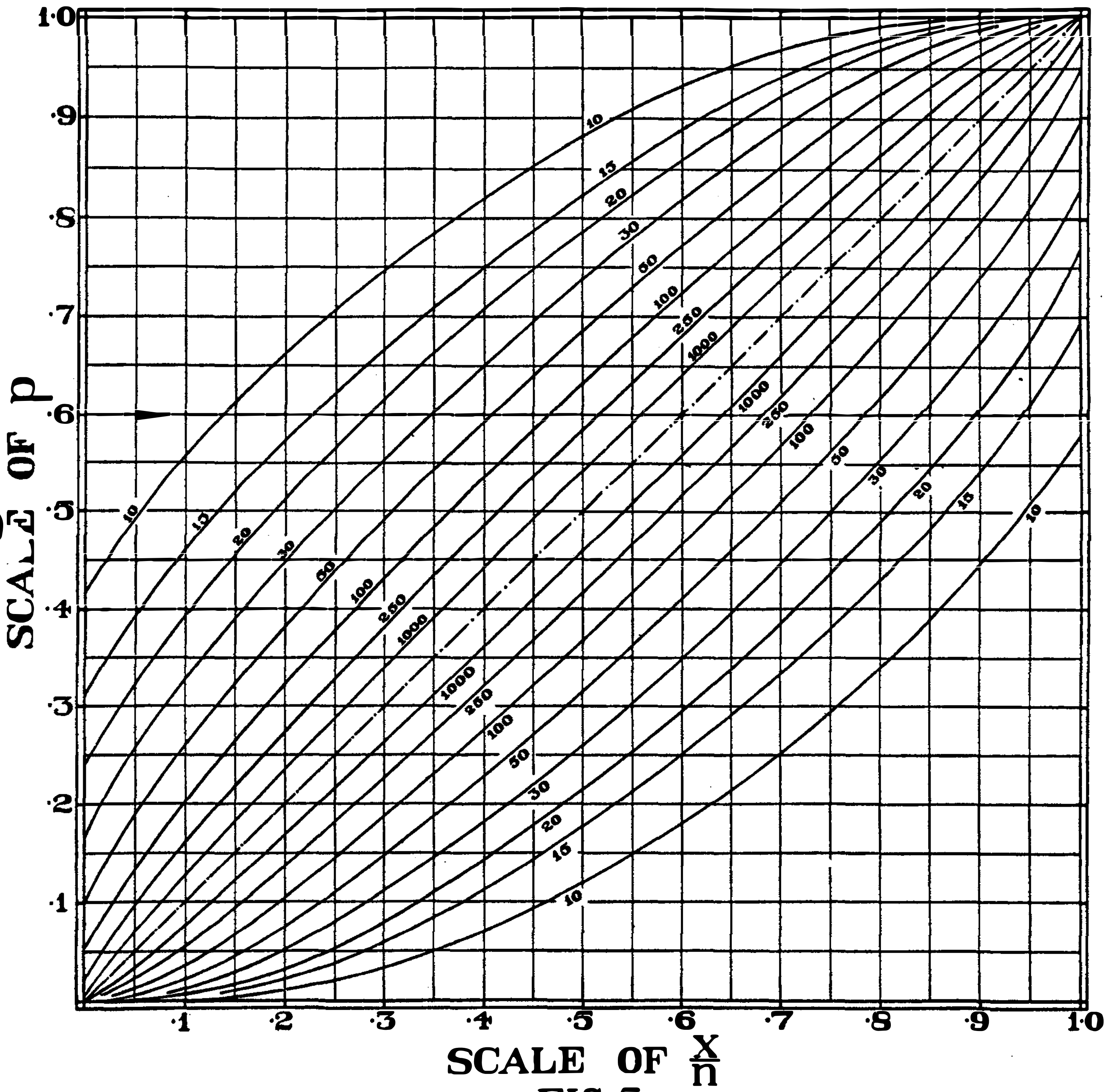


FIG. 5.

FROM: CLOPPER AND PEARSON (1934) IN BIOMETRIKA, 26: 404-413.

# Estimating Fish Populations in Lakes, from Net Catches Extending over Many Days

By Walter R. Crowe

To make population estimates by marking and releasing fish captured in nets over a period of many days, certain basic data must be tabulated from day to day. Estimates can be made by any one of several methods, but it has been found that the method developed by Dr. David H. Thompson and other workers is the most satisfactory for use in the field. The data, once collected and tabulated, may be applied to other methods of estimating (than the one here attributed to Thompson); but for all methods the required basic data are essentially the same.

Summarize for each day the following (treating each species separately):

1. Date.
2. Number of fish caught.
3. Number of fish marked and released.
4. Number of marked fish recaptured.
5. Number of marked fish present in the lake:

   a. At the beginning of the day--this figure does not include those fish marked and released during the day. It is this figure you will use in making an estimate for that day.

   b. At the end of that day--this figure does include those fish marked and released during the day, and you will use it in making your estimate for the following day.

   EXAMPLE:

   | Date | Caught | Marked | Marked fish present |
   |---|---|---|---|
   | July 1 | 10 | 10 | 0 |
   | 2 | 15 | 15 | 10 |
   | 3 | .. | .. | 25 |

   In the above example, note that the number of marked fish present at the end of July 2 is 25, but the figure will not be used until July 3.

6. Any fish found dead in the nets or killed in handling. These fish should be summarized in the day's catch, and any marked fish found dead must be subtracted from the total

of marked fish present. For instance, assume that at the beginning of operations on June 20, there were 250 marked fish present; that one marked recapture was found dead in the nets and was therefore removed from the lake; and that 10 additional fish were marked and released. On June 21 there would be 259 marked fish present, i.e., 250 plus 10 minus 1 dead in net. An occasional dead and marked fish will be observed on shore. The numbers of such fish which are marked should be subtracted from the total of marked fish present in the lake. Similar deductions should be made for marked fish removed by anglers. If the fishing is heavy, try to secure records of marked fish removed each day and modify the number of marked fish present before making the estimate. The numbers of unmarked fish removed by anglers are disregarded in making population estimates. The difference between recruitment and removal (by anglers) of game fish during the period of the population study theoretically would be reflected by a change in the daily estimates, provided that all marked fish lost from the population are recorded. Thus the daily figure for the number of marked fish present is very important.

7. Other pertinent data, such as weather and water temperatures, and changes in netting stations. (Data such as these usually will be desirable, but they are not an integral part of the estimating process.)

If the biologist is estimating the fish populations (one or more species separately) of a large lake (say 300 acres) by operating six to eight trap nets or fyke nets, he has a choice as regards to netting stations. He might use just eight netting stations positioned over the entire lake, and not move the nets during several weeks of netting. Or he might locate a much larger number of netting sites by some system of random selection, and then move the nets from station to station on an orderly schedule. In either event the fish which are marked and released each day should be liberated at some point away from the netting stations so that the fish are not unduly susceptible to recapture which they would be if released simply at the front of the net where first captured.

Separate records should be kept for each netting station, regardless of number of netting stations used. Reasons for keeping separate records for individual stations are: Certain species will be caught more readily at some stations than at others; nets will catch more fish at some stations; and individual station records will be of considerable assistance in judging the overall distribution of marked fish, and the general efficiency of the netting.

Records are combined for the lake as a whole in making the estimates. The calculation of the total population (by species separately) is based on the following assumption: If there are 1000 marked fish present in the lake on a given date and the nets on that date catch 10 marked fish (1%), it is assumed that the nets caught 1% of all fish (both marked and unmarked) in the lake. If the total number of fish caught on that date was 150, then the population estimate, based on the catch for that day alone, would be 15,000 fish. The method is expressed by the simple formula:

$$\text{Population} = \frac{\text{Total number of fish caught} \times \text{Total number of marked fish in lake}}{\text{Total number of marked fish recaptured}}$$

Thompson's method is to obtain accumulating summaries, for the several days of netting operations, of both numerator and denominator of the above equation; and these summaries are weighted according to the percent of the population made up of marked fish on individual days. Thompson's formula is:

$$P = \frac{\Sigma AB}{\Sigma C}$$

where,

P = estimated population on a given date

A = number of fish (both marked and unmarked) caught on that date

B = number of marked fish present in the lake on that date (see item 5a above)

C = number of recaptures on that date.

AB = product of A × B

ΣAB = sum of the calculated products of A × B to date

ΣC = sum of all recaptures to date

The following table contains the actual data and the figures used in estimating the largemouth bass population in Big Bear Lake, Otsego County, in the fall of 1946. The data were compiled from the results of the operation of several nets. For example the figures for September 16 were obtained from the following:

| Net number | Caught | Marked and released | Recaptures |
|---|---|---|---|
| 2 | 12 | 11 | 1 |
| 6 | 25 | 22 | 3 |
| 7 | 11 | 11 | 0 |
| 13 | 22 | 19 | 3 |
| Total | 70 | 63 | 7 |

It can be seen in the illustration that on September 16 there were 134 marked largemouth bass in the lake at the beginning of that day. On September 17 (at the beginning of that day) there were 197, i.e., 134 plus the 63 (70 captured minus 7 recaptures) which were initially marked and released on September 16.

Table 1.--Estimating population of largemouth bass in Big Bear Lake

| Date | A | B | AB | ΣAB | C | ΣC | P |
|---|---|---|---|---|---|---|---|
| September | | | | | | | |
| 5 | 5 | ... | ... | ... | - | .. | ... |
| 6 | 5 | 5 | 25 | 25 | - | .. | ... |
| 7 | 21 | 10 | 210 | 235 | - | .. | ... |
| 9 | 14 | 31 | 434 | 669 | - | .. | ... |
| 10 | 40 | 45 | 1,800 | 2,469 | 1 | 1 | 2,469 |
| 11 | 21 | 84 | 1,764 | 4,233 | 1 | 2 | 2,117 |
| 12 | 10 | 104 | 1,040 | 5,273 | 1 | 3 | 1,758 |
| 13 | 12 | 113 | 1,356 | 6,629 | - | 3 | 2,210 |
| 14 | 10 | 125 | 1,250 | 7,879 | 1 | 4 | 1,970 |
| 16 | 70 | 134 | 9,380 | 17,259 | 7 | 11 | 1,569 |
| 17 | 59 | 197 | 11,623 | 28,882 | 3 | 14 | 2,063 |
| 18 | 16 | 197 | 3,152 | 32,034 | 1 | 15 | 2,137 |
| 19 | 13 | 197 | 2,561 | 34,595 | 1 | 16 | 2,162 |
| 20 | 7 | 209 | 1,463 | 36,058 | - | 16 | 2,254 |
| 21 | 9 | 216 | 1,944 | 38,002 | - | 16 | 2,375 |
| 23 | 11 | 225 | 2,475 | 40,477 | 2 | 18 | 2,249 |
| 24 | 0 | 234 | 0 | 40,477 | - | 18 | 2,249 |
| 25 | 4 | 234 | 936 | 41,413 | 1 | 19 | 2,180 |
| 26 | 2 | 234 | 468 | 41,881 | - | 19 | 2,204 |
| 27 | 3 | 234 | 702 | 42,583 | - | 19 | 2,241 |
| 28 | 9 | 234 | 2,106 | 44,689 | 2 | 21 | 2,128 |

Separate estimates should be made for each species, and the total population (of all species) should be considered as the sum of the estimates for individual species. An alternative would be to combine the catch records for all species, and to calculate the total population for all species collectively. However, the total estimate obtained by this second method will ordinarily be smaller than the total obtained by computing for each species separately. The fallacy in the alternative method (all species considered collectively) lies in the fact that those species which are readily captured will have a greater effect on the total estimate than those species which are less readily caught. This is illustrated below by a theoretical example:

| | | | |
|---|---|---|---|
| a. Assume that your nets catch bass 10 times as readily as pumpkinseeds. | | | |
| b. Assume that the lake has a population of: | 100 bass | and | 4,000 pumpkinseeds |
| c. You catch and mark: | 10 bass (10% of bass) | | 40 pumpkinseeds (1% of pumpkinseeds) |
| d. Later you catch: | 5 marked bass and 45 unmarked bass (50% of all bass) | | 2 marked pumpkinseeds and 198 unmarked pumpkinseeds (5% of all pumpkinseeds) |

By using the formula $P = \frac{\Sigma AB}{\Sigma C}$ you calculate:

Bass population

| Date | A | B | AB | ΣAB | C | ΣC | P |
|---|---|---|---|---|---|---|---|
| 1 | 10 | 0 | 0 | 0 | 0 | 0 | ... |
| 2 | 50 | 10 | 500 | 500 | 5 | 5 | 100 |

Pumpkinseed population

| Date | A | B | AB | ΣAB | C | ΣC | P |
|---|---|---|---|---|---|---|---|
| 1 | 40 | 0 | 0 | 0 | 0 | 0 | ... |
| 2 | 200 | 40 | 8000 | 8000 | 2 | 2 | 4000 |

Sum of two populations equals 4, 100.

But if you calculate for both species combined

| Date | A | B | AB | ΣAB | C | ΣC | P |
|---|---|---|---|---|---|---|---|
| 1 | 50 | 0 | 0 | 0 | 0 | 0 | ... |
| 2 | 250 | 50 | 12,500 | 12,500 | 7 | 7 | 1786 |

Thus the combined estimate gives a value less than half as large as the figure obtained by adding the estimates made for the two species separately. Whether you are dealing with two species which differ in vulnerability to capture by the gear being used, or it applies just as well to different size groups, or different sexes, if there is a difference in vulnerability, the combining of data for purpose of the estimate always gives a total figure which is too small.

Other factors which unquestionably influence the estimate, besides the differential netting rate of various species, are:

1. Different habitat requirements of various species.
2. Migratory habits as related to the netting stations and the point at which marked fish are released in the lake.
3. Gear used.
4. Length of netting period.
5. Species present.

In order to minimize the above causes of error in the method, several practices are followed. All fish taken during the netting operations are released at a central point in the hope that they will redistribute themselves throughout the lake and not be unduly concentrated at the netting stations. Net locations should be selected with some care so as to improve the catch and have nets in all types of habitat. Do not hesitate to change the location of a net that does not catch fish; for, generally speaking, the greater the number of fish caught the more reliable will be the estimate. The period of netting should be prolonged until a considerable percentage of the population present has been marked, i.e., until a high ratio of marked to unmarked fish is obtained by the netting operations. Furthermore, the netting should be continued until the ratio of marked to unmarked fish in the catch remains fairly constant over a period of several days, and until the daily estimates of the population become quite constant.

If on one day half of the fish caught are recaptures, and the next day only 5% are recaptures, it indicates that the samples are not representative, and the netting should be continued. The formula (Thompson's) compensates to some extent for such variation, but it is when we obtain a constant percentage of recoveries from day to day that the estimate will be most reliable.

The question arises as to what percentage of the population must be marked in order to give a reliable estimate. In the study of the bass population in Big Bear Lake, a level of 5% to 8% (marked fish in the catch) gave quite consistent daily population estimates over a period of 10 days. In previous studies marked-fish percentages lower than 5% have given unreliable results. Obviously the necessary percentage level is related to the length of time over which the netting operations can be made. It is believed that the 5% level is adequate where netting for recoveries can be carried on for a period of 3 to 4 weeks; with a lower level, the netting period would necessarily be longer; and with a higher level, the period could be shorter. Generally, it is desirable to mark all available fish, in order to keep the length of the netting period at a minimum.

Insofar as possible all fish should be weighed and measured before being released. Recaptures should not be re-weighed and re-measured unless you are able to recognize individual fish. By taking weights and lengths, production (in pounds per acre, etc.) and average size of various species may be determined. Also an adequate series of scale samples should be taken from all species so that growth can be determined. In some instances you may want to follow population trends over the years, and keep track of year-class abundance; in that case you will want to take scale samples on some planned and systematic schedule. The taking of weights, lengths, and scale samples is not a part of the estimating process, but the information to be gained by taking them will greatly augment the whold study.

For any population estimate, a usual question is, what are its confidence limits? One set of formulae for variance and standard error of a population estimate are given by Schumacher and Eschmeyer

(1943) in Journal of Tennessee Academy of Science, Vol. 18, No. 3, pp. 228-249. Substituting the statistical notations given above (A, B and C), and using K for the number of days in the netting period, the Schumacher and Eschmeyer formulae are:

$$\text{Population estimate} = P = \frac{\Sigma(AB^2)}{\Sigma(BC)}$$

$$\text{Variance of population} = s^2 = \frac{1}{K}\left[\Sigma\left(\frac{C^2}{A}\right) - \frac{1}{P}\ \Sigma(BC)\right]$$

$$\text{Standard error of population} = s_{\bar{x}} = P\sqrt{\frac{Ps^2}{\Sigma(BC)}}$$

A value of twice the standard error gives approximately the plus and minus 95% confidence limits for the population estimates.

Prepared 3/18/47 by W. R. C.
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# Methods in Age and Growth Analyses of Fish

*J. C. Schneider, P. W. Laarman, and H. Gowing*

Scales of fishes are remarkable structures. Much information can be obtained on the growth history of a fish by close examination of the scales. How old is this fish? How can the age of a fish be determined? How does the growth rate compare with the average? These are common questions asked by anglers about fish they catch, especially about large ones. The fisheries biologist asks the same questions about all fish, for the growth of fish is an excellent index to the condition of a fish population.

Scales are bony structures growing shingle-like from pockets within the skin. The scales are covered with a very thin, outer layer of skin called the epidermis. Among Michigan fishes there are basically two kinds of scales: the ctenoid scale found on spiny-rayed fishes such as bass, sunfish, perch, and walleye; and the cycloid scale found on soft-rayed fishes such as trout, suckers, and northern pike (Figure 1). The ctenoid scale has small, sharp projections (ctenii); thus bass, sunfish, perch, and walleye feel rough to the hand. The cycloid scale lacks ctenii; thus trout, suckers, and northern pike feel smooth to the touch.

Scales start to form when the fish is about an inch long. The number of scales covering the body remains constant throughout the life of a fish, and in general, scale growth is proportional to growth in length of the fish. As the scale grows, ridges or circuli form around the edge. The pattern in which these ridges are formed is dependent upon how environmental conditions affect the fish. During the colder months when fish are relatively inactive and eating little, these ridges are crowded together. Incomplete ridges are the result of cessation of growth during the winter months. In the spring when feeding and growth are resumed, new ridges start to form and these are usually spaced farther apart. Also, the first new ridge in the spring cuts across the incomplete ridges. Year marks or annuli are characterized by crowded ridges and "cutting across".

Other factors may cause false annuli to be formed. Such things as extreme water temperatures, injuries to fish, or any stress that causes growth to stop for a period of

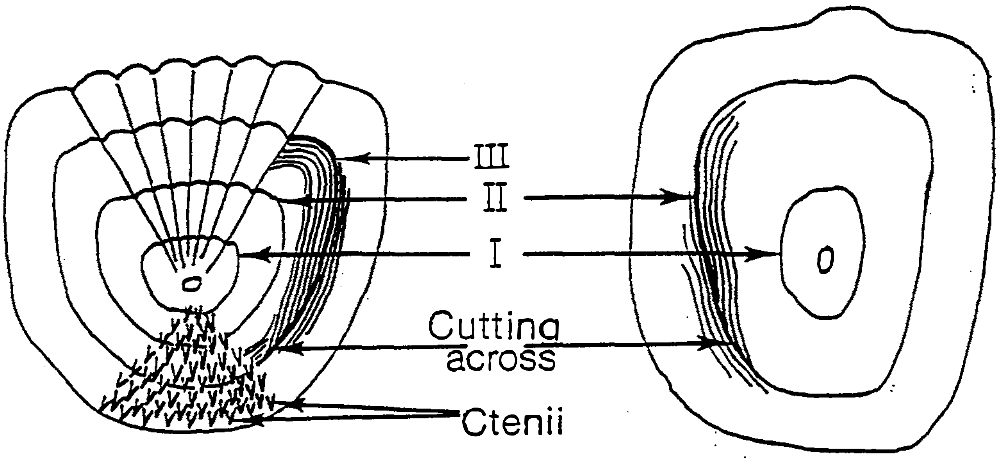


Figure 1.—Ctenoid scale of bluegill (left) and cycloid scale of sucker (right). Annuli are indicated by Roman numerals.

Other factors may cause false annuli to be formed. Such things as extreme water temperatures, injuries to fish, or any stress that causes growth to stop for a period of time during the normal growing season are responsible for false annuli. These marks may be similar in appearance to true annuli. False annuli are often characterized by showing "cutting across" on only one side of the scale, and may not be evident on all scales of a particular fish.

Extreme old age of a fish also confuses age determinations. As a fish becomes older, the growth rate slows down and the annuli are closer together. The result is that recognition of the later annuli of very old fish is difficult and sometimes impossible.

Some fish such as bullheads and catfish do not have scales. For these fish, a cross section of a spine or vertebra will show age-rings similar to the rings on trees. Scales of some species such as bowfin do not have annuli that can be recognized. Ear bones (otoliths) are sometimes used to determine the age of some species (e.g., burbot) on which scales are difficult to interpret.

## Recording data on scale envelopes

Accurate and complete information recorded on the scale envelope is essential to obtain the most value from a scale sample. One should give the following information:

Species. Give common name of the fish.

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

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

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

Date. The date when the fish was collected.

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

*Collector.*—Name of individual who caught the fish.

## Taking the Scale Sample

Age determinations are easier if care is used when taking the scale sample. Scale samples should be taken from a definite area on the fish. The recommended location on spiny-rayed fishes is just below the lateral line and below the middle of the spiny dorsal fin (Figure 2). For most soft-rayed fishes the area between the lateral line and the dorsal fin is preferred; for trout the best spot is directly below the lateral line beneath the posterior end of the dorsal fin (Figure 3).

About 25 scales should be taken from a fish. First, the mucous should be scraped from the spot where the scales are removed. This cleans the scales and makes processing easier. Then, scales are removed with a knife blade. The knife blade must be wiped clean after taking each sample to prevent mixing scales from two or more fish.

## Making Age Determinations

Preparing the scales for age determinations consists of placing four to six scales on a thin square of plastic (clear cellulose acetate, 0.5 mm thick) with sculptured side (side with ridges) down. The slide with the scales is sandwiched between two more pieces of plastic and run through a roller press, using enough pressure to make a distinct impression of the scales on the plastic slide. The plastic slide with the scale impressions is stored in the scale envelope from which the scales were taken. Only complete and normal scales can be used for age determinations. Abnormal or regenerated scales are often found on fish. When a fish loses a scale, it grows a new one, but new scales have no ridges in the regenerated area; thus they are useless for age determinations because the early part of the history of growth is lost.

To make age determinations (i.e., to "read" the scale), the plastic impression is viewed through a microprojector or microfiche reader which magnifies the impression up to 90 times. A binocular microscope provides suitable magnification for counting

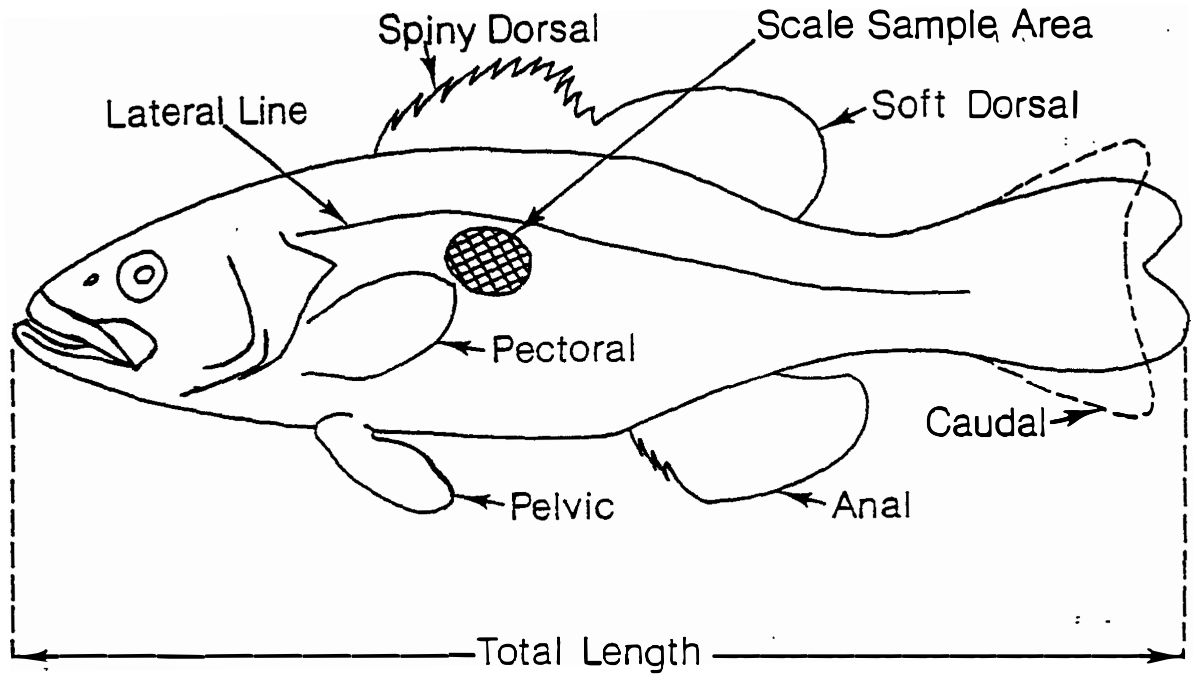


Figure 2.—Area for taking scale samples from a spiny-rayed fish.

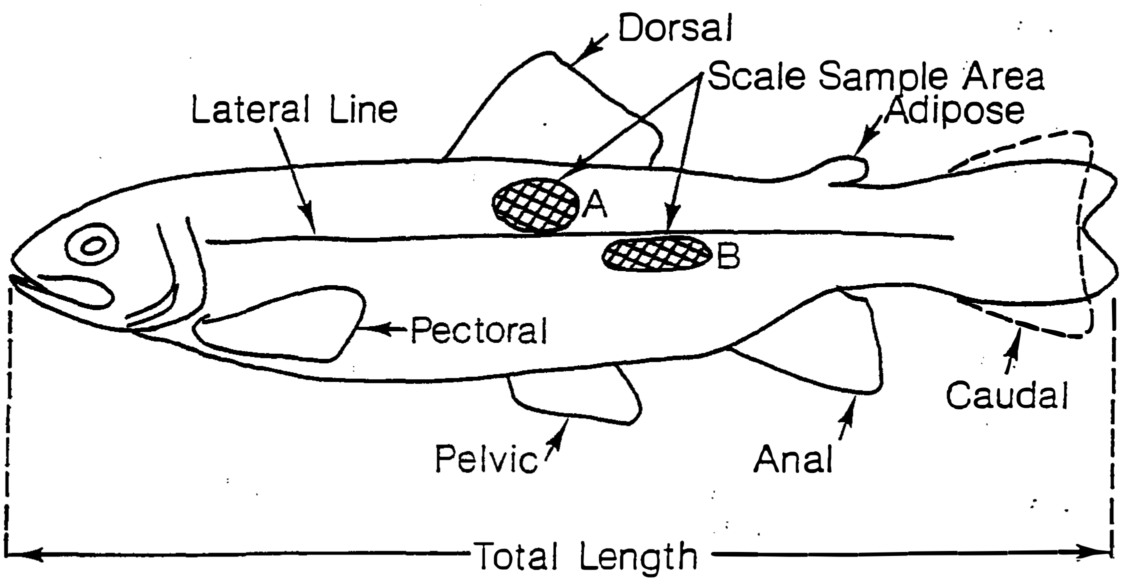


Figure 3.—Areas for taking scale samples from most soft-rayed fish (A) or trout (B).

year marks, but if the scales are to be measured, as is done in "back calculation", a microprojector is needed.

The age of a fish is determined by counting completed annuli (year marks) on the scale; the age is recorded on the scale envelope in Roman numerals.

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

## Back Calculation

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

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

1. Obtain scale samples from the same area of each fish. Ideally, use key scales because they have the same shape.

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

$$L=a+bS$$

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

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

The SCALE SAMPLE ANALYSIS form (8055) may be used for recording the measurements in Step 2. Computer analysis of the form is available, eliminating hand computation of Steps 3 and 4. Output of the computer analysis is the regression of fish length on scale radius, the back-calculated lengths at each annulus, and (if fish weights are reported) a length-weight regression.

Alternatively, a nomograph may be used to estimate $L_n$ while scales are being examined in Step 2. However, the intercept (a) will have to be determined first.

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

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

## Growth Summaries

Statewide average growth rates for many species of fish in Michigan have been determined from many years of collecting data in Michigan (Tables 1-3). More than 122,000 fish, representing 24 species, were used to calculate average length at age. The basic statistical unit used in determining the averages for each species was the mean length for each age group in each collection from each body of water; each mean was given equal weight in determining the final growth rate averages.

Sufficient data were available to compute average lengths attained at various months of the growing season for eight species of warmwater fish (Laarman 1963a). These data were plotted on graph paper and a smoothed stair-step curve was fit which reflected the known seasonal growth pattern (virtually all growth in length occurs between mid-May and mid-September). Similar curves were developed for walleye (Schneider 1978), tiger musky, and redear sunfish (data provided by Gary Towns). Comparable curves were developed for stream-dwelling brook, rainbow, and brown trout by graphing annual averages, smoothing them with straight lines, and then superimposing the seasonal growth pattern [determined by Cooper (1953) for age-0 and age-I brook trout in three streams]. Averages were recently developed for lake-dwelling trout and lake herring by plotting seasonal lengths at age and fitting linear regressions because no seasonal growth pattern was evident. (Trout growth does retard in mid-winter; however, considerable growth occurs in late fall and early spring, when warmwater fish are inactive.) For the most important species, Tables 1 and 2 contain the estimated average lengths at four-time periods during each age. For other species, refer to Table 3 for annual averages.

For simplicity, the lengths in Tables 1-3 will be taken as representative of waters throughout the state. Actually, there are regional differences in time of annulus formation, length of growing season, and growth rates (Beckman 1943; Laarman 1963b). Surprisingly, the average growth of bluegill and largemouth bass is better in Region I than in Region III. This indicates growth is more dependent on population density and relative food availability than on length of growing season. An additional problem with any average figure is that the time of annulus formation is not fixed but varies from year to year, depending upon spring weather. Even with these limitations, the lengths in Tables 1-3 are very useful and are to serve as standards for comparing the growth of fish populations in Michigan.

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

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

A growth index of 0.0 means that the sampled population is growing at exactly the state average rate for the species in question. An index of +1.0 inch means that the sampled population is growing 1.0 inch faster than average. In the following illustration, the bluegills sampled at Example Lake in June were growing, overall, 0.3 inch below the statewide average. The age group deviations ranged from +0.2 to -0.7; the growth index was -0.3.

| | Average length of each age group (Number of fish in parentheses) | | | | | |
|---|---|---|---|---|---|---|
| Species | I | II | III | IV | V | VI |
| Bluegill (Example Lake) | 3.2 (15) | 4.5 (3) | 5.2 (6) | 5.5 (17) | 6.4 (15) | 7.0 (5) |
| State average | 3.0 | 4.2 | 5.3 | 6.2 | 6.9 | 7.4 |
| Deviation | +0.2 | — | -0.1 | -0.7 | -0.5 | -0.4 |

$$\text{Growth index} = \frac{0.2 \ -0.1 \ -0.7 \ -0.5 \ -0.4}{5} = \frac{-1.5}{5} = -0.3 \text{ inch}$$

As a rule of thumb, satisfactory growth indices are in the range of +0.5 to -0.5 inch for panfish, and +1.0 to -1.0 inch for game fish. Thus the bluegills in Example Lake were growing rather slowly (-0.3 inch), but satisfactorily. Sometimes populations with growth rates as slow as -1.0 inch produce adequate numbers of large (and old) fish and provide satisfactory fishing.

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Table 1.—State average total length (inches) by age and month for important Michigan fishes.

| Age, and month | | Species | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Blue-gill | Pumpkin-seed | Redear sunfish | Rock bass | Black crappie | Yellow perch | Lake herring |
| 0 | Jan-May | | | | | | | |
| | Jun-Jul | | | | | | | |
| | Aug-Sep | | | | | | | |
| | Oct-Dec | 2.4 | 2.4 | 1.9 | 2.4 | 4.2 | 3.3 | 7.6 |
| I | Jan-May | 2.4 | 2.4 | 1.9 | 2.4 | 4.2 | 3.3 | 7.9 |
| | Jun-Jul | 3.0 | 2.8 | 2.8 | 3.0 | 4.8 | 4.0 | 8.2 |
| | Aug-Sep | 3.5 | 3.4 | 3.6 | 3.5 | 5.6 | 5.0 | 8.4 |
| | Oct-Dec | 3.8 | 3.8 | 4.4 | 3.9 | 6.0 | 5.2 | 8.7 |
| II | Jan-May | 3.8 | 3.8 | 4.4 | 3.9 | 6.0 | 5.2 | 8.9 |
| | Jun-Jul | 4.2 | 4.2 | 5.0 | 4.3 | 6.5 | 5.7 | 9.2 |
| | Aug-Sep | 4.7 | 4.6 | 5.6 | 4.8 | 7.2 | 6.3 | 9.5 |
| | Oct-Dec | 5.0 | 4.9 | 6.2 | 5.1 | 7.5 | 6.5 | 9.7 |
| III | Jan-May | 5.0 | 4.9 | 6.2 | 5.1 | 7.5 | 6.5 | 10.0 |
| | Jun-Jul | 5.3 | 5.2 | 6.9 | 5.4 | 7.9 | 6.8 | 10.3 |
| | Aug-Sep | 5.8 | 5.4 | 7.4 | 5.9 | 8.4 | 7.2 | 10.5 |
| | Oct-Dec | 5.9 | 5.6 | 7.6 | 6.1 | 8.6 | 7.5 | 10.8 |
| IV | Jan-May | 5.9 | 5.6 | 7.6 | 6.1 | 8.6 | 7.5 | 11.0 |
| | Jun-Jul | 6.2 | 5.8 | 8.0 | 6.4 | 8.9 | 7.8 | 11.3 |
| | Aug-Sep | 6.6 | 6.0 | 8.3 | 6.7 | 9.2 | 8.2 | 11.6 |
| | Oct-Dec | 6.7 | 6.2 | 8.7 | 6.9 | 9.4 | 8.5 | 11.8 |
| V | Jan-May | 6.7 | 6.2 | 8.7 | 6.9 | 9.4 | 8.5 | 12.1 |
| | Jun-Jul | 6.9 | 6.3 | 9.0 | 7.2 | 9.7 | 8.7 | 12.4 |
| | Aug-Sep | 7.1 | 6.5 | 9.1 | 7.6 | 10.0 | 9.2 | 12.6 |
| | Oct-Dec | 7.3 | 6.6 | 9.6 | 7.8 | 10.2 | 9.4 | 12.9 |
| VI | Jan-May | 7.3 | 6.6 | 9.6 | 7.8 | 10.2 | 9.4 | 13.1 |
| | Jun-Jul | 7.4 | 6.8 | 9.8 | 8.1 | 10.4 | 9.7 | 13.4 |
| | Aug-Sep | 7.6 | 7.0 | 10.1 | 8.4 | 10.7 | 10.1 | 13.7 |
| | Oct-Dec | 7.8 | 7.1 | 10.3 | 8.6 | 10.8 | 10.3 | 13.9 |
| VII | Jan-May | 7.8 | 7.1 | 10.3 | 8.6 | 10.8 | 10.3 | 14.2 |
| | Jun-Jul | 8.0 | 7.2 | 10.5 | 8.8 | 11.1 | 10.5 | 14.4 |
| | Aug-Sep | 8.1 | 7.4 | 10.7 | 9.2 | 11.3 | 10.9 | 14.7 |
| | Oct-Dec | 8.2 | 7.5 | 10.8 | 9.3 | 11.4 | 11.1 | 15.0 |
| VIII | Jan-May | 8.2 | 7.5 | 10.8 | 9.3 | 11.4 | 11.1 | 15.2 |
| | Jun-Jul | 8.4 | | | 9.4 | 11.6 | 11.3 | 15.5 |
| | Aug-Sep | 8.5 | | | 9.6 | 11.8 | 11.5 | 15.8 |
| | Oct-Dec | 8.6 | | | 9.8 | 11.9 | 11.6 | 16.0 |
| IX | Jan-May | 8.6 | | | 9.8 | 11.9 | 11.6 | 16.3 |
| | Jun-Jul | 8.7 | | | | | 11.7 | |
| | Aug-Sep | 8.8 | | | | | 11.9 | |
| | Oct-Dec | 8.9 | | | | | 12.1 | |
| X | Jan-May | 8.9 | | | | | 12.1 | |

Table 1.—Continued:

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

Table 1.—Continued: State average total lengths (inches) by age and month for trout in lakes and streams.

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

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

Table 2.-State average total length (millimeters) by age and month for important Michigan fishes.

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

Table 2.–Continued: State average total length (millimeters) by age and month for trout in lakes and streams.

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

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

Table 3.–Average annual total (inches and mm), at age, for Michigan fishes lacking established seasonal averages.[a]

| | Age group | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | 0 | I | II | III | IV | V | VI | VII | VIII | IX | X |
| Muskellunge | 6.8 | 15.7 | 19.9 | 25.4 | 31.9 | 34.7 | 36.8 | 39.2 | 41.7 | 45.3 | 48.7 |
| | 173 | 399 | 505 | 645 | 810 | 881 | 935 | 996 | 1,059 | 1,151 | 1,237 |
| Grass pickerel | 3.1 | 7.8 | 9.5 | 9.6 | 10.2 | 10.4 | 10.9 | | | | |
| | 79 | 198 | 241 | 244 | 259 | 264 | 277 | | | | |
| Warmouth | | 3.1 | 4.4 | 5.2 | 5.5 | 6.2 | 6.7 | 6.9 | 6.6 | 7.5 | |
| | | 79 | 112 | 132 | 140 | 157 | 170 | 175 | 168 | 191 | |
| Green sunfish | | 3.0 | 3.9 | 4.7 | 5.1 | 5.7 | 5.7 | | | | |
| | | 76 | 99 | 119 | 130 | 145 | 145 | | | | |
| Longear sunfish | 1.5 | 2.5 | 3.2 | 3.8 | 4.0 | 4.3 | | | | | |
| | 38 | 64 | 81 | 97 | 102 | 109 | | | | | |
| Rainbow smelt | | 5.3 | 6.9 | 7.7 | 8.1 | 8.8 | 9.6 | | | | |
| | | 135 | 175 | 196 | 206 | 224 | | | | | |
| White sucker | 3.5 | 8.6 | 12.0 | 14.3 | 16.3 | 16.9 | 18.1 | 18.1 | | | |
| | 89 | 218 | 305 | 363 | 414 | 429 | 460 | 460 | | | |

[a]Averages apply to the middle of the growing season, except for age-0 fish which were usually collected in the fall. Fish become 1 year older on January 1. Data are from inland lakes.

# Mapping Lakes with Echo Sounders

By B. V. Hughes and C. M. Taube

Echo sounders measure depth of water as a function of time for the transmission of sound waves to the lake or stream bottom and reception of the wave echoes back off the bottom. The time depends on the rate of speed of sound through water, which is about 4,800 feet per second. The sounder measures the interval of time required for a sound wave from a transducer to strike bottom and return to the transducer as an echo.

Briefly, the chain of events in a depth recording are as follows: The electronic unit of the sounding instrument produces electrical impulses that are converted into sound waves by the transducer. These waves are projected downward from near the surface of the water; upon striking the bottom, they are reflected and return to the transducer as echoes. When an echo is received, an electric current effected by this vibration is amplified and discharged to record the depth on a chart, and the rapid succession of echoes results in a continuous line of recordings.

Echo sounders are of two general types; one type momentarily flashes the readings on a dial, and a second type records readings graphically on paper. The latter instrument is the more practicable of the two for mapping lakes. Two distinct advantages of the (latter) instrument are that (1) it produces permanent recordings that can be handily checked for accuracy, and (2) depth recordings can be transcribed at convenience by virtue of their permanent character. The discussion that follows is confined to instruments of the recording type.

## Equipment

The structure of graph-type echo sounders is described here, based on the Bendix D R-10 Depth Recorder and the Raytheon Fathometer, Model D E-119. The recording unit is composed of an electronic section and a mechanical section. The components of the electronic section produce the electrical impulses and amplify the echoes to a voltage sufficient to mark the recording paper. A converter changes current from a 6-volt storage battery to suitable voltages.

In preparation for use, the recording unit of the sounder may be mounted on a board cut to fit between the gunnels near mid-length of the boat, with the board clamped to each gunnel. If the transducer is installed on the outside of the boat, it may be mounted in a small, streamlined wooden hull ("fish") to reduce turbulence. Some newer model transducers are streamlined and are not mounted in a wooden hull. The reason for streamlining is that air bubbles created by a wake or other turbulence may reflect sound waves and thereby interfere with reception. The transducer can be installed in several different ways. It may be mounted on the side of the boat, externally on the bottom of the boat, or internally inside the hull. Mounting on the side is recommended for use in mapping. Presently the transducer unit is attached to a wood lever with spring tension and is mounted on the side of the boat.

Equipment for mapping includes a row boat (a 12-foot boat is satisfactory) and an outboard motor (5 1/2 hp). Other equipment includes a battery charger, a tracing of the shore outline of the lake prepared from an aerial photo, a mounting board for the tracing, a notebook for sounding-run records and other data, a compass, a cable for horizontal measurements, a sounding cable equipped with a bottom sampler, a pole (preferably bamboo) for shallow-water soundings, and either a dumpy level and stadia rod, or a chalk line and line level, for establishment of bench marks. A hammer and spikes are needed for setting up bench mark monuments.

## Mapping Procedure

The field crew consists of two men: one who navigates the boat and another who operates the sounder. In selecting sites for sounding traverses, distinctive landmarks should be chosen (which are recognizable both on the lake itself, and on the map outline of the lake) to maintain a straight course for each traverse. The procedure in starting a run depends on the kind of sounder that is used. With an instrument of the Bendix D R-10 type, runs are started and ended at the shoreward limit of 5-foot depths as this instrument does not give discernible readings for water shallower than this depth. (The graph paper used with this instrument is calibrated in fathoms.) The 5-foot contour is located for the starting point with the sounding pole and the distance of this depth from shore is measured and recorded. Then the outboard motor and the echo sounder are started and a run is made at uniform speed toward the goal on the opposite shore. At the opposite shore the 5-foot contour is located again and its distance from shore recorded. It is necessary that boat speed be uniform so that water depths can be transcribed accurately from the sounder graph to the work outline. This uniformity is required to make the horizontal straight-line distance from the beginning to the end of the graph recording proportionately comparable to the actual distance of the run and also to the represented distance on the work map, i.e., the graph revolves at a uniform speed, therefore the boat speed must also be uniform. It follows that though the boat speed of each run must be uniform, different (uniform) speeds for the various runs are permissible.

With a sounder of the Raytheon Fathometer D E-119 type, sounding may be done in depths as shallow as 2 or 3 feet. (The graph paper used with this instrument is calibrated in feet.) Distances to shore from the beginning and from the end of a run with the sounder are measured and recorded as with the Bendix D R-10.

Numerous traverses are run from shore to shore and each is numbered on the base map as well as on the sounder graph paper. Many runs are recorded successively on one sheet of graph paper. If the curvature of the shoreline is fairly uniform, most (if not all) of the traverses may be made parallel to each other; change in direction of successive traverses is apt to be necessary when the shoreline is marked with bays or other distinctive irregularities. The number of sounding runs required on a given lake must be determined largely by the operator's judgment; basins that have numerous depressions will of course require more sounding than basins of uniform declivity. Ordinarily, lakes with a surface area of around 100 acres require 20 to 30 sounding runs; lakes with highly irregular bottoms require more extensive checking than those with fairly uniform bottoms. The operator should be sure to identify the lake by name and location on the graph. This can be done with pencil. When the recordings for a given lake are completed, this section of the graph paper is removed from the roll.

Now and then it may be necessary to sound with the hand line to verify echo sounder readings. This is done where an indistinguishable recording (characterized by fuzziness) results from dense vegetation. Such checks are also made when the instrument is suspected of improper function due to mechanical failure.

Another use of the hand line is determination of bottom soil types. A sample of the bottom is retained in a cup at the base of the sounder weight. The number of samples taken depends on extent of variation of soil types.

If corrections need to be made on the work outline (because of changes that have occurred on the lake since the aerial photo was taken), these corrections are made by the mapping crew while at the lake. Also, shore features (slopes, wooded areas, marsh, etc.) are entered on the work chart. Establishment of a bench mark completes the field work.

Later on, at a work table, depths are transcribed from the sounder graph to the work chart. Simple proportion is used in plotting the depths. Equal divisions are marked off both on the sounder chart recordings and on the traverse lines of the work chart. The depth shown at each division mark on the recording is determined and then transcribed to the corresponding mark on the traverse line. The number of divisions may range from three to seven or more equal parts, the number depending on the length of the traverse and the amount of depth data required for accurate contours. After a sufficient number of depths have been recorded on all traverse lines, the depth contours can be drawn.

## Sounder Operation Instructions

Refer to the instrument manual for detailed instructions on operation. The following comments are merely precautions and hints that will aid in operation, and apply specifically to the Bendix D R-10 Depth Recorder and the Raytheon D E-119 Fathometer. These suggestions may or may not apply to other sounders.

Adjustment of the power output regulates the uniformity and density of the recording trace. A strong vibration is required to register the surface of flocculent bottom in deep water. However, excess volume (sensitivity) may result in secondary reflections that are recorded on the graph as showing twice the actual depth. Also, excess power will burn the stylus point. The sensitivity (volume) control is adjusted at various depths so that there will be adequate power to produce a legible recording.

If the stylus point has been burned, the stylus will need to be readjusted. A spare stylus, an additional vibrator, and a complete extra set of tubes should be carried in the spare parts kit.

A fully charged storage battery will supply sufficient power to operate the sounder for about 8 hours. It is advisable to carry an extra battery for use while the other one is being recharged.

Dense vegetation is apt to cause false readings. When such difficulty occurs, the hand line or sounding pole will have to be employed. Where extensive areas are involved, mapping of the lake may need to be postponed until late fall or early spring when density of aquatic vegetation is minimal.

## Preparation of the Work Chart and Tracing

The work chart is prepared from an aerial photo which shows the outline of the lake to be mapped. Scales of the photos presently available are too small for lake mapping work. Hence the work chart consists of an enlargement of the photo, made with transparent sheet plastic grids and gridded map paper.

The grid cards are of clear plastic material that are marked with lined squares by a sharply pointed metallic instrument. Cards that are used have 2, 3, 4, 5, 6, 8, or 10 divisions in each linear inch (4, 9, 16, 25, 36, 64, or 100 sections per square inch). Outside dimensions of the cards range from 3 inches to 12 inches square. The size to be employed depends on the size of the photographic outline of the lake. The grids are subject to shrinkage and should be checked from time to time for accuracy. Usually they need to be replaced with new grids within a period of months.

For example, assume that a grid with 5 divisions to an inch is taped over the outline of a lake on an aerial photo the true scale of which is 1 inch equals 1,760 feet. We wish to enlarge the outline 5 times for the work chart. A section of shoreline that extends between successive division lines on the grid card is to be transcribed by inspection onto the sheet of map paper that is to show the work outline. The ends of this section to be transcribed will be 1/5 inch apart under the grid and 1 inch apart on the work chart. Since the lake outline from the one on the photo is enlarged 5 times, the scale of the enlargement will be 1 inch equals 352 feet (1, 760 ÷ 5).

After transcription of the shore outline, islands, roads, trails, and any other prominent features associated with the lake and which appear on the photo, are plotted on the chart. If shoal areas are evident on the photo, their outlines are also shown on the chart (with broken lines, for example) to aid in orientation at the time of mapping.

Nearly always the given scale for the aerial photo needs to be corrected because of primary error and/or inaccuracy due to shrinkage of the photographic print. In such cases the correct scale must be determined before the work chart can be prepared. Correction is made by comparing measurements of spread between points on the aerial photo where the actual distance is known (e.g., township section lines). The points of dividers or calipers are placed on two points on the photo whose distance apart is known, and then the divider spread is measured with an engineer's ruler. This measurement is compared with the measurement expected from the scale given on the aerial photo. A measurement of about 3 inches should be used for comparison. Corrections are computed on the basis of 40 parts to the inch.

If the photo lacks bases for checking scale accuracy and correction of scale, the check and any required correction must wait until the lake is visited when on-the-spot measurements can be taken between landmarks that appear on the photo.

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EXAMPLE: The scale given on an aerial photo is 1 inch equals 1, 666 feet. One mile represented on the photo is found to contain 120 1/40-inch units.

120 ÷ 40 = 3 inches

5, 280 ÷ 3 = 1, 760 feet

Therefore, 1 inch on the photo now actually represents 1, 760 feet rather than 1, 666 feet.

If the lake shown on the photo is enlarged 4× on the work chart:

$1,760 \div 4 = 440$

The scale on the work chart is 1 inch = 440 feet.

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In preparing the work chart, the grid card is taped (with masking tape) over the lake outline on the aerial photo. With pencil, small sections of shoreline are progressively transcribed, by inspection, from the photo to the map paper (that has been marked off in 1-inch squares) and by reference to the grid divisions.

Before the lake is to be sounded, the accuracy of the shore outline on the work chart is checked. This precaution is advised because the shoreline may have changed since the aerial photo was taken or the position of some of the shoreline may have been misinterpreted from the photo. The check is made on a run around the lake by boat. If corrections are necessary, these are made before sounding commences. Shoreline corrections are made with a common alidade, compass, and measuring cable. Positions of roads, trails, streams, etc., are also checked, and when desirable additions can be entered, these too are plotted on the work chart.

Final touches on the map are made in the laboratory. First, the work chart is carefully examined to see that all the required information is recorded correctly. The agency (if different from the one preparing the new map) responsible for the aerial photo is given a credit line and the date of the photo is recorded. Then the map is prepared for photographic "blow-up" to a standard scale. Over the past 40 years (of lake mapping and drafting) most maps have been drawn on a chart with outside dimensions 22 inches × 34 inches. In the final "blow-up" the scale selected is the one permitting maximum enlargement of the lake outline, but selected from the following scales (feet of lake dimension to each inch of final map): 25, 50, 75, 100, 150, 200, 300, 400, 600, 800, 1000, and 1200.

At the time of revision of this outline, lake maps are being drafted by the Engineering Division of the MDNR.

Prepared 2/6/57
Revised 3/10/76

# Instructions for Winter Lake Mapping

By C. M. Taube

This memo outlines the standards for lake maps and is intended to help the less experienced technician in the performance of his job. It will bypass those techniques with which the crew leader should already be familiar.

Because the Fish Division now does most of its mapping by the baseline-grid system on frozen lakes, the discussion will point toward this method, although the comments will generally apply also to other methods.

## Equipment

A check list of equipment and supplies is given in a following table. Although this list applies specifically to winter work, most of the items are also used in other methods.

Below are precautions which apply to the care and use of the battery-powered ice drill; this applies to the drill developed in the Research section.

1. Keep the bit or auger covered with the protective block when the drill is not in actual use.
2. Two sets of small set screws on the shaft of the drill must be kept tight with an Allen wrench, to guard against loss of the auger.
3. Drilling should be done with the drill perpendicular to the ice; there is danger of bending the auger if drilling is done at an angle.
4. Do not use the drill in very shallow water, as the auger can be ruined by stones or frozen earth. Over very shallow places, use a spud.

For lake soundings, the advantage of the drill is the time it saves on thick ice. Spudding is more efficient on relatively thin ice (to about 4-6 inches thick).

Check list of lake mapping equipment and supplies

Car
Sled and riggings
Ice drill
Augers (2, for drill)
Oil can
Batteries, storage (2)
Battery charger
Battery cables (2 extra)
Battery strap
Hydrometer
Ice spud
Plane table and tripod
Compass
Alidade
Alidade, right-angle, with tripod
Cables, 100-ft. measuring, with reels (2)
Cables, 100-ft. sounding, with reels (2)
Sounding weights (2)
Level, surveyor's, with tripod
Leveling rod
Level, line
Chalk line
Spikes (8-in, for bench marks)
Hammer, heavy
Cold chisel
Wrench, Allen
Pliers
Axe

Shovel
Ice creepers
Yard stick (or 6-foot steel tape)
Ruler (12-inch plain)
Ruler (12-inch engineer's triangular)
Clipboard
Map paper
Gridded work sheets (8 1/2- X 11-in)
Lake Mapping Record forms
Road map (state)
Map book (county)
Directory (Department personnel)
Personnel forms (Time & Attendance, etc.)
Diaries
Note books
Scratch paper
Stationery and postage
Mailing tubes
Parcel post labels
Pencils, #3 or #4 lead
Pencils, #2 lead
Erasers
Paper clips
Rubber bands
Thumb tacks
Masking tape
Instructions memo

Mapping data should be recorded on standard map paper, 22 inches × 34 inches, which is gridded with either 1/3-inch or 1/2-inch square divisions to assist with measurements. Sometimes the paper has shrunk so that the divisions are reduced in size. In this case, allowances must be made for the shrinkage when using the grid for measurements. With regard to soundings, there are two alternatives: (1) the recorder measures distances between the sounding locations on the map, rather than determining them with the printed grid, or (2) the actual distances between soundings are reduced to match the grid on the shrunken paper--e.g., if the map shrinkage amounts to 2% and if soundings were to be made at 200-foot intervals, the interval as measured on the ice should be reduced to 196 feet (for a 2% reduction).

Gridded 8 1/2-inch × 11-inch work sheets are provided for convenience in plotting the shoreline, especially on large lakes. Sections of shoreline may be sketched on these sheets for transfer to the map, which eliminates repeated transport of the map between the baseline and shore.

## Mapping Procedure

<u>Access to lakes</u>.

As to ownership and access, lakes are classed as follows:

1. Public lakes. Those having some publicly owned frontage, such as county park, public fishing site, state or federal land, etc.
2. Semi-public lakes. Those whose shores are entirely owned by private interests but on which the public is allowed to fish without charge; those with boat liveries, and those with navigable streams that lead to public access sites.
3. Private lakes. Those from which the public is excluded or charged a fee for access.

Any public lake may be mapped. Semi-public lakes ordinarily are mapped, but should not be mapped if there are clear indications that public fishing is likely to be prohibited in the near future. Private lakes should not be mapped, except in special instances, or on a consulting basis at private expense.

Lake outline

The map should be planned so the north direction will be located somewhere within the top half of the sheet. Symbols, legend, sounding data, etc., are to be entered parallel with the top border.

Choose a scale which will allow the lake outline to fill a large part of the sheet, but which will also allow ample room for shore features, the heading, and legend. One of the following scales (feet to 1 inch) should be used: 25, 50, 75, 100, 150, 200, 300, 400, 600, 800, 1000, 1200.

A feature sometimes overlooked is that of encroaching shore. This type of shoreline borders marshy areas where the lake's edge is not clearly defined; i.e., at high-level stages the lake covers adjacent land which is uncovered at normal or low-level stages. Indication on the lake map of encroaching shore can be very helpful to fisheries workers and to people who are buying frontage.

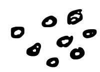
Soundings

The spacing of soundings has important bearing on both mapping accuracy and progress. Insufficiency of depth records may result in an inaccurate map, or one that does not give adequate information for management. On the other hand, over-intensive sounding wastes time and effort.

It is difficult to prescribe a definite pattern for spacing depth measurements, because of the broad variability among lake basins. Good decisions on how frequently soundings should be made will increase with experience. Following is a general guide when mapping is done on ice: on lakes of about 5 acres, soundings at 50-foot intervals are recommended; on 10-25 acres, 100-foot intervals; 50-300 acres, 200-foot intervals; larger lakes, 300- to 400-foot intervals. Additional soundings are often necessary between shore and the drop-off, in and around shoal areas that occur well out from shore in some fairly deep lakes, and throughout the basins of lakes in which depths are highly variable. Incompleteness of depth data may become evident as a set pattern of sounding is in progress; in such cases additional measurements should be made in the questionable area.

Soft bottom can account for significant errors in depth measurements. It may be so soft that the sounding weight passes into it almost as freely as through water. In such areas the sounding must be done with extreme care, and the cup which collects bottom materials should be inspected often to determine the top level of the deposits. After some experience, one acquires a "feel" for the difference in descent of the weight through water and through very soft bottom, which helps greatly in locating the boundary between the two strata.

A cup is attached to the lower end of the sounding weight to retain a sample of the bottom deposit when a depth is measured. The kind of deposit present at each measuring site is determined, and is recorded on the map with the depth figure--e.g., 4-S, 10-M, etc. If goodly quantities of two soils occur together in a sample, indicate the presence of both, listing the key letter of the predominant type first. Below is the classification of bottom deposits currently in use for lake maps, including the key letters and the symbol used on completed maps to show the distribution of each material:

| | | | |
|---|---|---|---|
| Organic | - O | Gravel | -  |
| Marl | - M | Rocks | -  |
| Sand | - S | Bed Rock | -BR |

The physical characteristics and usual locations of these materials are:

<u>Organic.</u>--Consists of decomposed or partially decomposed parts of plants. It may have any of a variety of colors, and generally has a smooth texture but often contains plant fibers. This is the most prevalent deposit of deep areas, but also may occur in shallow locations.

Marl.-- Gray in color, often gritty, pieces of snail or clam shells frequently included. This deposit may sometimes be mistaken for clay, especially if smoothly textured. When hydrochloric acid is dropped on a questionable sample, boiling action will ensue if it is marl, but not if it is clay. This is a fairly common lake bottom soil, which may be found in either shallow or deep places.

Sand, gravel, rocks, bed rock.--Identities are quite familiar. Sand is generally confined to shallow areas of inland lakes. (That is, the sand which appears at the surface of the bottom; sand probably is quite widely distributed in many Michigan lakes, but in the deeper places is usually covered by other soils.) Gravel may be differentiated from rocks by setting a 3-inch diameter limit on stones for the gravel category. It usually is difficult to pick up gravel with the sampler; sound or vibration from the sounder cable can help identify gravel and rock deposits.

Shore features

The sample legend on a following page illustrates the various features and their symbols which apply to our lake maps.

Formerly it was customary to show on the maps all or many of the cottages and other buildings present on lake shores. This practice has been discontinued because it often is impractical to show all homes or cottages, and on some lakes continuous building activity has tended to out-date such maps. However, for the sake of orientation, prominent structures (hotels, isolated homes, etc.) should be included. Leave out boat docks unless they are quite substantially constructed, but include boat houses situated over or near the water.

Public fishing sites are to be shown (with boundaries, if conveniently possible), as are the locations of other public frontage and semi-public establishments (boat liveries, Boy Scout camps, etc.). Buildings associated with such developments need not be plotted.

Roads and trails near the lake should be included. Their widths are not drawn to scale, but their distance from the shoreline should be to scale, and their compass directions true. Record the names or numbers of highways that have these designations.

Bench marks

Bench marks are established for measuring lake level fluctuations. They can be very useful. Trees, bridge or dam abutments, and concrete foundations are among the objects which serve as bench mark monuments. Spikes serve as reference points in trees; a cold chisel is used to mark concrete or steel objects. Measurements of water elevations are made with either a surveyor's level and leveling rod, or a line level, chalk line, and leveling rod or a pole. Measurements and locations of bench marks must be plainly recorded on the map, including the date of establishment. Bench marks should be established and recorded at the time the lake is mapped, so that the bench mark elevation will be related to the finished lake map.

Our system of presenting water-level data assigns the figure 100 as the level of the bench mark. The lake level reading appears as the difference between this figure and the distance in feet that the lake surface lies below the bench mark. For example, if the water surface is 3.8 feet lower than the bench mark at the time of mapping, the lake surface is 96.2, which is simply 100 minus 3.8.

The vertical measurements for level determinations should be recorded on the field map. Following is a sample computation from measurements made with a surveyor's level and leveling rod:

| | |
|---|---|
| Rod reading above water level | 6.78 feet |
| Rod reading above bench mark | -2.64 feet |
| Bench mark above water level | 4.14 feet |

100.00 - 4.14 = 95.86 = water surface elevation
(rounded off to 95.9 on the drafted map)

The computation is simpler if a line level is used; it consists of subtraction from 100 of the height above the lake surface that the leveled chalk line meets the measuring rod. This equipment is adequate if the bench mark is near the edge of the lake (within 50 feet or so). The

## Legend

### Bottom

| | |
|---|---|
| O | Organic |
| M | Marl |
| S | Sand |
| | Gravel |
| | Rocks |
| BR | Bed rock |
| | Deadheads (or snags) |
| | Stumps |
| | Brush shelter |
| | Trash |

### Outline and Contours

| | |
|---|---|
| | Shoreline |
| | Encroaching shore |
| | Breakwater |
| — 5' — | Contours |

### Shore features

| | |
|---|---|
| | Improved road (applying to gravel or pavement) |
| | Unimproved road |
| | Trail (foot trail, not passable for cars) |
| | Railroad |
| | Bridge |
| Culvert | (no symbol; use word "culvert" with arrow to show location) |
| | Building (if public or semi-public, also designated as "Hotel," "Store," etc.) |
| | Boathouse |
| | Dock |
| | Steep slope (use in series, showing course of formation) |
| (W) | Wooded |
| (PW) | Partly wooded |
| (P) | Pasture (or cleared land) |
| (C) | Cultivated land |
| | Brush |
| | Marsh |
| | Spring |
| | Inlet |
| | Intermittent inlet |
| | Outlet |
| | Intermittent outlet |
| | Dam |
| | Beaver dam |
| | Beaver house |
| | Bench mark |

surveyor's equipment may always be used, and is preferable when the bench mark is some distance from the lake.

Occasionally a bench mark may be higher above the lake than the maximum height of the leveling rod. In such situations it is necessary to make the level determination in successive steps from the bench mark to the lake, resetting the rod and adding the successive heights.

Below are cautions and guides on bench mark procedure:

1. Be sure you are thoroughly familiar with level determination and methods. The data are of no value if inaccurate. If a line level is used, place it on the chalk line approximately midway between the bench mark and the rod or pole at the other end.
2. Place the bench mark higher than the estimated maximum level of the lake. When a tree is chosen as a monument, drive the spike in near the base of the trunk, leaving at least 3 inches of the spike exposed.
3. Try to establish three bench marks at each lake that is mapped. One level monument was provided formerly, but loss of the bench mark at some lakes has pointed up the need for more than one.
4. Try to space the bench marks widely apart to insure against loss of all of them.
5. If public frontage is available, locate at least one of the bench marks there. Avoid yards of homes as locations.
6. If avoidable, do not place bench marks in willows, poplars, or birches, because these trees deteriorate rapidly if they die. Elms definitely should be bypassed because of the prevalence of Dutch elm disease. At some lakes, however, scarcity of suitable objects for monuments permits little choice.

Agencies other than the Fisheries Division have established bench marks at some lakes. At least in some instances, you will be informed if this has been done for any lakes on your mapping schedule. If a bench mark has already been provided for a lake that is to be mapped, its location, a new level determination made from it, and its original level data are to be included on the map. New level readings obtained from these previously established references should be expressed in the terms of the original data, which are usually sea level data.

Mapping crews may be asked to set up additional bench marks for lakes that have been mapped and which have a Fish Division bench mark. In such instances it is always necessary to obtain a water level reading from the original bench mark the same day the new reference points are installed.

## Completing the Map

### Depth contours

Contours are drawn after the sounding has been completed. Drawing contours while the crew is still located in the vicinity of the lake is advisable so that additional soundings can be made if required.

Ordinarily, space contours are drawn at 5-foot intervals to depths of 20 feet, and at 10-foot intervals beyond 20 feet. Exceptions are: (1) situations in which all or most of a lake is less than 5 feet deep (where either 2-foot contour intervals or no contours at all may apply), and (2) lakes in which the declivity is too abrupt to permit drawing contours with intervals of less than 10 feet. However, in situations of the latter kind, try to enter the first contour at the 5-foot level if at all possible.

Contour curves are to be rounded rather than pointedly abrupt. Where a recorded depth is identical to a contour interval, carry the line a little to the deeper side of the depth's location rather than through it; where several equal depths occur successively in a shore-to-deeper-water direction, draw the contour to the sounding near the middle of the series.

Contours naturally tend to parallel each other; be suspicious of the depth data if the contours deviate extremely from this tendency.

Too few soundings or erroneous records can account for marked variations; repeated and/or additional sounding may be necessary.

Bottom soils

Indicate bottom soil types by symbol, as listed previously. If only one kind of soil was found over the whole lake, a note on this fact is sufficient, e.g., "The entire bottom is organic." If one or more types are associated with another type that strongly predominates, the predominant type should be shown by symbol, whereas the subordinate types may be designated merely by notation.

Miscellaneous data

Other data which need to be recorded on the field map are the name of the lake, its location as to township tier, range, and sections (down to the quarter section if there is a chance the lake can be confused with another in the same section), the names of the persons who did the mapping, the dates spent on the job, and the scale. Be sure to record the scale which actually applies to the lake, and not one you had intended to use but discarded later, or one (not applicable to this map) unintentionally carried over from another map.

Printed forms (the Lake Mapping Record) are provided for entry of certain kinds of information about the lakes. This record is to be prepared for each lake that is mapped, and should also be filled out (as completely as available information will allow) for a lake that is visited but not mapped.

Send field maps to the drafting office periodically rather than submitting all of them at one time at the end of the work season. This practice will permit more orderly final drafting, and should clarification of work be required, it usually can be done best soon after a map has been drawn. For information on how lake maps are processed, see Inland Section, outline No. 7 by Jack Bails.

Prepared 12/8/60
Revised May 1969 by A.W.D.
Revised 3/1/76 by G.P.C.

# Three Methods for Computing the Volume of a Lake

By Clarence M. Taube

## Method No. 1

The formula in solid geometry for calculating the volume of a frustum of a circular cone has been applied by limnologists and fisheries biologists to compute the volume of a lake. This formula is:

$$V = 1/3\ H\ (A_1 + A_2 + \sqrt{A_1 \times A_2})$$

where: V represents volume of water, H is the difference of depth between two successive depth contours, $A_1$ is the area of the lake within the outer depth contour being considered, and $A_2$ is the area of the lake within the inner contour line under consideration. The procedure in this method consists of determining the volumes of successive layers of water (frustums), and then summing these volumes to get the total volume of the lake.

## Method No. 2

Another formula has occasionally been used in computing a lake volume. This method is employed by engineers in computing reservoir volumes, and is derived from the "end-area" formula sometimes applied to find the volume of prismoidal forms. The formula is expressed as:

$$V = 1/2\ H\ (A_1 + A_2)$$

where: H represents the difference in depth between two successive contours, $A_1$ is the area within the outer contour line, and $A_2$ is the area within the next inner contour line. The procedure here again is to compute volumes of consecutive depth segments, and summing to give total volume.

## Method No. 3

A third method which may be used is that of determining the average depth of the body of water under consideration and multiplying this by its area. The average depth is obtained by averaging depth soundings. For a reliable average, the soundings should be spaced in a uniform grid pattern. The accuracy attained by this means is dependent on frequent soundings at regular intervals, and the recording of all soundings resulting from a grid pattern. The omission of the records of depths in very shallow water--e.g., along the shore--would be a common source of error in this method.

## Procedures

Accurate depth contour maps and a planimeter are requisite for the first two methods. A field map showing actual depths on a grid pattern, and a planimeter, are necessary for Method No. 3.

When working with either Method No. 1 or No. 2, first the areas on the map within each contour are determined by tracing around the contour lines with the planimeter, starting with the shoreline and continuing to the innermost contour line. The resultant readings will be in square inches (the unit of measure of the planimeter). Then, using the scale on which the field map is drawn, the planimeter readings are converted to values of lake area, either in acres or square feet. For very small ponds it may be desirable to obtain areas in square feet, but ordinarily the areas will be obtained in acres.

As an example in calculating a lake area, and then areas within consecutive contours, assume that you are dealing with a lake map which was drawn on the scale of 1 inch equals 100 feet. Then 1 square inch of map area (planimeter reading) equals 10,000 square feet ($100 \times 100$), or 10,000/43,560 acre, or 0.22957 acre of lake area. Assume that the lake has a maximum depth of 23 feet, that depth contours are drawn for each 5-foot interval, and that the planimeter readings in square inches for area within these contours are as given in the second column of the following:

| Depth contour (feet) | Planimeter reading (square inches) | Calculated area | |
|---|---|---|---|
| | | Square feet | Acres |
| 0 (or shoreline contour) | 210 | 2,100,000 | 48.2 |
| 5 | 150 | 1,500,000 | 34.4 |
| 10 | 110 | 1,100,000 | 25.3 |
| 15 | 83.5 | 835,000 | 19.2 |
| 20 | 21.7 | 217,000 | 5.0 |
| 23 (Max. depth) | | | |

The above calculated areas in square feet are obtained by the conversion factor 10,000; and in acres by the factor 0.22957. Areas in acres could have been calculated by dividing the figures on area in square feet by 43,560 (number of square feet per acre). Note that 48.2 acres is the calculated area of the lake.

As an illustration in computing water volumes we continue to use the sample data given above. By Method No. 1 the calculations are as follows:

| Water volume | | Acre feet |
|---|---|---|
| 0 - 5 ft | $= 1/3 \times 5(48.2 + 34.4 + \sqrt{48.2 \times 34.4})$ | = 205.5 |
| 5 - 10 ft | $= 1/3 \times 5(34.4 + 25.3 + \sqrt{34.4 \times 25.3})$ | = 148.7 |
| 10 - 15 ft | $= 1/3 \times 5(25.3 + 19.2 + \sqrt{25.3 \times 19.2})$ | = 110.8 |
| 15 - 20 ft | $= 1/3 \times 5(19.2 + 5.0 + \sqrt{19.2 \times 5.0})$ | = 56.7 |
| 20 - 23 ft | $= 1/3 \times 3(5.0)$ | = 5.0 |
| | Total volume | = 526.7 |

Note that the calculation for the lowermost layer (20-23 ft) is based on the formula for volume of a cone = 1/3 HA. By applying this formula here we assume that the maximum depth of 23 feet occurred only in a restricted area. If the maximum depth of 23 feet prevailed over an extensive area, then a contour line encircling this area would be drawn; its area determined by planimeter, and the volume calculation for the 20 - 23-foot zone would involve the frustum formula.

For Method No. 2 the formula Volume = $1/2\ H(A_1 + A_2)$ is used in the same way:

| Water volume | | Acre feet |
|---|---|---|
| 0 - 5 ft | = 1/2 × 5(48.2 + 34.4) = | 206.5 |
| 5 - 10 ft | = 1/2 × 5(34.4 + 25.3) = | 149.3 |
| 10 - 15 ft | = 1/2 × 5(25.3 + 19.2) = | 111.3 |
| 15 - 20 ft | = 1/2 × 5(19.2 + 5.0) = | 60.5 |
| 20 - 23 ft | = 1/2 × 3(5.0) = | 7.5 |
| | Total volume = | 535.1 |

When using acres for area values and feet for depth values, the products are in acre-feet. An acre-foot of water is an acre of water 1 foot in depth, or 43,560 cubic feet.

In Method No. 3, a summation is made of the soundings of the lake; and this divided by the number of soundings gives the average depth. Multiplying average depth by the area of the lake gives the volume. The lake area is determined by planimeter measurements on the field map, as described above.

## Comparison of the three methods

Of course the methods which have been outlined give approximate rather than exact volumes of lakes, but these approximations probably are close enough to the true values for nearly all practical application of volume figures in fisheries work. The three methods have been compared by using them on three sample lakes. From this comparison it is obvious that they do not give greatly different results. In general practice, Methods 2 and 3 give higher values than Method 1. However, this may not always occur, as is illustrated in one of the examples listed below. Apparently the difference in types of lake basins gives rise to certain mathematical factors which account for such variation. In any event, the values resulting from the three methods do not vary from one another to the extent of being significant for most practical applications of the volume data. Methods Nos. 2 and 3 are preferable to Method No. 1 from the standpoint of simplicity. Assuming that the lake in question is, in shape, a series of frustums, the formula of Method No. 1 is mathematically correct.

Comparative results of three methods applied in computing
the volumes of three lakes

| Name of lake | Area (acres) | Location | Computed volumes (acre-feet) | | |
|---|---|---|---|---|---|
| | | | Method No. 1 | Method No. 2 | Method No. 3 |
| Frost | 60 | Ogemaw Co. | 1,949 | 1,963 | 1,977 |
| Robinson | 20.3 | Oakland Co. | 64 | 63 | 58 |
| Eagle | 19.9 | Oakland Co. | 137 | 142 | 138 |

4/8/47

Revised 3/9/76

# The Coefficient of Condition of Fish

By J. E. Williams

The relative robustness, or degree of well-being, of a fish is expressed by "coefficient of condition" (also known as condition factor, or length-weight factor). Variations in a fish's coefficient of condition reflect the state of sexual maturity and the state of nourishment (or fatness). The values have often been found to increase with the age of the fish, and in some species their condition factor varies between the sexes.

The coefficient of condition has usually been represented by the letter "K", when the fish is measured and weighed in the metric system (which is now preferred). The formula most often used is:

$$K = \frac{100,000\ W}{L^3}$$

where: W = the weight of the fish in grams

L = the standard length of the fish in millimeters

In the English system, coefficient of condition is expressed as "C", and the formula is:

$$C = \frac{100,000\ W}{L^3}$$

where: W = the weight of the fish in pounds

L = the total length (maximum) of the fish in inches

To best compare the coefficient of condition of fish from different waters, the values compared should be from fish of the same length, same age, same sex, and the fish collected on the same date or at least in the same season. If comparison is made between individuals from the same water, the fish must have been collected on the same date, being careful that selectivity of gear does not introduce a variable.

The metric coefficient of condition "K" may be converted into the English "C" by the following formula (devised by Hile and published by Beckman 1948):

$$C = 36.1\, r^3 K$$

where: r = the standard length divided by the total length,

K = the coefficient of condition in the metric system.

Klak (1941) devised conversion factors for changing from "K" to "C" and from "C" to "K". His factor is 0.02768 and is used as follows:

$$C = \frac{K}{0.02768}$$

$$K = 0.02768 \times C$$

Klak's factor has been found to be applicable to trouts and ciscoes, but not to species which are of a non-trout shape.

Carlander's "Handbook of Freshwater Fishery Biology" contains information from nearly all published works on condition factor of American fishes. It has very helpful alignment charts from which both "K" and "C" can be read with the use of a ruler.

As an alternative to calculating C or K, when ample data on lengths and weights are available, the relative robustness of a population of fish can be detected from a length-weight regression. Simply plot the length-weight regression for the population on graph paper and compare it to a similar plot for the Michigan average (see Appendix 12). Relatively robust fish will exceed the Michigan average weight at a given length, and relatively skinny fish will weigh less than average.

Revised 1981
by J. C. Schneider

# Conducting Roving and Access Site Angler Surveys

*Roger N. Lockwood*

## Introduction

Surveys of anglers are completed annually on various Michigan waters by the Fisheries Division to estimate angling effort and catch by species. Estimated angling effort is measured in angler hours, angler trips or angler days, and estimated angler catch is measured in numbers of fish harvested and/or caught and released. These surveys are conducted on inland lakes and rivers, and selected waters of the Great Lakes.

This appendix describes roving and access site angler surveys and discusses general methods for conducting these surveys. Equations for estimating angling effort and catch, and additional descriptions of survey methods, are given in Lockwood et al., in press. Other reference sources are also given at the end of this chapter.

### Description

Two separate sampling components are used to estimate fishing activity and success over a given period of time at a specified location – counts of angler activity and interviews of anglers or angler parties. Numerous methods exist for collecting data on both components. For example, angling effort (anglers or angler units which represent one or more anglers) may be counted from an airplane while a survey clerk interviews anglers at an access site as they complete their fishing trip. This type of complemented survey is referred to as an aerial-access angler survey. When anglers are counted from an airplane and a survey clerk interviews anglers while they are actively fishing (before they complete their fishing trip) the survey is called aerial-roving. Similarly, when anglers at a single location are both counted and interviewed by the survey clerk, the surveys are designated as either access-access (completed-trip interviews) or access-roving (incompleted-trip interviews). When angling effort is estimated by mail survey and catch by access interviews, the survey is a mail-access angler survey. Other complemented angler survey types may be used, but Michigan currently uses the access-access, access-roving, aerial-access and aerial-roving methods.

Counts provide estimates of angling effort (pressure) while interviews provide estimates of catch rate by species. The product of estimated effort and estimated catch rate is estimated catch. Counts and interviews each sample only a portion of the entire angling population and are assumed to accurately (without bias) represent that population. Routine information collected on count forms for each count are: location, date, type of count, duration of count (where applicable), mode of count, time of count, and counted numbers of units (anglers, boats etc.). Routine information collected on interview forms for each angler or angler party are: location, date, angling mode, whether fishing trip is completed or incompleted, number of anglers, start time of fishing trip, time of interview, and number of fish caught by species (catch-and-release and harvest information are recorded separately).

Catch and effort estimates may be calculated by day or multiple days within a time period (e.g., week days within a month). Angling modes (boat, shore, pier etc.) are calculated separately. These estimates may be summed to estimate catch and effort for longer time periods. Likewise, estimates from more than one location are summed to estimate catch and effort for a larger area. When anglers report the species or group of species they are targeting, targeted catch and effort may be estimated.

In addition to angling effort and catch, the angler interviewing process may be used to collect tag information from fish, angler residency, and bait type used. Anglers may also be queried regarding current or proposed fishing regulations and other issues.

## Methods

Angler surveys consist of four basic elements: sampling schedule, survey clerk, angler counts and angler interviews.

### *Sampling Schedule*

Sampling schedules are constructed to randomly sample anglers on various days and at various times within these days. Since survey estimates are based on mean values, both active and less active days and time periods are sampled. Stratification, such as by week day or weekend day, tend to congregate similar activity levels and reduce variability in estimates. Supervisors must ensure that survey clerks follow sampling schedules. When a sampling schedule is not followed, data is not representative of angling population effort and catch, and resulting estimates will not accurately portray angling statistics during a given time period and location.

### *Survey Clerk*

Survey clerks are an integral component in any angler survey and their importance cannot be stressed enough. Clerks must be able to perform in all weather conditions and in periods of both high and low fishing activity. The quality of a clerk's performance is determined by the quality of their supervision. Weekly contact by a supervisor promotes reliability and demonstrates to the clerk the importance of the job.

Just as the supervisor must not take the clerk for granted, neither should the clerk become complacent or indifferent. Changes may occur during an angler survey that directly influence the results of that survey. For example, concentrations of anglers may shift to a new area (such as a new boat access site). Clerks should recognize the importance of this change and notifying the supervisor so that modifications in the sampling scheme can be implemented. Training prepares a clerk for most, but not all situations, so a good survey clerk must be prepared to ask questions. For example, a species of fish may appear in the angler's catch that was not anticipated during training. Clerks should contact the supervisor so that additional training in identification can be implemented. The last thing any supervisor wants is to learn of problems after all data have been collected. When meeting the public, survey clerks represent the entire Department of Natural Resources. A survey clerk's mannerism and professionalism, and the way in which they treat equipment entrusted to them, are all important and reflect upon the Division.

*Counts*

Single or multiple counts may be made at a given location and day. Counts are made of individual anglers or of angler units, which may represent more than one angler (such as boats, trailers, ice shanties etc.). Two types of counts are made, instantaneous and over time interval. Instantaneous counts are suitable for access or aerial surveys, while interval counts are only suitable for access surveys.

*Instantaneous*—When all angling activity may be observed from a single vantage point, the instantaneous method is appropriate. Angling activity may be enumerated from the ground or from an airplane. In some situations a ground-based clerk must drive to more than one vantage point to count an area, however the count is still considered instantaneous. Spatial stratification is often used to ensure that counts are as instantaneous as possible. For example, a lake may be divided into several areas and each counted from a unique vantage point; or a clerk may drive along a river and count vehicles at access locations. From the air, angling activity is enumerated as the plane flies over each area. When more than one count location is used, direction and order of count are randomized to avoid potential biases. Care must also be taken to prevent double counting of anglers or angler units, especially if they may move from one area to another while the count is being made.

When instantaneous counts are made of ice shanties, either only occupied shanties are counted or all shanties (occupied and unoccupied) are counted. In the later alternative, the ratio of occupied to unoccupied shanties must be obtained during representative time periods to adjust the total shanty counts.

In some situations, fishing boats on a lake may be difficult to distinguish from non-fishing boats. In such situations, all boats (fishing and non-fishing) are counted and all parties (fishing and non-fishing) using the site are interviewed. Counts are then adjusted by the proportion of angling parties in the interview data set. This same technique may be applied to other counting units, such as boat trailers or vehicles at an access site.

*Interval*—When anglers enter a fishery and disappear from the clerk's view, interval counts are appropriate. Typically, this situation occurs on the Great Lakes where boats leave a port and travel some distance out onto the lake to fish. Boats may be present in the fishery, but are not visible to the clerk for instantaneous enumeration. In this situation, all fishing boats leaving a port during a randomly selected time interval (duration) are counted. Interval counts are generally 15 minutes or longer in duration. As above, when fishing boats are difficult to distinguish from non-fishing boats, all boats are counted and all boating parties interviewed, then boat counts are adjusted to reflect only fishing boats. While counting units other than boats are entirely possible, appropriate conditions are rare. As previously noted, interval counts are made by ground based clerks (access count).

### *Interviews*

Since catch rates of completed-trip interviews and incompleted-trip interviews are calculated differently, care should be taken to collect only one type of interview (completed- or incompleted-trip) within a strata.

*Completed-Trip Interviews*—When anglers or angler parties are interviewed by the clerk upon completing their fishing trip, the interview is referred to as a completed trip. Completed-trip interview information may be collected either from individual anglers or collectively from angling parties. Often the counting technique employed will dictate whether angler or angler party information is collected. In situations where instantaneous counts of anglers are made, either individual angler or angler party information may be collected. When angler units which may represent more than one angler are counted, angler party size information is collected.

*Incompleted-Trip Interviews*—When anglers are interviewed by the survey clerk while actively fishing, prior to completion of their fishing trip, interviews are of incompleted trips. To avoid angler party size bias, only individual angler catch information is recorded, not angler party catch information (Lockwood 1997). Incompleted-trip interviews are advantageous when instantaneous angler counts are made and the clerk has easy access to anglers. For example, anglers at a pier or open ice fishery are readily accessible for interviewing. In the case of an open ice fishery where anglers may gain access to the lake at many points, incompleted-trip interviews provide a very efficient sampling method. When this method is appropriate, a clerk is usually able to collect more incompleted-trip interviews than completed-trip interviews, thus sampling a greater proportion of the angling activity. Minimum fishing time for incompleted-trip interviews is 0.5 h (Pollock et al. 1977).

The situation and type of count may dictate whether completed- or incompleted-trip interviews are required. For example if interval boat counts are made, angler party trip length information is required to convert boats per interval to boat angler hours. This information can only be obtained from completed-trip interviews. In addition, anglers are not available for interviewing prior to completion of their trip.

*Voluntary Interviews*—Catch records voluntarily submitted by individuals not randomly selected are called voluntary interviews. Such records may be submitted by fishing guides, boat livery or resort operators, lake association members, or cooperating anglers. Interview forms may be distributed prior to the starting date of the angler survey, or made available from boxes on site or be distributed after the trip (e.g., post cards left on vehicle windshields). These records are especially valuable for fishing localities or anglers inaccessible to survey clerks. This situation occurs when anglers enter a fishery from resorts or cottages on a lake. The survey clerk may easily interview anglers using public launch sites, but anglers accessing the fishery from private dwellings may be difficult or impossible to interview. Voluntary interviews will be of completed trips and catch rates are calculated as for completed-trip interviews collected by a survey clerk.

There are disadvantages to voluntary interviews. Of primary concern is the uncertainty as to their representation of an angling population. For example, avid anglers may report their fishing trips more often than less avid anglers, anglers may exaggerate their catch, anglers may report successful trips more often than less successful trips, and species of fish may be more likely to be misidentified. When using voluntary interviews in conjunction with interviews collected by a survey clerk, catch rates of all sampled anglers and percentages of successful anglers should be compared before combining these two types of interviews. Differences or similarities in rates of catch and success should be viewed objectively.

## Implementation

Implementation of an angler survey begins with planning and includes: determining purpose of survey, site evaluation, designing count and interview forms, determining number of clerks needed, special equipment needs, and survey clerk hiring and training. Assistance in planning and conducting a Great Lakes survey is available through the Charlevoix Great Lakes station (study 427) and for inland surveys through the Institute for Fisheries Research in Ann Arbor (study 646). Surveys categorized as Great Lakes are those surveys done on the Michigan waters of the Great Lakes, connecting waters, and river sections with fisheries for runs of Great Lakes species. Inland surveys are those done on any of the remaining lakes or rivers, including river sections directly connected to the Great Lakes where runs of Great Lakes species are not present.

Often, the survey purpose and site evaluation will greatly influence number of survey clerks required. In some situations, subsampling prior to the actual survey will determine potential precision of estimates and number of survey clerks needed. When a survey is designed to extend over an entire season (summer months for example), a seasonal vehicle from Motor Transport Division may be required for the duration of the survey. In the case of river surveys or ice fishing surveys, a canoe or snowmobile, may be needed.

Training is a joint effort between Research personnel and the biologist requesting the angler survey. Orientation should include a general overview of angler surveys and the purpose for the current survey. Training should include correct completion of count and interview forms, clerk behavior (public relations), operation of equipment and fish identification.

The biologist (supervisor) initiating the angler survey is responsible for procurement of vehicle(s), special equipment and survey clerk(s), and daily supervision. Regular contact (weekly) with the survey clerk is essential for quality survey results. The supervisor should check count and interview forms submitted by the clerk for completeness and correctness; additional proof reading will be done by Research personnel. Data processing and timely calculation of estimates are the responsibility of Research personnel.

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# Calculation of Weighted Average Length and Weighted Age Composition

By James C. Schneider

Simple averages computed from subsamples stratified by size of fish usually give biased estimates of growth and age composition of fish populations. This bias can be eliminated by computing weighted averages with the aid of a length-frequency distribution representative of the population.

In the example below, a large number of bluegills were captured by electrofishing. A length frequency was tabulated for the first 200 fish, and scale samples were taken from 20 of each inch group.

The calculations show that simple averages tend to overestimate the average length of older, rarer, fish (e.g., 6.2 inches versus 5.8 inches for age IV), and to greatly distort the relative frequency of the various age groups (e.g., as much as 22%).

Note that a bias may still exist in weighted averages due to gear size selectivity. Among young fish, the larger individuals are often more vulnerable to capture. In this example, both the length-frequency and the age-frequency information indicate that either the small age-I fish were not fully vulnerable to the gear, or that the age-I cohort was relatively weak and the age-II cohort was relatively strong.

When recording average lengths on the FISH GROWTH form, indicate (on the appropriate blank) if a weighted method was used.

| Length group (inches) | Length-frequency sample number (A) | Sample aged: Ages present | Number | Percent (B) | Average length (inches) (C) | Relative number (A × B) |
|---|---|---|---|---|---|---|
| 2.0-2.9 | 40 | I | 15 | 100.0 | 2.4 | 4,000 |
| 3.0-3.9 | 80 | I | 5 | 33.3 | 3.2 | 2,664 |
| | | II | 10 | 66.7 | 3.5 | 5,336 |
| 4.0-4.9 | 50 | II | 7 | 46.7 | 4.3 | 2,335 |
| | | III | 8 | 53.3 | 4.7 | 2,665 |
| 5.0-5.9 | 28 | II | 2 | 13.3 | 5.1 | 373 |
| | | III | 5 | 33.3 | 5.4 | 932 |
| | | IV | 8 | 53.4 | 5.7 | 1,495 |
| 6.0-6.9 | 2 | IV | 15 | 100.0 | 6.5 | 200 |

Weighted average length for an age group = sum of A × B × C ÷ A × B for relevant size groups.

For age I: $\frac{4000 \times 2.4 + 2664 \times 3.2}{4000 + 2664} = 2.7$ (Simple average = 2.6)

For age II: $\frac{5336 \times 3.6 + 2335 \times 4.3 + 373 \times 5.1}{5336 + 2335 + 373} = 3.9$

(Simple average = 4.0)

For age III: $\frac{2665 \times 4.7 + 932 \times 5.4}{2665 + 932} = 4.9$ (Simple average = 5.0)

For age IV: $\frac{1495 \times 5.7 + 200 \times 6.5}{1495 + 200} = 5.8$ (Simple average = 6.2)

Weighted age-frequency for an age group = Sum of A × B for all relevant size groups.

For age I: 4000 + 2664 = 6664 or 33.3 (Simple average = 26.7)

For age II: 5336 + 2335 + 373 = 8044 or 40.2 (Simple average = 25.3)

For age III: 2665 + 932 = 3597 or 18.0 (Simple average = 17.3)

For age IV: 1495 + 200 = 1695 or 8.5 (Simple average = 30.7)

Total = 20,000 or 100%

# Endangered and Threatened Fishes in Michigan

By W. C. Latta

The following annotated list of endangered and threatened species was prepared in 1976 by the technical advisory committee responsible for fish (a group composed of university, federal and state ichthyologists). Since that time the bloater (Coregonus hoyi) has increased substantially in abundance and surveys have indicated that the northern madtom (Noturus stigmosus) should be advanced to the endangered category and the southern redbelly dace (Phoxinus erythrogaster), bigeye chub (Hybopsis amblops) and creek chubsucker (Erimyzon oblongus) should be added to the threatened list. The last four species were officially listed in January 1980, and the above comments for the bloater (Coregonus hoyi) indicate its change in abundance since 1976. Specific questions on the threatened and endangered species program of the Department of Natural Resources should be made to the Wildlife Division in Lansing.

## Endangered

1. Longjaw cisco, Coregonus alpenae (Koelz).

   This species is officially listed as endangered by the Secretary of the Interior. It was last reported in Lake Erie in 1961, and is believed to be extinct in Lakes Huron and Michigan.

2. Deepwater cisco, Coregonus johannae (Wagner).

   This species is regarded (by the Great Lakes Fishery Laboratory, U.S. Department of Interior) as extinct in both Lake Huron and Lake Michigan, the only known places where it occurred. Nevertheless, it is recommended for this list to get the species on record for a year or so. It is very difficult to be certain of extinction of species unless the distribution is so localized that there can be no question of survival.

3. Blackfin cisco, Coregonus nigripinnis (Gill).

Regarded as extinct in Lakes Ontario, Huron, Michigan and Superior. Recent studies on Lake Superior fish indicate that, although the species was recorded from this lake by Koelz, in actuality the species he had from Lake Superior was C. zenithicus (Parsons et al. 1975, mimeo account of status of some endemic Great Lakes fishes). The reason for listing this species is the same as given under the account of C. johannae.

4. Shortnose cisco, Coregonus reighardi (Koelz).

Regarded as extinct in Lake Ontario, endangered in Lakes Huron and Michigan, and greatly reduced in Lake Superior (according to the Great Lakes Fisheries Laboratory).

5. Shortjaw cisco, Coregonus zenithicus (Jordan and Evermann).

Regarded as greatly reduced in Lake Superior, and as erroneously recorded by Koelz from Lakes Huron and Michigan (his specimens are properly identified as C. reighardi--Parsons et al. 1975--see above).

6. Blue pike, Stizostedion vitreum glaucum (Hubbs).

Although there is no valid basis for believing this fish survives at the present time in Lake Erie, the only known locality of occurrence, Endangered status is recommended for a year or so, to keep the species "on record" until its status is finalized. The fish is officially recognized as endangered by the Secretary of the Interior.

7. Northern madtom, Noturus stigmosus (Taylor).

This fish was traditionally found in the river drainages in southeastern lower Michigan. All of the major drainages in that area have been surveyed to determine fish species present and abundance. The results of those surveys indicate the fish has become very rare. Thus moving the status of the fish from threatened to endangered is recommended.

## Threatened

1. Lake sturgeon, Acipenser fulvescens (Rafinesque).

   Sturgeons as a group are late-maturing, and very long-lived fishes that do not tolerate a high level of exploitation. They are diminishing notably in numbers in many parts of the world. In Michigan, because of purposeful overexploitation during the late 1800's, this species was greatly reduced in all lakes by the early 1900's. In fact, this fish became so scarce by the 1920's that sturgeon fishing was prohibited throughout most U.S. waters of Lakes Superior, Michigan and Huron. The species now occurs in Michigan in less than five percent of its former abundance. Threatened status is recommended because there are places where a regulated sport fishery is compatible with maintenance of the species. The fishery should be carefully monitored to make sure that sufficient breeding stock persists each year. Maturity is not attained by most females of this species until an age approaching 25 years is reached; males mature between 14 and 20 years.

2. Cisco or lake herring, Coregonus artedii (Lesueur).

   It is regarded by the Great Lakes Fishery Laboratory as rare or threatened in Lake Erie, threatened in Lakes Huron and Michigan, and declining (i.e., showing a recent general decline in abundance that obviously is not part of natural fluctuations) in Lake Superior.

3. Bloater, Coregonus hoyi (Gill).

   At present this species is common in Lake Huron, increasing in Lake Michigan, and abundant in Lake Superior. It was assigned to "threatened" status when the populations were sharply declining. Status should be reviewed.

4. Kiyi, Coregonus kiyi (Koelz).

   Regarded as extinct in Lakes Ontario and Huron, endangered in Lake Michigan, and declining in Lake Superior (Great Lakes Fishery Laboratory). These are the only lakes from which the species is known.

5. Silver shiner, Notropis photogenis (Cope).

Michigan is the periphery of the range of this species. It is now very rare here, occurring naturally only in the southeastern part of the state. In recent years, it has been taken only in the Huron River (1940, 1954) and Raisin River (1973). This species, and several to follow, are part of the natural wildlife heritage of Michigan. Irrespective of the status of peripheral Michigan species outside of the state, it is important that as much of the native biota as possible be retained. Placing this species in the threatened category calls attention to its rarity in Michigan, and to its need for help if it is to remain a part of Michigan biota.

6. Redside dace, Clinostomus elongatus (Kirtland).

This species has a very discontinuous range in the U.S. and occurs in Michigan only in a few tributaries of Lake Erie. The only recent record (1970) is from near Farmington, in the outlet to Devil's Lake. Reasons for listing this peripheral species are the same as given above for the silver shiner.

7. River redhorse, Moxostoma carinatum (Cope).

The first (and last) valid known record of this mollusk-eating fish for Michigan is of a single adult taken on 25 July 1935 at Croton Dam, Newaygo County, in the Muskegon River drainage. An effort should be made to determine if the species still persists in that basin.

8. Southern redbelly dace, Phoxinus erythogaster (Rafinesque).

This fish was traditionally found in the river drainages in southeastern lower Michigan. All of the major drainages in that area have been surveyed to determine fish species present and abundance. The results of these surveys indicate the fish is much less abundant than anticipated. Thus threatened status for this fish is recommended.

9. Bigeye chub, Hybopsis amblops (Rafinesque).

See rationale above for southern redbelly dace.

10. Creek chubsucker, Erimyzon oblongus (Mitchill).

    See rationale above for southern redbelly dace.

11. Eastern sand darter, Ammocrypta pellucida (Putnam).

    Species of this genus generally require clear, clean water with sand bottom; this type of habitat is under threat nearly everywhere. This fish--rare and peripheral in Michigan--is known from the St. Joseph River of the Maumee River basin (1929); Little Raisin River in Dover Township, Lenawee County (1927); Rouge River at Rouge Park, Wayne County (1936); Strawberry Lake, Livingston County (1949--and likely still present); Bouvier Bay of Lake St. Clair (1942); Big Gallagher Lake, Livingston County (1955); and Saline River near its mouth (1929). Reasons for retaining this peripheral species in Michigan's biota are the same as given for the silver shiner (Notropis photogenis).

# Length-Weight Relationships

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

The relationship between total length (L) and total weight (W) for nearly all species of fish is expressed by the equation:

$$W = aL^b$$

Values of W usually have been calculated from the logarithmic (base 10) equivalent:

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

A graph of log W against log L forms a straight line with a slope of b and a Y-axis (log W) intercept of log a. Invariably, b is close to 3.0 for all species.[a]

The exact relationship between length and weight differs among species of fish according to their inherited body shape, and within a species according to the condition (robustness) of individual fish. Condition sometimes reflects food availability and growth within the weeks prior to sampling. But, condition is variable and dynamic. Individual fish within the same sample vary considerably, and the average condition of each population varies seasonally and yearly. Sex and gonad development are other important variables in some species, especially percids. Surprisingly, type of habitat – stream, inland lake, Great Lake – is not a reliable predictor of fish condition. Appendix VI-A-8 discusses traditional coefficients of condition which may be derived from length-weight data. A more direct approach is, for a given length, to calculate a weight from the regression and compare it to a reference weight such as a state average weight.

Even for routine population surveys it is both practical and worthwhile to collect length-weight data on individual fish. Fish of all sizes can be accurately and easily weighed on portable electronic balances in a sheltered location. Number of fish sampled need not be high, 5-10 fish per inch group over a wide size range are enough to establish a regression line for each important species. Weight data for species which are scale-sampled can be conveniently recorded on the same envelopes. The resulting length-weight regressions are useful for (a) calculating total

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[a] In previous versions of this appendix, and in much fisheries literature, the regression constant is represented by "c" rather than "a", and the regression slope is represented by "n" rather than "b". Equations in the form of natural logarithms (base e) and power functions are commonly used instead of $\log_{10}$.

weight of fish caught from length-frequency data (thereby eliminating the need for bulk weighing of groups of fish while at the lake or stream), (b) measuring changes in robustness/health of this population (relative to past or future samples at the same place and season), (c) determining the relative condition of small fish compared to large fish (from the slope of the regression), and (d) comparing condition of this population to the state-wide standards discussed below.

State average length-weight relationships (analogous to state average growth rates) have been compiled for 16 species of fish. For two of these species, brook and brown trout, there is one set of regressions for stream dwellers and another set for lake dwellers (which tend to be significantly plumper at larger sizes). These data were obtained mainly from wild fish in inland lakes and streams, of both sexes, in all seasons. Included for each species were several to many populations and a variety of growth rates.

A recent compilation of data indicates Great Lakes fish populations are not consistently heavier at the same length than populations in inland waters and it is not practical to present separate regressions by habitat. Across all habitats, deviations from the accepted standards rarely exceeded 15%. Sources of these data were publications, reports, and the Great Lakes Sport Fishing Survey (Rakoczy 1996). For example, for yellow perch the average length-weight regression based on seven Great Lakes samples was identical to that long-used as the State average (inland). Likewise, lake trout and rainbow trout (including stream residents and steelhead) seem to be adequately represented by single equations developed earlier. Brown trout in streams, inland lakes, and the Great Lakes seem to vary the most; consequently, both stream and lake equations are offered. Very large brown trout in the Great Lakes may exceed predictions derived from the lake equation by 20%. Smallmouth bass condition may also vary with habitat, but additional sampling is needed to confirm it's consistency and importance. Fish in Lake Superior are often relatively thin, but do not warrant separate equations at this time.

For 61 other species (or species groups) for which no Michigan average has been determined, length-weight data or regressions were assembled from various sources. These will be the standard until more data are available. Preference was given to Michigan or midwestern sources when possible. Sources included: (1) median values, or the best data, compiled in Carlander's Handbooks (1969 and 1977); (2) data or regressions in the original literature; and (3) unpublished data, kindly supplied by Peter Bayley (formerly Illinois National History Survey), Mike Wiley (The University of Michigan), and Jerry Rakoczy (MDNR).

Table 1 lists the coefficients for the regression equations and sources of the data. For all but two fishes, splake and Atlantic salmon, the regressions cover the size range likely to be collected in routine fisheries surveys. The regressions may not be as accurate for relatively small fish (less than 2 inches) or for very large fish which tend to have high variability.

For example, to calculate weight in pounds of a 20-inch largemouth bass, the equation would be:

$$\begin{aligned} \log_{10} Lb &= -3.43162 + 3.12735 \cdot \log_{10}(20) \\ &= 0.63716 \\ Lb &= 4.34 \end{aligned}$$

Tables 2-6 contain some commonly used lengths and weights calculated from these equations.

Tables 7-9 contain average lengths and weights typical of some hatchery-reared fish.

The length-weight relationships in these tables may be used for computing biomass estimates from length-frequency distributions when weight data specific to the time and site are not available. The FISH COLLECTION form provides columns for biomass, and if empirical weights were not taken during a survey, the standards may be used to calculate biomass estimates. Be sure to note on the form if the standards were used in lieu of empirical weights.

A computerized version of the FISH COLLECTION form is being developed with these equations built in. It will automatically calculate biomass estimates and perform other required computations.

State average length-weight regressions may also be used to evaluate the relative condition of populations. If a population has a length-weight curve which is below the average curve, then it's fish are relatively skinny. Conversely, if a population's curve is above the average curve, then its fish are relatively plump. The lines may cross, possibly indicating a change in condition caused by a change in diet as fish grow. For many species, a nationwide system of relative weight indices has been developed (Murphy et al. 1991). However, it advocates the use of the 75th percentile rather than the 50th percentile (the average) as a standard for condition.

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Table 1.–Length-weight regression coefficients for Michigan fishes. Values for the intercept (a) are given in both English (E) and metric (M) systems; the value for the slope (b) is the same in both systems. English equations are in lb and in; metric equations are in g and mm. The standard equation is: $\log_{10}$ Weight = a + b·($\log_{10}$ Length).

| | | Intercept (a) | | |
|---|---|---|---|---|
| Species[a] | slope (b) | E | M | Notes[b] |
| Alewife | 3.06370 | -3.64198 | -5.28911 | VA (Boaze and Lackey 1974)[c] |
| Bass, Largemouth | 3.12735 | -3.43162 | -5.16885 | |
| Smallmouth | 3.02635 | -3.31934 | -4.91466 | |
| Rock | 3.05438 | -3.17738 | -4.81208 | |
| White | 3.0342 | -3.41794 | -5.0233 | IL (Bayley and Austen 1987)[c] |
| Bloater | 3.1110 | -3.71552 | -5.429045 | L. MI (Carlander 1969)[d] |
| Bluegill | 3.17266 | -3.30288 | -5.10377 | |
| Bowfin | 2.96004 | -3.39775 | -4.89906 | MI+(Carlander 1969)[e] |
| Bullhead, all | 2.88495 | -3.20930 | -4.60512 | Brown, yellow, black (Carlander 1969)[d] |
| Buffalo, Bigmouth & all | 3.09298 | -3.36229 | -5.05036 | (Carlander 1969)[d] |
| Burbot | 3.03888 | -3.60272 | -5.21478 | (Carlander 1969)[d] |
| Carp, Common | 2.83840 | -3.11203 | -4.44245 | (Carlander 1969)[d] |
| Catfish, Channel | 3.2764 | -3.8665 | -5.8116 | IL (Bayley and Austen 1987)[c] |
| Flathead | 3.16495 | -3.60167 | -5.39084 | MI+(Carlander 1969)[d] |
| Chub, all | | | | Use horneyhead |
| Creek | 2.92494 | -3.39611 | -4.84812 | (Carlander 1969)[d] |
| Hornyhead | 3.170 | -3.4740 | -5.2702 | IL (Bayley unpublished)[c] |
| River | | | | Use hornyhead chub |
| Chubsucker, all | 3.18937 | -3.41781 | -5.24128 | Blueberry Lake+Carlander (1969)[d] |
| Cisco, all | | | | Use bloater |
| Crappie, Black | 3.17980 | -3.43238 | -5.24330 | |
| White | 3.3835 | -3.7282 | -5.8236 | IL (Bayley and Austen 1987)[c] |
| Dace, all | | | | Use fathead minnow |
| Darter, all | | | | Use blackside |
| Blackside | 3.236 | -3.6003 | -5.4899 | IL(Bayley unpublished)[c] |
| Johnny | 3.198 | -3.5686 | -5.4040 | IL (Bayley unpublished)[c] |
| Rainbow | 3.403 | -3.5391 | -5.6619 | IL (Bayley unpublished)[c] |
| Drum, Freshwater | 3.1973 | -3.6007 | -5.4353 | IL (Bayley and Austen 1987)[c] |
| Eel, American | 3.47 | -4.722 | -6.94 | (Carlander 1969)[d] |
| Gar, Longnose | 3.5070 | -4.7973 | -7.067 | MO (Carlander 1969)[c] |
| Spotted | 3.4563 | -4.5239 | -6.7224 | (Carlander 1969)[d] |
| Herring, Lake | 2.85755 | -3.45588 | -4.81321 | (Carlander 1969; except tullibee)[d] |
| Killifish, all | | | | Use topminnow |
| Lamprey, ammocete spp | 2.65465 | -4.09370 | -5.16569 | W. brook (Carlander 1969)[d] |
| Brook | 2.8355 | -4.0634 | -5.3917 | W. brook (Carlander 1969)[d] |
| Chestnut | 3.21468 | -4.38861 | -6.23605 | MI (Hall 1963)[c] |
| Sea | 2.63133 | -3.66299 | -4.70251 | Ocqueoc R. (Applegate 1950)[e] |
| Logperch | | | | Use blackside darter |
| Madtom, all | | | | Use tadpole madtom |
| Tadpole | 3.102 | -3.3401 | -5.0396 | IL (Bayley unpublished)[c] |
| Minnow, all | | | | Use bluntnose |
| Bluntnose | 3.390 | -3.6038 | -5.7089 | IL (Bayley unpublished)[c] |
| Fathead | 3.07650 | -3.36851 | -5.03343 | (Carlander 1969)[e] |
| Mooneye | 3.12105 | -3.6165 | -5.3459 | L. Erie (Carlander 1969)[d] |
| Mudminnow | | | | Use creek chub |

Table 1.–Continued.

| Species[a] | slope (b) | Intercept (a) E | Intercept (a) M | Notes[b] |
|---|---|---|---|---|
| Musky, Northern | 3.44346 | -4.25593 | -6.43636 | MI+WI (Hanson 1986)[ce] |
| Tiger | 3.07273 | -3.82649 | -5.48612 | Limited sites |
| Perch, Pirate | 3.102 | -3.2306 | -4.9310 | IL (Bayley unpublished)[c] |
| White | 3.21747 | -3.51718 | -5.38013 | NE (Thoits 1958 and Reid 1972)[e] |
| Yellow | 3.17285 | -3.53359 | -5.33475 | |
| Pickerel, Grass | 3.00982 | -3.72313 | -5.29438 | WI (Kleinert and Mraz 1969; pooled)[ce] |
| Pike, Northern | 3.14178 | -3.85333 | -5.61083 | |
| Pumpkinseed | 3.21060 | -3.25719 | -5.11138 | |
| Quillback | 3.09633 | -3.46781 | -5.16059 | (Carlander 1969)[d] |
| Redhorse, all | | | | Use golden |
| Golden | 2.908 | -3.3410 | -4.7690 | (Bayley unpublished)[c] |
| Shorthead | 2.94414 | -3.33201 | -4.81098 | (Carlander 1969)[d] |
| Silver | 2.778 | -3.2034 | -4.4489 | IL (Bayley unpublished)[c] |
| Salmon, Atlantic | 2.78090 | -3.22020 | -4.47028 | To 25" (Dexter 1991)[c] |
| Chinook | 3.113913 | -3.594065 | -5.31348 | L. MI 1983-93 (Wesley 1996)[c] |
| Coho | 3.42700 | -4.01200 | -6.16900 | G. L. 1992-94 (Rakoczy)[e] |
| Pink | 2.877 | -3.344 | -4.737 | MI (Wagner 1985)[c] |
| Sculpin, all | 3.25202 | -3.38754 | -5.29903 | MI (Wiley unpublished)[c] |
| Shad, Gizzard | 3.03707 | -3.46799 | -5.07752 | (Carlander 1969)[d] |
| Shiner, all | | | | Use spottail shiner |
| Common | 3.320 | -3.6055 | -5.6124 | Assume same as striped shiner. |
| Emerald | 2.730 | -3.5320 | -4.7100 | IL (Bayley unpublished)[c] |
| Golden | 3.08217 | -3.57486 | -5.24775 | (Carlander 1969)[d] |
| Spottail | 2.98913 | -3.49145 | -5.03363 | MN (Smith and Kramer 1964)[c] |
| Striped | 3.320 | -3.6055 | -5.6124 | IL (Bayley unpublished)[c] |
| Smelt, Rainbow | 2.96408 | -3.63360 | -5.12117 | Lake Superior (Bailey 1964)[e] |
| Stonecat | 2.862 | -3.3759 | -4.7390 | IL (Bayley unpublished)[c] |
| Stoneroller | | | | Use horneyhead chub |
| Sturgeon, Lake | 3.13960 | -3.86356 | -5.61713 | MI (Baker 1980)[c] |
| Sucker, all | | | | Use white |
| Hog | 3.16433 | -3.57116 | -5.35946 | (Carlander 1969)[e] |
| Longnose | 3.05946 | -3.41194 | -5.05295 | (Carlander 1969)[d] |
| Spotted | | | | |
| White | 3.00004 | -3.40672 | -4.96508 | Use golden redhorse |
| Sunfish, all | | | | Use longear |
| Green | 3.1644 | -3.2813 | -5.0697 | IL (Bayley and Austen 1987)[c] |
| Longear | 3.16 | -3.26 | -5.04 | IL (Lewis and Elder 1952)[c] |
| Redear | 3.33276 | -3.43879 | -5.46370 | (Carlander 1977)[d] |
| Topminnow, Blackstripe | 3.326 | -3.5513 | -5.5659 | IL (Bayley unpublished)[c] |
| Trout, Brook (lakes) | 3.14041 | -3.57650 | -5.33120 | |
| (streams) | 2.98634 | -3.43599 | -4.97427 | |
| Brown (lakes) | 3.00809 | -3.37430 | -4.94311 | |
| (streams) | 3.01000 | -3.46113 | -5.03265 | |
| Lake | 3.17882 | -3.71034 | -5.51900 | |
| Rainbow (all) | 3.05253 | -3.51688 | -5.14777 | |
| Splake | 3.37517 | -3.91829 | -6.00279 | to 21". Higgins L. + WI (Brynildson & Kempinger (1920)[e] |
| Trout-perch | | | | Use white sucker |
| Walleye | 3.03606 | -3.53280 | -5.14176 | |

Table 1.–Continued.

| Species[a] | slope (b) | Intercept (a) E | Intercept (a) M | Notes[b] |
|---|---|---|---|---|
| Warmouth | 3.20625 | -3.27670 | -5.12390 | MI (Schneider unpublished)[e] |
| Whitefish, Lake | 3.29176 | -3.82670 | -5.79403 | Carlander 1969)[d] |
| Round | 3.18825 | -3.76016 | -5.58208 | (Carlander 1969)[e] |

[a] Under the species heading, the lines ending in "all" (eg., Bullhead, all) are to be used for either: fish not identified to species, any species not listed separately, or each species in the group.
[b] Restrictions because of size range or source are noted. Otherwise, regression is based on an average of several to many Michigan populations.
[c] A regression equation from the source was used to calculate English and metric equivalents.
[d] Regressions were fit to the means, mean of means, or medians provided by Carlander (1969; 1977).
[e] Regressions were fit to raw or pooled data provided by the source.

Table 2.–Length-weight relationships (inches-pounds) for wild panfish.

| Length (inches) | Bluegill | Pumpkin-seed | Redear sunfish | Warmouth | Green sunfish | Longear sunfish | Rainbow smelt |
|---|---|---|---|---|---|---|---|
| 1.5 | .0018 | .0020 | .0014 | .0019 | .0019 | .0020 | .0008 |
| 2.5 | .0091 | .0105 | .0077 | .0100 | .0095 | .0099 | .0035 |
| 3.5 | .0265 | .0309 | .0237 | .0294 | .0276 | .0288 | .0095 |
| 4.5 | .0588 | .0692 | .0547 | .0657 | .0611 | .0637 | .0201 |
| 5.5 | .1112 | .1318 | .1068 | .1251 | .1152 | .1201 | .0364 |
| 6.5 | .189 | .225 | .186 | .214 | .195 | .204 | .060 |
| 7.5 | .297 | .357 | .300 | .338 | .301 | .320 | .091 |
| 8.5 | .442 | .533 | .456 | .505 | .457 | .475 | .132 |
| 9.5 | .630 | .762 | .660 | .721 | .650 | .676 | .184 |
| 10.5 | .865 | 1.051 | .922 | .994 | .892 | .927 | .247 |
| 11.5 | 1.15 | 1.41 | 1.25 | 1.33 | 1.19 | 1.24 | .32 |
| 12.5 | 1.50 | 1.84 | 1.65 | 1.74 | 1.54 | 1.61 | .41 |

Table 2.–Continued.

| Length (inches) | Perch | | Rock bass | Crappie | | White bass | Bull-head[a] |
|---|---|---|---|---|---|---|---|
| | Yellow | White | | Black | White | | |
| 1.5 | .0011 | .0011 | .0023 | .0013 | .0007 | .0013 | .0020 |
| 2.5 | .0054 | .0058 | .0109 | .0068 | .0042 | .0062 | .0087 |
| 3.5 | .0156 | .0171 | .0305 | .0198 | .0130 | .0171 | .0229 |
| 4.5 | .0346 | .0384 | .0657 | .0441 | .0303 | .0366 | .0473 |
| 5.5 | .0654 | .0733 | .1213 | .0835 | .0598 | .0674 | .0845 |
| 6.5 | .111 | .125 | .202 | .142 | .105 | .112 | .137 |
| 7.5 | .175 | .199 | .313 | .224 | .171 | .173 | .207 |
| 8.5 | .260 | .297 | .459 | .333 | .261 | .252 | .297 |
| 9.5 | .370 | .425 | .644 | .475 | .380 | .354 | .409 |
| 10.5 | .509 | .587 | .874 | .653 | .533 | .479 | .545 |
| 11.5 | .68 | .79 | 1.15 | .87 | .73 | .63 | .71 |
| 12.5 | .88 | 1.03 | 1.49 | 1.14 | .96 | .81 | .90 |
| 13.5 | 1.13 | 1.32 | 1.88 | 1.45 | 1.25 | 1.03 | 1.13 |
| 14.5 | 1.42 | 1.66 | 2.34 | 1.82 | 1.59 | 1.28 | 1.38 |
| 15.5 | 1.75 | 2.05 | 2.87 | 2.25 | 1.99 | 1.56 | 1.68 |

[a] Weights for brown, yellow, and black bullheads are similar.

Table 3.–Length-weight relationships (inches-pounds) for large wild sport fish.

| Length (inches) | Bass Large-mouth | Bass Small-mouth | Walleye | Northern pike | Muskel-lunge | Lake sturgeon | Catfish Channel | Catfish Flathead | Lake white-fish |
|---|---|---|---|---|---|---|---|---|---|
| 1.5 | .0013 | .0016 | .0010 | .0005 | .0002 | .0005 | .0005 | .0009 | .0006 |
| 2.5 | .0065 | .0077 | .0047 | .0025 | .0013 | .0024 | .0027 | .0045 | .0030 |
| 3.5 | .0186 | .0212 | .0132 | .0072 | .0041 | .0070 | .0082 | .0132 | .0092 |
| 4.5 | .0409 | .0454 | .0282 | .0158 | .0098 | .0154 | .0188 | .0292 | .0211 |
| 5.5 | .0765 | .0834 | .0519 | .0297 | .0197 | .0289 | .0362 | .0551 | .0408 |
| 6.5 | .129 | .138 | .086 | .050 | .035 | .049 | .063 | .094 | .071 |
| 7.5 | .202 | .213 | .133 | .079 | .057 | .077 | .100 | .147 | .113 |
| 8.5 | .299 | .311 | .195 | .117 | .088 | .113 | .151 | .219 | .171 |
| 9.5 | .423 | .436 | .273 | .165 | .129 | .161 | .217 | .311 | .246 |
| 10.5 | .578 | .590 | .369 | .226 | .182 | .220 | .302 | .427 | .343 |
| 11.5 | .77 | .78 | .49 | .30 | .25 | .29 | .41 | .57 | .46 |
| 12.5 | 1.00 | 1.00 | .63 | .39 | .33 | .38 | .53 | .74 | .61 |
| 13.5 | 1.27 | 1.26 | .79 | .50 | .43 | .48 | .69 | .95 | .78 |
| 14.5 | 1.59 | 1.57 | .98 | .62 | .55 | .61 | .87 | 1.19 | .99 |
| 15.5 | 1.95 | 1.92 | 1.21 | .77 | .70 | .75 | 1.08 | 1.46 | 1.23 |
| 16.5 | 2.38 | 2.32 | 1.46 | .94 | .86 | .91 | 1.33 | 1.78 | 1.52 |
| 17.5 | 2.86 | 2.77 | 1.74 | 1.13 | 1.06 | 1.09 | 1.61 | 2.15 | 1.84 |
| 18.5 | 3.40 | 3.28 | 2.06 | 1.34 | 1.28 | 1.30 | 1.93 | 2.56 | 2.21 |
| 19.5 | 4.01 | 3.84 | 2.42 | 1.58 | 1.54 | 1.54 | 2.29 | 3.03 | 2.63 |
| 20.5 | 4.68 | 4.47 | 2.82 | 1.85 | 1.82 | 1.80 | 2.70 | 3.55 | 3.10 |
| 21.5 | 5.44 | 5.17 | 3.26 | 2.15 | 2.15 | 2.09 | 3.16 | 4.13 | 3.63 |
| 22.5 | 6.27 | 5.93 | 3.74 | 2.48 | 2.51 | 2.41 | 3.66 | 4.76 | 4.21 |
| 23.5 | 7.18 | 6.76 | 4.26 | 2.85 | 2.92 | 2.76 | 4.22 | 5.47 | 4.86 |
| 24.5 | 8.18 | 7.67 | 4.84 | 3.24 | 3.37 | 3.15 | 4.84 | 6.24 | 5.57 |
| 25.5 | 9.27 | 8.66 | 5.46 | 3.68 | 3.87 | 3.57 | 5.52 | 7.08 | 6.36 |
| 26.5 | | | 6.14 | 4.15 | 4.42 | 4.03 | 6.26 | 8.00 | 7.22 |
| 27.5 | | | 6.87 | 4.66 | 5.02 | 4.52 | 7.07 | 8.99 | 8.15 |
| 28.5 | | | 7.66 | 5.22 | 5.67 | 5.06 | 7.95 | 10.07 | 9.17 |
| 29.5 | | | 8.50 | 5.81 | 6.39 | 5.64 | 8.90 | 11.23 | 10.27 |
| 30.5 | | | 9.41 | 6.46 | 7.16 | 6.26 | 9.92 | 12.48 | 11.46 |
| 31.5 | | | 10.4 | 7.1 | 8.0 | 6.9 | 11.0 | 13.8 | |
| 32.5 | | | 11.4 | 7.9 | 8.9 | 7.6 | 12.2 | 15.3 | |
| 33.5 | | | 12.5 | 8.7 | 9.9 | 8.4 | 13.5 | 16.8 | |
| 34.5 | | | 13.7 | 9.5 | 11.0 | 9.2 | 14.9 | 18.4 | |
| 35.5 | | | 14.9 | 10.4 | 12.1 | 10.1 | 16.3 | 20.2 | |
| 36.5 | | | | 11.4 | 13.3 | 11.0 | 17.9 | 22.0 | |
| 37.5 | | | | 12.4 | 14.6 | 12.0 | 19.5 | 24.0 | |
| 38.5 | | | | 13.4 | 16.0 | 13.0 | 21.3 | 26.1 | |
| 39.5 | | | | 14.5 | 17.5 | 14.1 | 23.2 | 28.3 | |

Table 4.–Length-weight relationships (inches-pounds) for salmonids in streams and inland lakes.

| Length (inches) | Stream trout[b] | Trout in lakes[a] | | | | Atlantic salmon |
|---|---|---|---|---|---|---|
| | | Lake | Splake | Brown | Brook | |
| 1.5 | .0012 | .0007 | .0005 | .0014 | .0009 | .0019 |
| 2.5 | .0056 | .0036 | .0027 | .0066 | .0047 | .0077 |
| 3.5 | .0150 | .0105 | .0083 | .0183 | .0136 | .0196 |
| 4.5 | .0320 | .0232 | .0193 | .0390 | .0298 | .0395 |
| 5.5 | .0590 | .0440 | .0381 | .0712 | .0560 | .0690 |
| 6.5 | .097 | .075 | .067 | .118 | .095 | .163 |
| 7.5 | .148 | .118 | .108 | .181 | .148 | .231 |
| 8.5 | .220 | .175 | .165 | .264 | .220 | .315 |
| 9.5 | .306 | .250 | .241 | .369 | .312 | .417 |
| 10.5 | .411 | .343 | .338 | .498 | .427 | .417 |
| 11.5 | .54 | .46 | .46 | .66 | .57 | .54 |
| 12.5 | .70 | .60 | .61 | .84 | .74 | .68 |
| 13.5 | .87 | .76 | .79 | 1.06 | .94 | .84 |
| 14.5 | 1.08 | .96 | 1.00 | 1.32 | 1.18 | 1.02 |
| 15.5 | 1.33 | 1.18 | 1.26 | 1.61 | 1.45 | 1.23 |
| 16.5 | 1.60 | 1.44 | 1.55 | 1.94 | 1.77 | 1.46 |
| 17.5 | 1.90 | 1.74 | 1.89 | 2.32 | 2.12 | 1.72 |
| 18.5 | 2.26 | 2.08 | 2.28 | 2.74 | 2.53 | 2.01 |
| 19.5 | 2.64 | 2.46 | 2.73 | 3.21 | 2.98 | 2.33 |
| 20.5 | 3.08 | 2.88 | 3.23 | 3.73 | 3.49 | 2.68 |
| 21.5 | 3.54 | 3.35 | 3.79 | 4.30 | 4.05 | 3.06 |
| 22.5 | 4.05 | 3.87 | 4.42 | 4.93 | 4.68 | 3.47 |
| 23.5 | 4.63 | 4.45 | 5.12 | 5.62 | 5.36 | 3.91 |
| 24.5 | 5.25 | 5.08 | 5.89 | 6.37 | 6.11 | 4.39 |
| 25.5 | 5.92 | 5.76 | 6.75 | 7.19 | 6.93 | 4.91 |
| 26.5 | 6.65 | 6.51 | 7.68 | 8.07 | | 5.47 |
| 27.5 | 7.44 | 7.33 | 8.70 | 9.02 | | 6.06 |
| 28.5 | 8.28 | 8.21 | 9.82 | 10.05 | | 6.69 |
| 29.5 | 9.18 | 9.16 | 11.03 | 11.14 | | 7.37 |
| 30.5 | 10.15 | 10.19 | 12.34 | 12.32 | | 8.08 |
| 31.5 | | 11.3 | 13.8 | 13.6 | | 8.8 |
| 32.5 | | 12.5 | 15.3 | 14.9 | | 9.6 |
| 33.5 | | 13.7 | 16.9 | 16.3 | | 10.5 |
| 34.5 | | 15.1 | 18.7 | 17.8 | | 11.4 |
| 35.5 | | 16.5 | 20.6 | 19.5 | | 12.3 |
| 36.5 | | 18.0 | 22.6 | | | 13.3 |
| 37.5 | | 19.6 | 24.8 | | | 14.4 |
| 38.5 | | 21.4 | 27.1 | | | 15.4 |
| 39.5 | | 23.2 | 29.5 | | | 16.6 |

[a] Rainbow trout in lakes are similar to stream trout.
[b] Brook, brown, and rainbow trout in streams are similar in weight.

Table 5.–Length-weight relationships (inches-pounds) for other large wild fish.

| Length (inches) | Lake herring | Burbot | Bowfin | Common carp | Freshwater drum | Longnose gar |
|---|---|---|---|---|---|---|
| 1.5 | .0011 | .0009 | .0013 | .0024 | .0009 | .0001 |
| 2.5 | .0048 | .0040 | .0060 | .0104 | .0047 | .0004 |
| 3.5 | .0126 | .0112 | .0163 | .0271 | .0138 | .0013 |
| 4.5 | .0257 | .0241 | .0343 | .0552 | .0307 | .0031 |
| 5.5 | .0457 | .0444 | .0622 | .0976 | .0584 | .0063 |
| 6.5 | .073 | .074 | .102 | .157 | .100 | .011 |
| 7.5 | .111 | .114 | .156 | .235 | .157 | .019 |
| 8.5 | .158 | .167 | .226 | .336 | .235 | .029 |
| 9.5 | .218 | .234 | .314 | .460 | .335 | .043 |
| 10.5 | .290 | .317 | .422 | .612 | .462 | .061 |
| 11.5 | .38 | .42 | .55 | .79 | .62 | .08 |
| 12.5 | .48 | .54 | .71 | 1.00 | .81 | .11 |
| 13.5 | .59 | .68 | .89 | 1.25 | 1.03 | .15 |
| 14.5 | .73 | .84 | 1.10 | 1.53 | 1.30 | .19 |
| 15.5 | .88 | 1.03 | 1.34 | 1.85 | 1.60 | .24 |
| 16.5 | 1.05 | 1.25 | 1.61 | 2.21 | 1.96 | .30 |
| 17.5 | 1.24 | 1.50 | 1.91 | 2.61 | 2.36 | .36 |
| 18.5 | 1.46 | 1.77 | 2.25 | 3.05 | 2.82 | .44 |
| 19.5 | 1.70 | 2.08 | 2.64 | 3.54 | 3.34 | .53 |
| 20.5 | 1.96 | 2.42 | 3.06 | 4.09 | 3.92 | .64 |
| 21.5 | | 2.80 | 3.52 | 4.68 | 4.56 | .75 |
| 22.5 | | 3.21 | 4.02 | 5.32 | 5.28 | .88 |
| 23.5 | | 3.66 | 4.58 | 6.02 | 6.06 | 1.03 |
| 24.5 | | 4.16 | 5.18 | 6.78 | 6.93 | 1.19 |
| 25.5 | | 4.69 | 5.83 | 7.59 | 7.88 | 1.37 |
| 26.5 | | 5.28 | 6.53 | 8.47 | | 1.56 |
| 27.5 | | 5.91 | 7.29 | 9.41 | | 1.78 |
| 28.5 | | 6.58 | 8.10 | 10.41 | | 2.02 |
| 29.5 | | 7.31 | 8.97 | 11.48 | | 2.28 |
| 30.5 | | 8.09 | 9.90 | 12.62 | | 2.56 |
| 31.5 | | 8.9 | 10.9 | 13.8 | | 2.9 |
| 32.5 | | 9.8 | 12.0 | 15.1 | | 3.2 |
| 33.5 | | 10.8 | 13.1 | 16.5 | | 3.6 |
| 34.5 | | 11.8 | 14.3 | 17.9 | | 3.9 |
| 35.5 | | 12.8 | 15.5 | 19.4 | | 4.4 |
| 36.5 | | 14.0 | | 21.0 | | 4.8 |
| 37.5 | | 15.2 | | 22.7 | | 5.3 |
| 38.5 | | 16.4 | | 24.4 | | 5.8 |
| 39.5 | | 17.7 | | 26.3 | | 6.3 |

Table 6.–Length-weight relationships (inches-pounds) for suckers and redhorses.

| Length (inches) | Sucker | | | Redhorse | | |
|---|---|---|---|---|---|---|
| | White | Hog | Longnose | Shorthead | Golden | Silver |
| 1.5 | .0013 | .0010 | .0013 | .0015 | .0015 | .0019 |
| 2.5 | .0061 | .0049 | .0064 | .0069 | .0065 | .0080 |
| 3.5 | .0168 | .0141 | .0179 | .0186 | .0174 | .0203 |
| 4.5 | .0357 | .0313 | .0386 | .0390 | .0362 | .0409 |
| 5.5 | .0652 | .0591 | .0713 | .0704 | .0649 | .0713 |
| 6.5 | .108 | .100 | .119 | .115 | .105 | .114 |
| 7.5 | .165 | .158 | .184 | .176 | .160 | .169 |
| 8.5 | .241 | .234 | .270 | .254 | .230 | .239 |
| 9.5 | .336 | .333 | .380 | .352 | .318 | .326 |
| 10.5 | .454 | .457 | .516 | .473 | .425 | .430 |
| 11.5 | .60 | .61 | .68 | .62 | .55 | .55 |
| 12.5 | .77 | .79 | .88 | .79 | .71 | .70 |
| 13.5 | .96 | 1.01 | 1.11 | .99 | .88 | .86 |
| 14.5 | 1.20 | 1.27 | 1.38 | 1.22 | 1.09 | 1.05 |
| 15.5 | 1.46 | 1.57 | 1.70 | 1.49 | 1.32 | 1.27 |
| 16.5 | 1.76 | 1.91 | 2.06 | 1.79 | 1.58 | 1.51 |
| 17.5 | 2.10 | 2.30 | 2.46 | 2.13 | 1.89 | 1.78 |
| 18.5 | 2.48 | 2.75 | 2.92 | 2.50 | 2.21 | 2.07 |
| 19.5 | 2.91 | 3.24 | 3.43 | 2.92 | 2.57 | 2.40 |
| 20.5 | 3.38 | 3.80 | 3.99 | 3.39 | 2.98 | 2.76 |
| 21.5 | 3.90 | | 4.62 | 3.90 | 3.42 | 3.15 |
| 22.5 | 4.47 | | 5.31 | 4.46 | 3.90 | 3.57 |
| 23.5 | 5.09 | | 6.06 | 5.07 | 4.43 | 4.03 |
| 24.5 | 5.77 | | 6.89 | 5.73 | 5.00 | 4.52 |
| 25.5 | 6.50 | | 7.79 | 6.44 | 5.61 | 5.06 |

Table 7.–Length-weight relationships (inches-pounds) for some non-sport fish.

| Length (inches) | Gizzard shad | Alewife | Chubsucker spp. | Chub Creek | Chub Hornyhead | Grass pickerel | Stonecat |
|---|---|---|---|---|---|---|---|
| 1.5 | .0012 | .0008 | .0014 | .0013 | .0012 | .0006 | .0013 |
| 2.5 | .0055 | .0038 | .0071 | .0059 | .0061 | .0030 | .0058 |
| 3.5 | .0153 | .0106 | .0208 | .0157 | .0178 | .0082 | .0152 |
| 4.5 | .0328 | .0229 | .0463 | .0327 | .0395 | .0175 | .0312 |
| 5.5 | .0603 | .0423 | .0878 | .0588 | .0746 | .0320 | .0554 |
| 6.5 | .100 | .071 | .150 | .096 | .127 | .053 | .089 |
| 7.5 | .155 | .109 | .236 | .146 | .200 | .081 | .135 |
| 8.5 | .226 | .161 | .352 | .210 | .297 | .119 | .192 |
| 9.5 | .317 | .226 | .502 | .291 | .422 | .166 | .265 |
| 10.5 | .430 | .307 | .690 | .390 | .580 | .224 | .352 |
| 11.5 | .567 | .405 | .923 | .509 | | .295 | .457 |
| 12.5 | .730 | .523 | 1.204 | .649 | | .379 | .580 |
| 13.5 | .922 | .662 | 1.539 | .813 | | .478 | .723 |
| 14.5 | 1.146 | .824 | 1.933 | 1.002 | | .592 | .887 |
| 15.5 | 1.403 | 1.011 | 2.391 | 1.218 | | .724 | 1.074 |
| 16.5 | 1.70 | | | | | | |
| 17.5 | 2.03 | | | | | | |
| 18.5 | 2.40 | | | | | | |
| 19.5 | 2.82 | | | | | | |
| 20.5 | 3.28 | | | | | | |

Table 7.–Continued.

| Length (inches) | Pirate perch | Tadpole madtom | Sculpin spp. | Blackside | Darter Johnny | Rainbow |
|---|---|---|---|---|---|---|
| 1.5 | .0021 | .0016 | .0015 | .0049 | .0010 | .0011 |
| 2.5 | .0101 | .0078 | .0081 | .0145 | .0051 | .0065 |
| 3.5 | .0286 | .0223 | .0241 | .0326 | .0148 | .0205 |
| 4.5 | .0625 | .0485 | .0545 | .0624 | .0331 | .0483 |
| 5.5 | .1164 | .0905 | .1047 | .1072 | .0630 | .0956 |

Table 8.–Length-weight relationships (inches-pounds) for shiners and minnows.

| Length (inches) | Shiner | | | | Minnow | | |
|---|---|---|---|---|---|---|---|
| | Golden | Spottail | Emerald | Common/ striped | Fathead | Bluntnose | Blackstripe topminnow |
| 1.5 | .0009 | .0011 | .0009 | .0010 | .0015 | .0010 | .0011 |
| 2.5 | .0045 | .0050 | .0036 | .0052 | .0072 | .0056 | .0181 |
| 3.5 | .0126 | .0136 | .0090 | .0159 | .0202 | .0174 | .0418 |
| 4.5 | .0274 | .0289 | .0178 | .0366 | .0438 | .0408 | .0815 |
| 5.5 | .0509 | .0527 | .0308 | .0722 | .0811 | .0805 | .1421 |
| 6.5 | .085 | | .049 | .124 | | | |
| 7.5 | .133 | | .072 | .199 | | | |
| 8.5 | .195 | | .101 | .302 | | | |
| 9.5 | .275 | | .137 | .437 | | | |
| 10.5 | .374 | | .180 | .609 | | | |
| 11.5 | .495 | | | .824 | | | |
| 12.5 | .640 | | | 1.087 | | | |
| 13.5 | .811 | | | 1.404 | | | |
| 14.5 | 1.011 | | | 1.779 | | | |
| 15.5 | 1.241 | | | 2.220 | | | |

Table 9.–Length-weight relationships for hatchery-reared muskellunge, if pounds = 0.0001600 $L^3$.

| Total length | | Weight | | Total length | | Weight | |
|---|---|---|---|---|---|---|---|
| inches | mm | pounds | grams | inches | mm | pounds | grams |
| 0.3 | 8 | .0000043 | 0.00196 | 4.2 | 107 | .0118 | 5.38 |
| 0.4 | 10 | .0000102 | 0.00464 | 4.3 | 109 | .0127 | 5.77 |
| 0.5 | 13 | .0000200 | 0.00907 | 4.4 | 112 | .0136 | 6.18 |
| 0.6 | 15 | .0000346 | 0.0157 | 4.5 | 114 | .0146 | 6.61 |
| 0.7 | 18 | .0000549 | 0.0249 | 4.6 | 117 | .0156 | 7.06 |
| 0.8 | 20 | .0000819 | 0.0372 | 4.7 | 119 | .0166 | 7.54 |
| 0.9 | 23 | .000117 | 0.0529 | 4.8 | 122 | .0177 | 8.03 |
| 1.0 | 25 | .000160 | 0.0725 | 4.9 | 124 | .0188 | 8.54 |
| 1.1 | 28 | .000213 | 0.0966 | 5.0 | 127 | .0200 | 9.07 |
| 1.2 | 30 | .000276 | 0.0125 | 5.1 | 130 | .0212 | 9.63 |
| 1.3 | 33 | .000352 | 0.159 | 5.2 | 132 | .0225 | 10.2 |
| 1.4 | 36 | .000439 | 0.199 | 5.3 | 135 | .0238 | 10.8 |
| 1.5 | 38 | .000540 | 0.245 | 5.4 | 137 | .0252 | 11.4 |
| 1.6 | 41 | .000655 | 0.297 | 5.5 | 140 | .0266 | 12.1 |
| 1.7 | 43 | .000786 | 0.357 | 5.6 | 142 | .0281 | 12.6 |
| 1.8 | 46 | .000933 | 0.423 | 5.7 | 145 | .0296 | 13.4 |
| 1.9 | 48 | .00110 | 0.498 | 5.8 | 147 | .0312 | 14.2 |
| 2.0 | 51 | .00128 | 0.581 | 5.9 | 150 | .0329 | 14.9 |
| 2.1 | 53 | .00148 | 0.672 | 6.0 | 152 | .0346 | 15.7 |
| 2.2 | 56 | .00170 | 0.773 | 6.1 | 155 | .0363 | 16.5 |
| 2.3 | 58 | .00195 | 0.883 | 6.2 | 158 | .0381 | 17.3 |
| 2.4 | 61 | .00221 | 1.00 | 6.3 | 160 | .0400 | 18.2 |
| 2.5 | 64 | .00250 | 1.13 | 6.4 | 163 | .0419 | 19.0 |
| 2.6 | 66 | .00281 | 1.28 | 6.5 | 165 | .0439 | 19.9 |
| 2.7 | 69 | .00315 | 1.43 | 6.6 | 168 | .0460 | 20.9 |
| 2.8 | 71 | .00351 | 1.59 | 6.7 | 170 | .0481 | 21.8 |
| 2.9 | 74 | .00390 | 1.77 | 6.8 | 173 | .0503 | 22.8 |
| 3.0 | 76 | .00432 | 1.96 | 6.9 | 175 | .0525 | 23.8 |
| 3.1 | 79 | .00477 | 2.16 | 7.0 | 178 | .0549 | 24.9 |
| 3.2 | 81 | .00524 | 2.38 | 7.1 | 180 | .0573 | 26.0 |
| 3.3 | 84 | .00575 | 2.61 | 7.2 | 183 | .0597 | 27.1 |
| 3.4 | 86 | .00629 | 2.85 | 7.3 | 185 | .0622 | 28.2 |
| 3.5 | 89 | .00686 | 3.11 | 7.4 | 188 | .0648 | 29.4 |
| 3.6 | 91 | .00746 | 3.39 | 7.5 | 190 | .0675 | 30.6 |
| 3.7 | 94 | .00810 | 3.68 | 7.6 | 193 | .0702 | 31.9 |
| 3.8 | 96 | .00878 | 3.98 | 7.7 | 196 | .0730 | 33.1 |
| 3.9 | 99 | .00949 | 4.31 | 7.8 | 198 | .0759 | 34.4 |
| 4.0 | 102 | .0102 | 4.64 | 7.9 | 201 | .0789 | 35.8 |
| 4.1 | 104 | .0110 | 5.00 | 8.0 | 203 | .0819 | 37.2 |

Table 10.–Length-weight relationships for hatchery-reared walleye, if pounds = 0.000300 $L^3$.

| Total length | | Weight | | Total length | | Weight | |
|---|---|---|---|---|---|---|---|
| inches | mm | pounds | grams | inches | mm | pounds | grams |
| 0.3 | 8 | .0000081 | 0.00367 | 4.2 | 107 | .02223 | 10.1 |
| 0.4 | 10 | .0000192 | 0.00871 | 4.3 | 109 | .02385 | 10.8 |
| 0.5 | 13 | .0000375 | 0.0170 | 4.4 | 112 | .02556 | 11.6 |
| 0.6 | 15 | .000065 | 0.0294 | 4.5 | 114 | .02734 | 12.4 |
| 0.7 | 18 | .000103 | 0.0467 | 4.6 | 117 | .02920 | 13.2 |
| 0.8 | 20 | .000154 | 0.0697 | 4.7 | 119 | .03115 | 14.1 |
| 0.9 | 23 | .000219 | 0.0992 | 4.8 | 122 | .03318 | 15.0 |
| 1.0 | 25 | .000300 | 0.136 | 4.9 | 124 | .03529 | 16.0 |
| 1.1 | 28 | .000399 | 0.181 | 5.0 | 127 | .03750 | 17.0 |
| 1.2 | 30 | .000518 | 0.235 | 5.1 | 130 | .03980 | 18.0 |
| 1.3 | 33 | .000659 | 0.299 | 5.2 | 132 | .04218 | 19.1 |
| 1.4 | 36 | .000823 | 0.373 | 5.3 | 135 | .04466 | 20.3 |
| 1.5 | 38 | .001013 | 0.459 | 5.4 | 137 | .04724 | 21.4 |
| 1.6 | 41 | .001229 | 0.557 | 5.5 | 140 | .04991 | 22.6 |
| 1.7 | 43 | .001474 | 0.669 | 5.6 | 142 | .05268 | 23.9 |
| 1.8 | 46 | .001750 | 0.794 | 5.7 | 145 | .05556 | 25.2 |
| 1.9 | 48 | .002058 | 0.933 | 5.8 | 147 | .05853 | 26.6 |
| 2.0 | 51 | .002400 | 1.09 | 5.9 | 150 | .06161 | 28.0 |
| 2.1 | 53 | .002778 | 1.26 | 6.0 | 152 | .06480 | 29.4 |
| 2.2 | 56 | .003194 | 1.45 | 6.1 | 155 | .06809 | 30.9 |
| 2.3 | 58 | .003650 | 1.66 | 6.2 | 158 | .07150 | 32.4 |
| 2.4 | 61 | .004147 | 1.88 | 6.3 | 160 | .07501 | 34.0 |
| 2.5 | 64 | .004687 | 2.13 | 6.4 | 163 | .07864 | 35.7 |
| 2.6 | 66 | .005273 | 2.39 | 6.5 | 165 | .08239 | 37.4 |
| 2.7 | 69 | .005905 | 2.68 | 6.6 | 168 | .08625 | 39.1 |
| 2.8 | 71 | .006586 | 2.99 | 6.7 | 170 | .09023 | 40.9 |
| 2.9 | 74 | .007317 | 3.32 | 6.8 | 173 | .09433 | 42.8 |
| 3.0 | 76 | .008100 | 3.67 | 6.9 | 175 | .09855 | 44.7 |
| 3.1 | 79 | .008937 | 4.05 | 7.0 | 178 | .10290 | 46.7 |
| 3.2 | 81 | .009830 | 4.46 | 7.1 | 180 | .10737 | 48.7 |
| 3.3 | 84 | .01078 | 4.89 | 7.2 | 183 | .1120 | 50.8 |
| 3.4 | 86 | .01179 | 5.35 | 7.3 | 185 | .1167 | 52.9 |
| 3.5 | 89 | .01286 | 5.83 | 7.4 | 188 | .1216 | 55.1 |
| 3.6 | 91 | .01400 | 6.35 | 7.5 | 190 | .1266 | 57.4 |
| 3.7 | 94 | .01520 | 6.89 | 7.6 | 193 | .1317 | 59.7 |
| 3.8 | 96 | .01646 | 7.47 | 7.7 | 196 | .1370 | 62.1 |
| 3.9 | 99 | .01780 | 8.07 | 7.8 | 198 | .1424 | 64.6 |
| 4.0 | 102 | .01920 | 8.71 | 7.9 | 201 | .1479 | 67.1 |
| 4.1 | 104 | .02068 | 9.38 | 8.0 | 203 | .1536 | 69.7 |

Table 11.–Length-weight relationships for hatchery-reared brook, brown, and rainbow trout.

| Length (inches) | Weight (pounds) | Length (inches) | Weight (pounds) | Length (inches) | Weight (pounds) |
|---|---|---|---|---|---|
| 1.0 | .0004 | 5.3 | .0565 | 9.6 | .352 |
| 1.1 | .0006 | 5.4 | .0600 | 9.7 | .364 |
| 1.2 | .0007 | 5.5 | .0645 | 9.8 | .376 |
| 1.3 | .0009 | 5.6 | .0685 | 9.9 | .388 |
| 1.4 | .0011 | 5.7 | .0730 | 10.0 | .399 |
| 1.5 | .0013 | 5.8 | .0775 | 10.1 | .410 |
| 1.6 | .0015 | 5.9 | .0835 | 10.2 | .422 |
| 1.7 | .0018 | 6.0 | .0900 | 10.3 | .435 |
| 1.8 | .0021 | 6.1 | .0950 | 10.4 | .447 |
| 1.9 | .0025 | 6.2 | .1000 | 10.5 | .461 |
| 2.0 | .0029 | 6.3 | .105 | 10.6 | .475 |
| 2.1 | .0033 | 6.4 | .110 | 10.7 | .489 |
| 2.2 | .0037 | 6.5 | .115 | 10.8 | .503 |
| 2.3 | .0042 | 6.6 | .120 | 10.9 | .518 |
| 2.4 | .0046 | 6.7 | .126 | 11.0 | .532 |
| 2.5 | .0050 | 6.8 | .132 | 11.1 | .545 |
| 2.6 | .0058 | 6.9 | .138 | 11.2 | .560 |
| 2.7 | .0069 | 7.0 | .144 | 11.3 | .575 |
| 2.8 | .0080 | 7.1 | .151 | 11.4 | .590 |
| 2.9 | .0095 | 7.2 | .158 | 11.5 | .605 |
| 3.0 | .0109 | 7.3 | .165 | 11.6 | .621 |
| 3.1 | .0122 | 7.4 | .172 | 11.7 | .639 |
| 3.2 | .0138 | 7.5 | .179 | 11.8 | .655 |
| 3.3 | .0152 | 7.6 | .186 | 11.9 | .672 |
| 3.4 | .0165 | 7.7 | .193 | 12.0 | .690 |
| 3.5 | .0180 | 7.8 | .199 | 12.1 | .706 |
| 3.6 | .0195 | 7.9 | .205 | 12.2 | .723 |
| 3.7 | .0210 | 8.0 | .211 | 12.3 | .740 |
| 3.8 | .0225 | 8.1 | .219 | 12.4 | .758 |
| 3.9 | .0245 | 8.2 | .227 | 12.5 | .777 |
| 4.0 | .0265 | 8.3 | .235 | 12.6 | .798 |
| 4.1 | .0287 | 8.4 | .244 | 12.7 | .819 |
| 4.2 | .0308 | 8.5 | .251 | 12.8 | .839 |
| 4.3 | .0329 | 8.6 | .259 | 12.9 | .860 |
| 4.4 | .0350 | 8.7 | .267 | 13.0 | .880 |
| 4.5 | .0370 | 8.8 | .274 | 13.1 | .904 |
| 4.6 | .0390 | 8.9 | .282 | 13.2 | .928 |
| 4.7 | .0410 | 9.0 | .290 | 13.3 | .952 |
| 4.8 | .0434 | 9.1 | .300 | 13.4 | .975 |
| 4.9 | .0459 | 9.2 | .310 | 13.5 | 1.00 |
| 5.0 | .0482 | 9.3 | .320 | 13.6 | 1.02 |
| 5.1 | .0509 | 9.4 | .330 | 13.7 | 1.05 |
| 5.2 | .0535 | 9.5 | .340 | 13.8 | 1.07 |

# Sampling Zooplankton in Lakes

By Merle G. Galbraith, Jr.

This memo describes the methods for estimating the number of zooplankters in lakes. Laboratory procedures are given also for determining the number of large (≧ 1.4 mm) zooplankters.

## Equipment

Thirty-inch long, Wisconsin-style plankton net and straining bucket with drain stopper; mesh size should be 153- or 160-μm nytex netting. Three 125-ml plastic wash bottles with fine tipped spouts. Preserve samples in 3- or 4-ounce widemouthed bottles. A homemade filter funnel of No. 30 mesh brass screening of 0.006-inch width opening and made with a pouring spout. Binocular microscope with at least 20X magnification and containing an ocular micrometer which covers as wide a field as possible. A petri dish (grid counting) or other type counting chamber. Equipment for determining dissolved oxygen and a portable fathometer for locating the sampling sites.

## Methods

Determine the depth at which oxygen is <u>less</u> than 0.5 ppm. This depth will hereafter be referred to as the "critical depth" and is the minimum depth from which to start retrieving the plankton net. To locate the sampling stations, divide the lake into four quadrants with the center over the center of the deepest basin (Fig. 1). One axis of the quadrants should be in line with the direction of the current wind. Choose a site on each axis as far out from the center as possible and near where the "critical depth" intersects the lake bottom. Allow enough room below the "critical depth" so that the sampler will not agitate the bottom. To minimize agitation of the bottom always lower the sampler very slowly and carefully for the last 3 feet. Upon reaching the proper depth, pause for at least 30 seconds, then raise the sampler at a rate of approximately 4 feet per second. A hand reel with revolving handles on both sides will greatly facilitate smooth uninterrupted

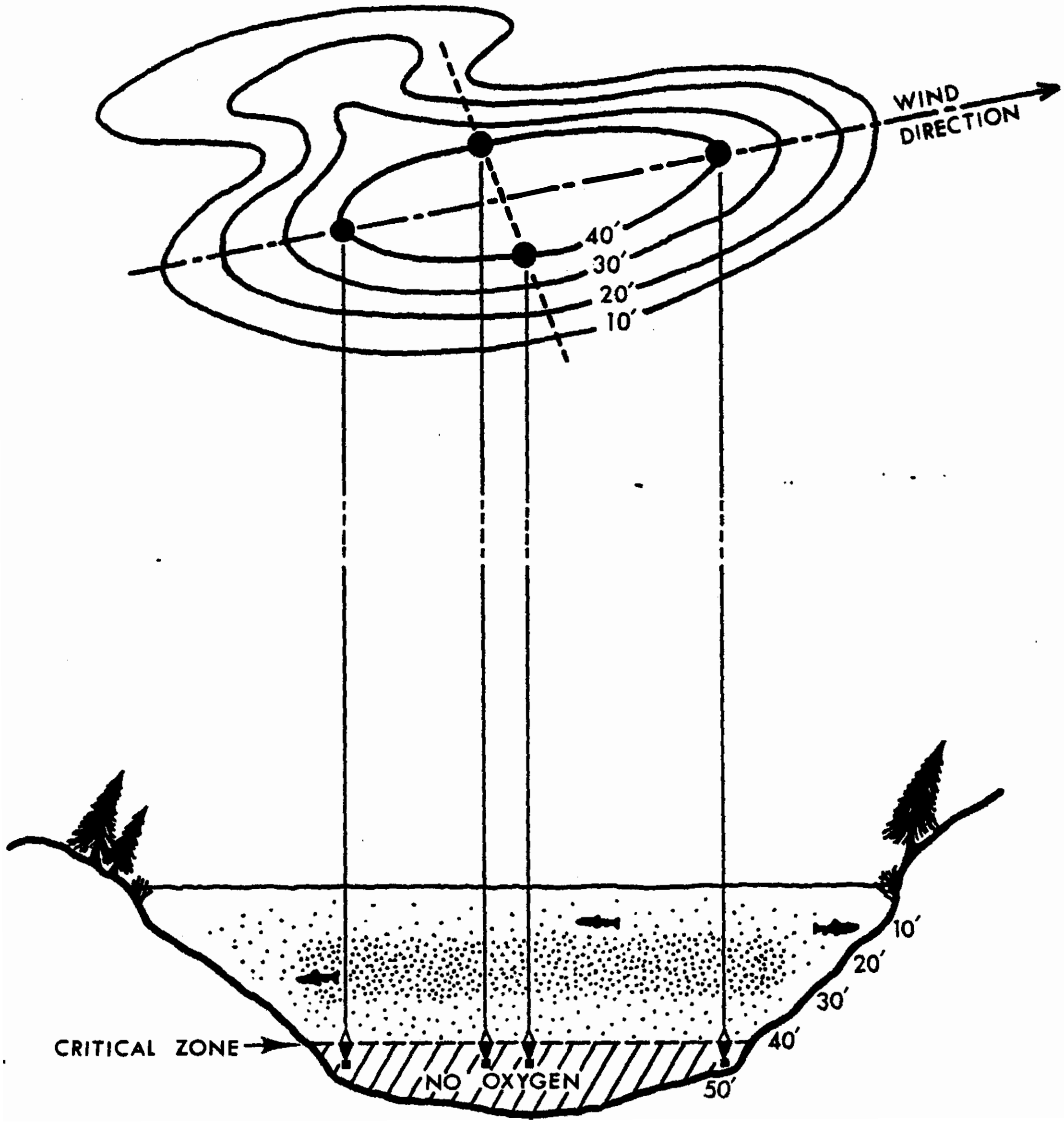


Figure 1.--Location of stations for sampling zooplankton in lake with oxygen depletion.

retrieval. Raise the net out of the water all in one motion so that the plankton bucket is just above the surface. While hanging on to the net with one hand, scoop water from the lake and throw it forcibly on all sides of the net in order to dislodge any plankton that might still adhere to the net. After washing down the net, detach bucket and wash down the sides with a 125-ml wash bottle so that all of the plankton settles to the bottom. Remove stopper and allow sample to drain into the preserving bottle while at the same time washing the sides of the bucket. Add enough formalin to make approximately a 5% solution. The correct amount of formalin can be added to a small amount of water in each sample bottle before collecting samples.

If interested only in the larger zooplankton ($\geqq$ 1.4 mm) in the laboratory pour the contents of a sample through the 30-mesh screen in order to get rid of the smaller organisms. Wash the contents through the screen using either a wash bottle or with a 5-mm (inside diameter) tap hose with a small tapered eye dropper attached. When using a hose be sure to regulate water pressure carefully beforehand so that the organisms are not accidentally splattered from the screen or forced through it. Pour off the contents from the 30-mesh screen into a counting dish containing 70% alcohol. Examine contents and count all those 1.4 mm or larger under magnification. An ocular micrometer should be installed in the eye piece in order to make the measurements. Measure daphnids from the crest of the head to the base of the spine and copepods from the head to the last segment on the tail which bear the long hairs. After measuring organisms in a few samples it will become easy to judge the size of most or many of the zooplankton. The number of individuals in a lake of each important species is the average of counts from each quadrant and may be expressed as the number per square meter of surface area. Knowing the area of the mouth of the plankton sampler in square inches or square meters, the density can be easily calculated by direct proportion. As a word of caution, to prevent losing any part of the plankton sampler, tie nylon cord to unattached parts of the plankton net, including the brass stopper, so that everything is connected together.

If there are too many zooplankters to count in a sample (i.e., over 200 individuals for each of several species), then a sample may be diluted to a known volume and subsampled. To subsample separate counts of organisms must be made of five 1-ml aliquots and the counts averaged. The total count for a sample is found by multiplying the average of the five different subsamples by the original total volume of the liquid in the sample. However before removing and counting all the subsamples, the proper dilution must be obtained that will provide at least 30 organisms of each of the common species, or of a particular species, in a 1-ml aliquot. After counting the organisms in an aliquot they must all be returned to the sample before removing the next aliquot.

To remove an aliquot from a sample a Wildco-Hensen-Stemple pipet with plunger spring made for this purpose may be used, or a cheaper automatic pipet with a glass tubing tip constructed from a burette tip will suffice. But the original burette tip must be cut off and the inside diameter should be at least 5 mm wide. When removing each subsample, gently agitate sample so that the plankton is uniformly dispersed throughout the sample.

The selection of sampling sites is not always simple. Most lakes will have a zone of deoxygenated water and one large basin; these will be easy to sample. However, there are some lakes which are more complex. Some lakes may have oxygen in the deepest portion of the lake. These lakes will usually be those which are quite deep or else very shallow with oxygen throughout. The oxygen in the deep lakes will often be confined to only a very small basin. If one uses the "critical depth" as previously defined, the sampling stations will be too close together. Therefore the "critical depth" (Fig. 2) is redefined as the greatest depth at which a few or no zooplankton are present. To find this "critical depth" take water samples in the deepest part of the lake every 2 feet, progressing upward from the bottom. Draw at least three-fourths of the water from the sampler through the standard 250-ml oxygen sample bottle, stopper it, and examine the contents for zooplankton. Holding the bottle toward a light background will help visual

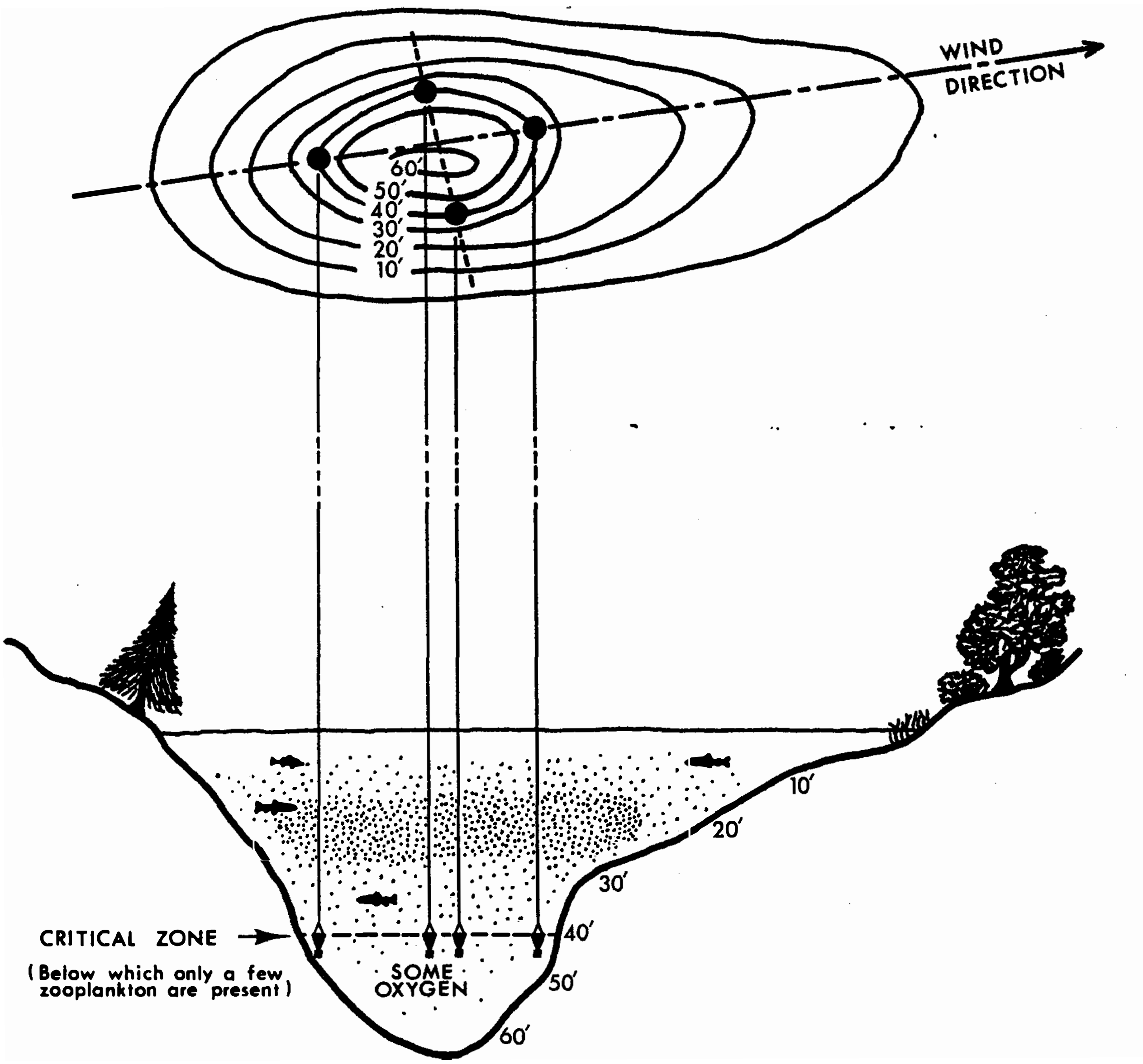


Figure 2.--Location of stations for sampling zooplankton in a deep lake with little or no oxygen depletion.

inspection. Once several zooplankters are sighted in a bottle, go back and sample a foot deeper. The "critical depth" will either be at that depth or 1 foot deeper.

In shallow but completely oxygenated lakes there is no critical depth to determine. Instead select station locations which are approximately equidistant from the center of the lake and the shoreline, yet are all the same depth. The lake should be divided into quadrants in the same manner as described previously.

To sample lakes having more than one basin, one or both criteria for determining "critical depths" may have to be used to locate sampling sites. It is foreseeable that in multi-basin lakes the zone of deoxygenated water may be high enough above the basin contours so that individual basins need not be sampled. But, if there is a difference between basins in their oxygen profile, then each should be sampled separately. At least two stations should be collected in each basin at a location 180° from the other, and then all counts from the lake averaged.

One sample collected in each quadrant represents a minimum number. An additional sample from a location in the center of the quadrants, at the same "critical depth," will probably improve the estimate. But, if additional samples are deemed necessary, continue to select them in pairs with each 180° from the other. Be cognizant of the current wind direction or recent wind direction because strong continuous winds tend to "pile up" zooplankters on the lee side of a lake.

Suggested source of equipment:

Wildco Instruments, 301 Cass Street, Saginaw, MI 48602

Phoenix Wire Works, Inc., 585 Stephenson Hwy, Troy, MI 48084

# Measurement of Stream Velocity and Discharge

By Frank F. Hooper

There can be a number of reasons for one to measure stream flow characteristics:

1. To describe the habitat of benthic fauna in relation to current preferences
2. To determine the amounts (weight) of materials being transported in the stream (sediment load, nutrient mass)
3. To estimate land runoff rates, i.e., discharge per some unit of land area, for agriculture and flood predictions
4. For river basin development in terms of (a) flood control, (b) industrial and domestic water supply potential, and (c) irrigational projects

The pattern of stream flow is based on several hydrological features inherent in natural stream channels. Stream velocities are not uniform in all parts of a traverse section but are reduced near the surface due to friction with the surface tension and along the bottom or sides of the channel due to friction with a solid surface (Fig. 1). For this reason, in studies of bottom organisms and their responses to current, one may find velocities at or near the bottom substrate, where these organisms reside, of more importance than the average velocity in the stream. Methods for current measurements very close to a surface are not well established and are often considered imprecise. However, in biological studies in streams such measurements may be critical. Hynes (1970) cites a number of such methods.

The maximum velocity in streams is usually found in the upper one-third of the water column (Fig. 2). However, in shallow streams the region of maximum velocity is near the surface while in deep rivers the maximum is usually at the one-third point. The mean velocity at any point across a stream is ordinarily at 0.55 to 0.65 of the depth. The velocity at 0.6 of the depth is usually within 5% of the mean velocity.


Figure 1.--Idealized diagrams ~~of the patterns of f~~low in cross-section of open channels: left shows the pattern on a straight reach, right shows the pattern on a bend. The units on the lines of equal flow-rate could be centimeters per second. (Taken from Hynes 1970)

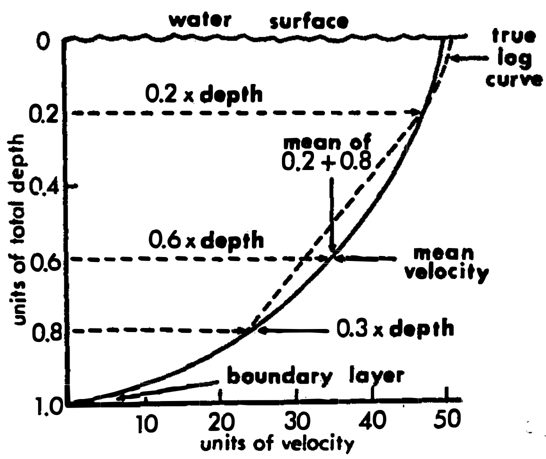


Figure 2.--The rate of flow of water at different depths in an open channel, and depths at which the mean flow can be measured. (Taken from Hynes 1970)

The exact distribution of velocities in natural streams is governed by several factors operating simultaneously. These are:

1. Shape of the channel
2. Roughness of the channel
3. Size of the channel
4. Slope of the channel

Details of how these factors interact to determine the velocity of water are discussed in Hynes (1970) and Whitton (1975).

Velocity measurements with mechanical current meters (e.g., the Price-Gurley meters) are usually taken at 0.4 of the depth for shallow streams and an average of 0.4 and 0.6 of the depth for rivers or streams having bottom obstructions. Ice cover reduces the surface velocity because of the greater retarding effect of ice as compared to air. Under conditions of ice, therefore, mean velocity is taken as the average of velocities at the 0.2 and 0.8 points of depth.

Stream discharge (units of volume/time) is dependent upon the products of two somewhat independent measurements: velocity (units of distance/time) and cross-sectional area (an area measure). Both current or velocity and discharge may be estimated in a variety of ways.

Methods for current measurement

Current velocity may be measured using various types of meters and devices. Apparatus and procedures are described in more detail in Welch (1948) and Buchanan and Sommers (1973). A brief discussion of these methods follows:

Embody Float Method. One of the simplest ways of measuring velocity and discharge in a stream is simply using a float (Davis 1938). The float should be of proper buoyancy such that it floats just beneath the surface so as to avoid effects of wind. Oddly enough, oranges serve as good floats since they have the right buoyancy and are quite visible. By measuring the time such a float takes to travel downstream over a known distance, one obtains an estimate of the surface velocity. Repeating the float measurement over the same stretch of stream but at various distances from shore will give, when averaged, a rough estimate of the average surface velocity. To obtain an estimate of discharge, one takes the average time (t) in seconds for the float to travel the known distance (l) of stream along with additional measurements of the average depth (z) and average width (w) made at preferably two transects of the stream. With these data, the discharge (Q) is given by

$$Q = \frac{wdla}{t}.$$

The constant "a" of this formula is a correction of the surface velocity to the overall stream mean velocity and varies with the degree of roughness of the stream bottom from 0.9 for sandy and mud bottoms to 0.8 for coarse gravel or loose rocky substrates.

Current Meters (Price-Gurley). The best known and most dependable mechanical current meter for measuring stream flow is the Price pattern Gurley meter manufactured by the W. and E. Gurley Company. The original Gurley current meter was designed in 1882 and the latest model is called Type AA. Stream velocities are determined by a carefully balanced bucket wheel mounted on a pivot. Upon each rotation of the bucket wheel, or every fifth turn depending on the contact setting, an electrical impulse is produced. The impulse may be heard as a click over headphones or recorded on a counter. By noting the number of impulses per unit time, velocity may be determined by consulting the special rating chart prepared for each instrument. A smaller version of this meter is called the Pygmy Gurley current meter which allows closer measurements to the stream bottom and also at somewhat slower velocities.

The Type AA Gurley current meter or the Pygmy Gurley may be suspended from either a wading rod assembly or by a flexible cable assembly employing a 15-pound torpedo-shaped lead weight. The Type AA is capable of accurately measuring velocities from 0.1 to 10 ft/sec.

Use of these current meters with a headphone apparatus requires one to count the number of clicks produced by the instrument in a current over a known length of time. Thus, a stopwatch or watch with a second hand is needed. One should select a location in the stream where there is a minimum of turbulence (no eddy currents). When using the current meter to estimate discharge, one should attach the directional fins available with the unit for the most accurate work. These fins allow one to not only determine the current rate but also the current direction. This is important since deviations of the flow from moving downstream and parallel to the banks requires a correction. With the fins attached an angle deviation of the flow from being parallel to the bank can be measured and referred to a table of correction coefficients (called "K" coefficients) which when multiplied with the measured velocity gives an exact measure of current moving directly downstream. Details of this procedure are best left for the instructions available with each meter.

Alternatively, one can obtain a somewhat more approximate estimate of discharge with the current meter by using it strictly as a measure of velocity and ignoring directional variability of the flow. In this simpler method one measures the current along transects across the river or stream at 0.6 of the depth at selected intervals on a transect line. The arithmetic average of these values thus gives an overall mean velocity at the point of the transect. If one also records the depth of water at selected intervals along the same transects and the width of the stream, these results can be plotted on graph paper. Thus, the width-depth data so plotted can be used to estimate the stream's cross-sectional area by simply counting squares on the graph and applying an appropriate weighting factor for each square. Multiplying the cross-sectional area by the mean velocity at the same transect gives a discharge estimate at that point of the river. One can and should measure the discharge at two points or more in close proximity to obtain an average discharge of the river at a particular reach.

Cone and Rubber Bag Method.[1] A simple, inexpensive device for measuring current velocity has been described by Hynes (1970). The device consists of a truncated cone with a small opening (less than 10 mm diameter) with a rubber bag attached to its base. It is helpful if the bag is surrounded by a clear, open-ended plastic cylinder (Fig. 1). A suitable cone is a small, plastic garden hose attachment. Balloons are suitable rubber bags. They should be long and relatively large. A balloon is easily attached to the garden hose cone using the rubber washer that is supplied with the cone.

Operation

Close the cone opening with a finger and place the device, facing into the current, at the point where a measurement is to be made. (This should be a measured distance from the bottom for precision and replication). Remove the finger for a few seconds (precisely timed; usually 5 seconds or less, depending upon the size of the cone opening, the size of the bag, and the current velocity) and then replace it. Measure the volume of water collected with a graduated cylinder. The measurement should be repeated several times at a given point. An average of four or five measurements should always be used; more for precise work.

Calculations

Current velocity is determined using the discharge relationship $V = Q/A$, where:

$V$ = velocity;

$$Q = \frac{\text{volume of water sampled in milliliters (ml)}}{\text{time for sample in seconds (s)}}; \text{ and}$$

$A = \pi(D/2)^2$ with D the diameter of the cone opening in centimeters (cm).

This gives V in units of cm/s (30.5 cm/s = 1 ft/s). D should be measured as precisely as possible. Since Q is a linear function of

[1] Prepared by Steven L. Kohler, School of Natural Resources, The University of Michigan.

V (with slope A), a plot of Q versus V can be prepared and used to provide a quick estimate of V in the field.

Recommendations

The sampling time should be chosen so that the bag does not become full. In relatively fast currents (more than 50 cm/s), this necessitates the use of either short sampling times or fairly large bags. The latter is preferable because of the error associated with measuring short-time intervals.

Be sure the bag is empty between measurements. Air should be expelled by squeezing the bag before placing a finger over the opening.

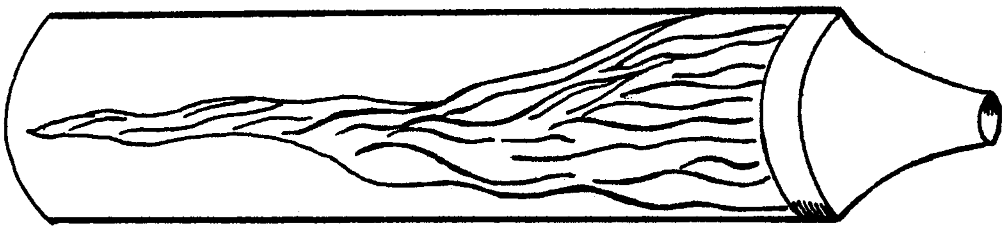

Figure 1. A rubber-bag current meter.

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# Michigan Stream Classification: 1967 System

Anonymous

## Introduction

Michigan's 36,000 miles of streams occur in all degrees of size, quality, and development. A classification system is prerequisite to orderly and effective fish and recreation management programs.

A previous classification of trout streams proved valuable in adopting trout management policy, and in providing a basis for habitat protection. The new classification will involve a revision of the existing trout stream classification, and an extension to include warmwater streams. It will serve as the means for identification of legally defined trout streams. The new system will also include additional inventories to provide a more comprehensive basis for establishing policy and action programs for the management of fisheries, streams, and related lands. Streams will be classified by: I. Type and quality, II. Size, and III. Extent of building development. The inventory will be applicable in the following situations: establishment of water quality standards; determination of recreation values; "wild" or "scenic" river designations; stream and stream frontage improvement and preservation; dam and impoundment problems; fishing and boating access programs; fishing regulations; research planning; fish planning and management and stream land acquisition.

Part IA.--Stream type and quality

Top quality trout mainstream.--Contain good self-sustaining trout or salmon populations and are readily fishable, typically over 15 feet wide.

Top quality trout feeder stream.--Contain good self-sustaining trout or salmon populations, but difficult to fish due to small size, typically less than 15 feet wide.

Second quality trout mainstream.--Contain significant trout or salmon populations, but these populations are appreciably limited by such factors as inadequate natural reproduction, competition, siltation, or pollution. Readily fishable, typically 15 feet wide.

Second quality trout feeder stream.--Contain significant trout or salmon populations, but these populations are appreciably limited by such factors as inadequate natural reproduction, competition, siltation, or pollution. Difficult to fish because of small size, typically less than 15 feet wide.

Top quality warmwater mainstream.--Contain good self-sustaining populations of warmwater game fish and are readily fishable, typically over 15 feet wide.

Top quality warmwater feeder stream.--Contain good self-sustaining populations of warmwater game fish, but are difficult to fish because of small size, typically less than 15 feet wide.

Second quality warmwater mainstream.--Contain significant populations of warmwater fish, but game fish populations are appreciably limited by such factors as pollution, competition, or inadequate natural reproduction. Readily fishable, typically over 15 feet wide.

Second quality warmwater feeder stream.--Contain significant populations of warmwater fish, but game fish populations are appreciably limited by such factors as pollution, competition, or inadequate natural reproduction. Difficult to fish because of small size, typically less than 15 feet wide.

Part IB.--Designation of existing runs of anadromous trout and salmon, Director's designated trout streams

Streams or stream sections which currently receive significant runs of anadromous trout or salmon are also to be designated as trout streams, regardless of whether they are "trout" or "warmwater" according to the above classification. These streams, together with the additional streams classified as trout in Part I, will constitute our legally designated trout streams. This meets our obligation to "designate those streams which, in the opinion of the Director of the Natural Resources Department contain significant populations of trout or salmon."

In outline form this stream type and quality classification can be presented as follows:

I. Trout stream
   A. Top quality
      1. Mainstream
      2. Feeder stream
   B. Second quality
      1. Mainstream
      2. Feeder stream

II. Warmwater stream
   A. Top quality
      1. Mainstream
      2. Feeder stream
   B. Second quality
      1. Mainstream
      2. Feeder stream

Anadromous designation: Additive to each of the above, when applicable.

Discussion--Parts IA and IB

Usually, top quality trout streams will not require stocking as a management procedure. However, it will not be necessary to designate a stream second quality to justify its being stocked. All streams should be classified as your judgment dictates, and if for some reason you deem it advisable to stock a top quality trout stream, the matter will be resolved on its own merits, not entirely on the basis for this classification.

A value judgment will have to be made in the case of streams which contain warmwater game fish populations year-round as well as anadromous runs of trout and salmon during certain parts of the year. If, in your opinion, the runs of anadromous fish are significant enough to warrant the protection provided by legal classification as a trout stream, the stream should be classified as anadromous. If, however, the warmwater fishery that would be made unavailable by trout stream classification outweighs in value expected losses of trout or salmon, then the stream should not be classified as anadromous.

In this classification system the term "feeder" can, on the basis of size, be applied to a stream that flows directly into one of the Great Lakes. Similarly, the term "mainstream" can be applied to a stream that does, in fact, feed another larger stream.

Two criteria are provided for differentiating between "mainstream" and "feeder stream"--fishability, and the 15-foot width. Usually, the two criteria will be complementary, but when this is not the case, fishability is to be the dominant criterion, with the 15-foot criterion used to help resolve difficult cases, or to handle abnormal situations such as recently ditched or extraordinarily brushy streams.

Mapping--Parts IA and IB (Stream type and quality and anadromous streams)

Part I of the inventory will be recorded on one map; parts II and III on a second. One-inch-to-the-mile maps showing public ownership are to be utilized. This will permit the subsequent measurement of stream classes by ownership category.

The classification will be indicated on maps by coloring the thread of the stream by color code and pattern. The trout stream will be indicated by a cold color--blue, and the warmwater streams will be indicated by a warm color--red. The top quality waters will be indicated by the primary colors, blue or red, and the second quality waters by the respective yellow modification, green or orange. Mainstreams will be indicated by a solid line, approximately 1/8 inch wide, and the tributaries will be indicated by a broken or dashed line of the same width.

To signify runs of anadromous trout or salmon, superimpose upon the classifications in Part IA a series of thin black arrows pointing upstream. The arrows should proceed upstream in each drainage to the point where the runs stop or become insignificant.

The following is a list of the categories and their proper colors and color patterns:

Top quality trout mainstream

Top quality trout tributary

Second quality trout mainstream

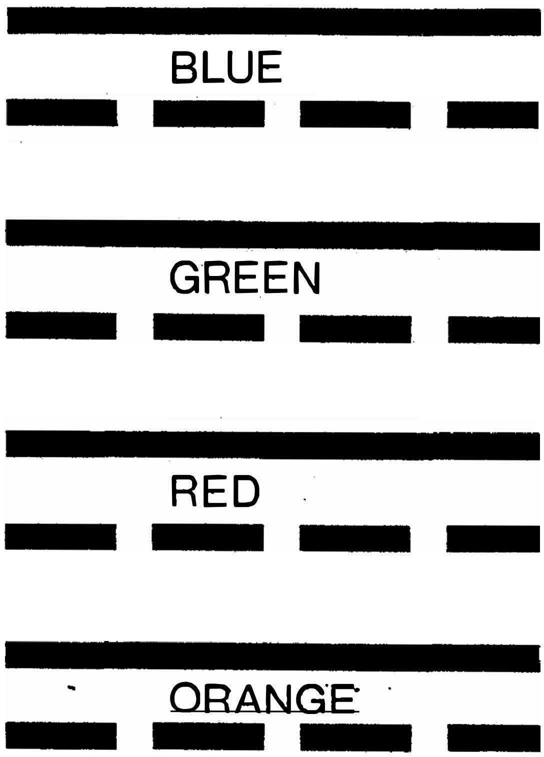
Second quality trout tributary

Top quality warmwater mainstream

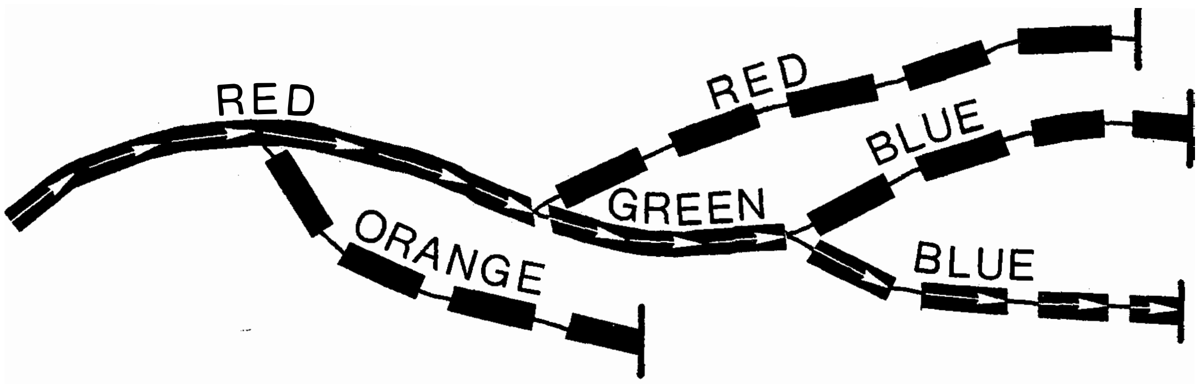
Top quality warmwater tributary

Second quality warmwater mainstream

Second quality warmwater tributary




Application of system illustrating
use of anadromous symbol



Part II.--Stream size

While the stream size category definitions and criteria utilized in this inventory are based on boatability, the purpose of the classification is to provide information which will be useful not only in relationship to boating, but also with reference to the following factors: Capacity of stream to provide fish and fishing; capacity to handle waste effluents; scenic attraction; scale of problems involved in impoundment and bridge construction; capacity of stream to attract development, and to withstand impact of development, etc. It is realized that a size classification based only on boatability is less than ideal, but it has been selected as being the most feasible of the several alternative systems considered. (It is not intended that this size classification be based on "navigability" in its legal sense. The treatment of legal navigability and public status of waters is not within the purpose or scope of this inventory.)

Stream size categories

Very small stream.--With perennial flow (except that streams not flowing during infrequent short periods during dry summers are to be included); but, based on size alone, too small for canoe travel. Temporary barriers to canoe travel such as windfalls or fences will not serve as criteria for applying this category.

Small stream.--Canoeable, with difficulty. Limitations imposed by amount of wading or lift-overs required, extended low water periods, rockiness, etc. Streams with removable windfall barriers can be considered as canoeable if volume, etc., is otherwise adequate.

Medium stream.--Readily canoeable, with not more than a limited number of lift-overs or carrys; or requiring only occasional and short stretch wading.

Large stream.--Of a size that will permit the use of small to medium-sized outboard motorboats, but too small to permit the use of large outboard or inboard motorboats.

Very large stream.--Of a size that will permit the use of large outboard and inboard motorboats.

Fluctuating stream subclass

Streams having an extended high flow period during which its rating would be one size class larger than during the major part of the dominant fishing-recreation season can be placed in a subclass.

Stream class should be based on size of the stream during the season of dominant fishing and recreation use, or the major part of the total fishing-recreation year. In most cases, the fact that a stream typically has a high flow during spring runoff and lower flow during some weeks in the summer can be ignored, since this is fairly typical for Michigan streams.

However, the pattern of flow fluctuation in some streams is of such character as to establish significantly different use patterns and use potential in different seasons. Therefore, a seasonal high flow subclass can be applied if the following criteria apply: (a) the flow is sufficiently high as to raise the class by at least one level; (b) the season is sufficiently protracted, sufficiently dependable, and desirably timed as to weather characteristics; (c) all in all, the high flow period presents a distinct recreational or fishing use opportunity, present or potential. This subtype should be applied conservatively.

Part II.--Mapping (Stream size)

Stream size will be indicated by coloring the thread of the stream one of five colors: brown for the largest category, and the remaining four in order of decreasing size as colors occur in the spectrum--violet (purple), red, orange and yellow. The color line should be about 1/8 inch wide.

The purpose of the survey does not include the identification of individual riffles and pools. Therefore, you are not asked to indicate change in size class unless, usually, a stretch of at least 2 miles is involved.

Seasonal high flow subclass streams will be indicated by entering a narrow black line adjacent of the basic stream size symbol. (Basic color will refer to size during the major part of the fishing-recreation season.) This line should be entered on the left side, looking upstream.

Following are the stream size symbols:

| | | Standard symbol | Seasonal high flow Subclass symbol |
|---|---|---|---|
| Very small stream | Yellow | | |
| Small stream | Orange | | |
| Medium stream | Red | | |
| Large stream | Violet | | |
| Very large stream | Brown | | |

Part III.--Stream zone development

A development is a building or set of buildings, of whatever kind, sufficiently close to the stream to influence the character or aesthetics of the stream setting; its use for fishing, boating or other recreational purposes; its management, or value. Ordinarily, buildings within view of those who are fishing or boating on the stream would be classed as developments, but this would not necessarily apply to distant farm buildings lying across open fields. Also, those developments should be counted which, though not readily evident from the stream, yet have definite influence on character of the streamside zone. The general objective of this classification is to establish the degree of presence or absence of human occupancy which influences the character of the stream and land within the streamside zone.

The following classes are established:

Undeveloped.--From 0 development to 1 development per 3 miles of stream.

Very light development.--From more than 1 development per 3 miles of stream up to 3 developments per mile.

Light development.--From more than 3, up to 12 developments per mile.

Medium development.--From more than 12, up to 20 developments per mile.

Heavy development.--More than 20 developments per mile.

Part III.--Mapping (Development)

Streambank development will be indicated on the size-development map by a circled Roman numeral in black appearing above or north of stream sections occurring on an east-west axis, and to the right or east of stream sections occurring on a north-south axis. The point of change from one classification to the next will be indicated by a black line drawn perpendicular to the stream. (This line need not be placed at the downstream terminus of a tributary unless the mainstream has a different class.)

Use Roman numerals in accordance with the following system:

| Numeral | Class | Degree of development | Usual minimum length to be mapped |
|---|---|---|---|
| I | Undeveloped | None up to 1 in 3 miles | 2 1/2-3 miles |
| II | Very light development | More than 1 in 3 miles, to 3 per mile | 1 mile |
| III | Light development | More than 3 up to 12 per mile | 3/4-1 mile |
| IV | Medium development | More than 12, up to 20 per mile | 1/2-1 mile |
| V | Heavy development | More than 21 per mile | 1/4-1 mile |

General instructions and discussion.--All parts

1. Streams to be included: All streams are to be included that have a perennial flow, regardless of existence of public access or ditching. Stream type and stream size classifications should be based on flows and other conditions existing during the major fishing-recreation season.

2. Base map correction: Where the base map is in error, showing incorrect locations or courses for the streams, or showing incorrect upstream limits of perennial flow, the errors should be corrected by a thin black line and applicable color.

3. A short, prominent black line perpendicular to the stream should be placed at the point on each stream where it ceases to be identified as perennial, and upstream from which this inventory does not apply. This will assist in assuring there are no errors of omission in classifying or copying, and will also serve to "correct" the base map when the stream appears on that map as extending beyond the termination of its perennial flow.

4. Dams and impoundments: Locations of dams should be indicated by a solid black isosceles triangle with the baseline at the dam site and the apex pointing downstream. Impoundments over 5 acres in size should be outlined by a thin black line. The type quality of the impounded waters should be indicated by a line through the thread of the impoundment of the same color as used to indicate comparable stream type quality. Parts II and III, size and development, should not be entered on large impoundments which distinctly have the nature of lakes, such as the Fletcher Pond, Michigamme Reservoir, or Thornapple Lake. However, impoundments which retain significant riverine character in shape, size, use or development should be classified under Parts II and III.

5. When entered in color, erroneous entries will be difficult to remove. Therefore, simply cancel out by running a wavy black line through the erroneous entry, with adjacent entry of the correct color.

6. In estimating distances for part III, make realistic generalizations as needed. For instance, see the diagrams on the following page.

## Procedure

It is recommended that field data be collected on two sets of 14- X 18-inch maps, one set for type quality and one set for size development.

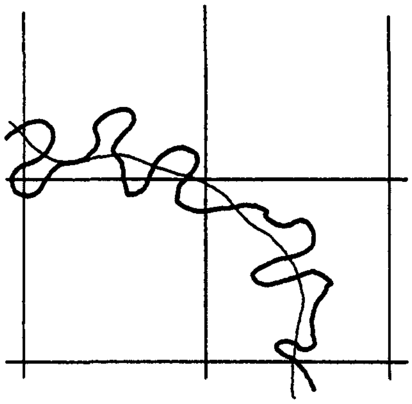
In instances where streams cross District boundaries, the District Fish Biologist from the neighboring District should be consulted to insure uniformity.

After the field data have been collected, the information should be transferred to 1-inch-per 1-mile county maps for both the type quality and size development classifications. These maps should be made in triplicate so that District, Region and Lansing all have identical copies of both classifications. After completion of the set for each county, they should be forwarded to Region where they will be reviewed to insure completion and uniformity of approach. After satisfactory review at Region, the maps should be forwarded to Lansing for review and tabulation. After review at Lansing, the Regional and District copies will be returned.

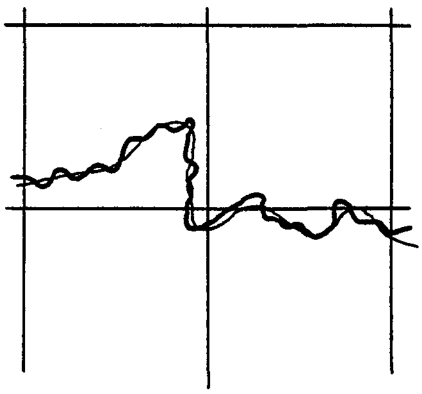
The necessary 1-inch-per-1-mile maps and the colored felt pens will be provided by Lansing Fish and Recreational Resources Planning divisions.

Pens being supplied have felt tip about 3/16-inch wide. Trim to not over 1/8-inch with vertical razor blade cut.

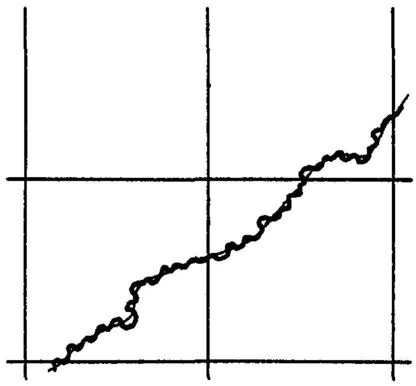
To approach the task systematically and to avoid error of omission, it is suggested that classification work be commenced at the downstream end of the stream system, working upstream and completing each tributary in turn. All copies should be checked in this manner to assure there are no omissions.



Actual 5.5
Generalized 2.5
(ratio 1:2.2)
Use the actual



Actual, about 3.6
Generalized 2.9
(ratio 1:1.24)
Use the generalized



Actual, about 3.7
Generalized 2.6
(ratio 1:1.42)
Use the generalized

Revised 3/12/81 by J. W. Merna

# Instructions for Sampling Lakes and Completing Forms for the Inland Lakes Management Unit

By James W. Merna

The Inland Lake Management Unit, of the Land Resource Programs Division, is responsible for determining the state of eutrophication of Michigan lakes. One aspect of their program involves nutrient and chlorophyll analysis of water samples from lakes throughout the state. All data from these studies are stored in STORET, a computer storage operated by the U.S. Fish and Wildlife Service.

It is advantageous for a fisheries biologist to accumulate any available knowledge of the productivity of a managed lake. It is thus mutually desirable for the Fisheries Division and the Inland Lakes Management Unit to cooperate in the collection of water samples for this program. Any lake scheduled for a complete biological survey should be considered for complete water analysis.

By the end of 1981 the Inland Lakes Management Unit will have completed sampling all lakes in the state larger than 50 acres which have boat launching facilities. If lakes with fisheries problems fall within the above category, the manager should check to learn if there is interest in a repeat sampling.

Data from lakes sampled to date are available from STORET retrieval. Anyone with questions concerning water quality of lakes in a district, should request a printout of the stored data from the Inland Lakes Management Unit. Table 1 is an example of STORET data available for Elk Lake, Antrim County.

Because of heavy laboratory commitments it is essential that proposed study lakes be submitted before January 1. Lakes may be scheduled by sending lake names to Richard L. Mikula of the Inland Lakes Management Unit. He will assign a STORET number to the lake and write a description of the station to be sampled. This information

Table 1.--STORET retrieval data for Elk Lake, Antrim County.

STORET RETRIEVAL DATE 80/11/13

/TYPA/AMBNT/LAKE

050089 AC07730.2
44 53 47.0 085 22 26.0 2
ELK LAKE IN NORTH BASIN; MILTON TWP., SEC 22
26009 ANTRIM CO., MI
MAJ BASIN: LAKE MICHIGAN 081500
MIN BASIN: ELK RIVER 0713
21MICH 761203
0160 FEET DEPTH CLASS 00

| DATE FROM TO | TIME OF DAY | DEPTH FEET | 00500 RESIDUE TOTAL MG/L | 00530 RESIDUE TOT NFLT MG/L | 00080 COLOR PT-CO UNITS | 00940 CHLORIDE CL MG/L | 00958 SILICATE UNF REAT MG/L SI | 01045 IRON FE,TOT UG/L | 01046 IRON FE,DISS UG/L | 00946 SULFATE SO4-DISS MG/L | 00929 SODIUM NA,TOT MG/L | 00930 SODIUM NA,DISS MG/L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 75/08/20 | 10 30 | 0000 | 159 | 1 | 1 | 4.7 | 3.00 | 40 | | 10.0 | | 4.10 |
| | 10 30 | 0060 | 162 | 2 | 2 | 4.5 | 3.20 | 34 | | 8.4 | | 4.10 |
| | 10 30 | 0150 | 165 | 3 | 5 | 4.8 | 3.20 | 40 | | 8.3 | | 4.10 |

| DATE FROM TO | TIME OF DAY | DEPTH FEET | 00925 MGNSIUM MG,DISS MG/L | 00927 MGNSIUM MG,TOT MG/L | 00915 CALCIUM CA,DISS MG/L | 00916 CALCIUM CA-TOT MG/L | 00935 PTSSIUM K,DISS MG/L | 00937 PTSSIUM K,TOT MG/L | 01042 COPPER CU,TOT UG/L | 01067 NICKEL NI,TOTAL UG/L | 01092 ZINC ZN,TOT UG/L | 01055 MANGNESE MN UG/L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 75/08/20 | 10 30 | 0000 | 13.0 | | 35.0 | | 0.84 | | | | | |
| | 10 30 | 0060 | 13.0 | | 34.0 | | 0.84 | | | | | |
| | 10 30 | 0150 | 13.0 | | 36.0 | | 0.82 | | | | | |

| DATE FROM TO | TIME OF DAY | DEPTH FEET | 00300 DO MG/L | 00010 WATER TEMP CENT | 00400 PH SU | 00410 T ALK CACO3 MG/L | 00900 TOT HARD CACO3 MG/L | 00095 CNDUCTVY AT 25C MICROMHO | 00070 TURB JKSN JTU | 00076 TURB TRBIDMTR HACH FTU | 00077 TRANSP SECCHI INCHES | 32209 CHLRPHYL A UG/L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 75/08/20 | 10 30 | 0000 | 8.5 | 23.0 | 8.60 | 124 | 140 | 265 | | 0.7 | 156 | |
| | 10 30 | 0015 | 8.4 | 23.0 | 8.50 | | | | | | | |
| | 10 30 | 0030 | 8.6 | 23.0 | 8.30 | | | | | | | |
| | 10 30 | 0045 | 9.2 | 22.0 | 8.30 | | | | | | | |
| | 10 30 | 0060 | 11.6 | 11.0 | 8.30 | 132 | 146 | 280 | | 0.5 | | |
| | 10 30 | 0075 | 11.9 | 8.0 | 8.40 | | | | | | | |
| | 10 30 | 0090 | 11.6 | 6.0 | 8.40 | | | | | | | |
| | 10 30 | 0105 | 11.5 | 6.0 | 8.40 | | | | | | | |
| | 10 30 | 0120 | 11.1 | 6.0 | 8.40 | | | | | | | |
| | 10 30 | 0135 | 11.0 | 5.0 | 8.30 | | | | | | | |
| | 10 30 | 0150 | 10.9 | 5.0 | 8.30 | 128 | 146 | 280 | | 0.5 | | |
| | 10 30 | | | | | | | | | | | 0.6 |

| DATE FROM TO | TIME OF DAY | DEPTH FEET | 00680 T ORG C C MG/L | 00630 NO2&NO3 N-TOTAL MG/L | 00620 NO3-N TOTAL MG/L | 00610 NH3+NH4- N TOTAL MG/L | 00605 ORG N N MG/L | 00665 PHOS-TOT MG/L P | 70507 PHOS-T ORTHO MG/L P | 00515 RESIDUE DISS-105 C MG/L | 47004 TOT DISS SOL-E.C. MG/L | 70301 DISS SOL SUM MG/L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 75/08/20 | 10 30 | 0000 | | 0.240 | | 0.007 | 0.100 | 0.007 | 0.001K | | | 158 |
| | 10 30 | 0060 | | 0.440 | | 0.019 | 0.150 | 0.004 | 0.002 | | | 160 |
| | 10 30 | 0150 | | 0.400 | | 0.017 | 0.130 | 0.021 | 0.001 | | | 162 |

will be returned to the field prior to sampling since it is required on sample data sheets going to the laboratory. The laboratory is divided into three units, and consequently three data sheets are required.

Sample bottles for all scheduled lakes will be delivered to the Fisheries Division office in Lansing by Mikula. It will be the responsibility of Fisheries Division to deliver the bottles to the field. The bottles will be available well in advance of sampling dates.

Laboratory methods, and thus sample requirements, are subject to change as instrumentation improves. Instructions will be sent to field personnel as sample size, preservatives, etc. change. Samples are collected at the surface, middle of the thermocline, and within 3 feet of the bottom. At the present time three 500-ml bottles of water are required from each depth. One bottle from each depth is to be preserved as directed with the acid supplied. All bottles are to be kept on ice until delivered to the laboratory. They should be delivered within 48 hours. This can be accomplished either by Department of Natural Resources plane or by commercial bus. Fisheries Division in Lansing will arrange to pick up samples for delivery to the laboratory. Data sheets furnished with the bottles should accompany all samples.

All bottles must be labeled with a waterproof wick pen. Sanford's "Sharpie" waterproof pens are recommended. Label information must include: lake name, county, date, depth (surface, middle, bottom), and which bottle is preserved with acid.

Only one station is to be sampled in most lakes. Only if a lake has two or more distinct basins, and there is reason to believe the water quality varies between basins, should more than one station be sampled. The station will usually be over the deepest part of the lake, and will be located from the station description furnished by the Inland Lakes Management Unit on the STORET station location form.

The laboratory will report all data to the Inland Lakes Management Unit. They will be responsible for getting the data into STORET, and will also return a copy of the laboratory data sheet to the fisheries district submitting the samples. The sheet can either be filed or the data transferred to the limnology survey form.

One STORET station location form and three environmental laboratory analysis forms will be sent to the field for each lake to be sampled. The station location form will be completed prior to being sent to the field, and the only responsibility of district personnel will be to see that it accompanies the samples to the laboratory.

The three laboratory analysis forms will need to be partially completed by the district biologist. The three forms are essential since they are each designated for a separate unit of the laboratory. The following information is needed on these forms.

1. LOCATION SAMPLED: Name of lake and county.
   (Example: Long Lake, Oakland County)
2. COLLECTED BY: Name of biologist conducting survey. Also include district number to assure receiving analysis data.
3. DESCRIPTION OF SAMPLING SITE OR SAMPLE: There should be three samples per lake identified as follows:

   Long Lake: Surface
   Long Lake: Middle
   Long Lake: Bottom
4. STORET NUMBER: This number is supplied on the station location form. Record the number in the space provided if it has not already been done.
5. START DATE YYMMDD: Record the date sampled in the order requested (year, month, date) with no break in the number, e.g., August 15, 1981 will be 810815.
6. TIME MIL TTTT: Record in military (Navy) time when the surface sample was collected, e.g., 2:15 PM will be 1415 under TTTT.
7. DEPTH FEET: Record depth of the three samples in feet. The surface sample is recorded as 0.
8. TEMP. DEGREES CENT: Measure and record.
9. SECCHI DISK INCHES: Measure and record.
10. OXYGEN DIS MG/L: Oxygen must be run in the field. Record as requested.

# Guidelines for sampling warmwater rivers with rotenone

By P. W. Seelbach, G. L. Towns, and D. D. Nelson (1988)

## Introduction

Michigan contains a number of medium- to large-sized warmwater rivers, some of which attract significant angler attention. Nearly all of these presently have good-to-excellent water quality and have the potential to be high quality fishery and recreational resources. Sampling with rotenone has proven to be effective in surveying fish communities in these rivers and likely will be used in future surveys. Rotenone surveys are to be used to complete inventories of warmwater river fish communities and to monitor the gross status of these communities through time. Rotenone surveys are not intended to provide annual population estimates.

## Sampling frequency

Major river systems should be surveyed with a minimum frequency of once every 20 years. River systems, or portions of systems, that are actively managed or receive a high degree of angler interest should be surveyed more frequently.

## Sampling methodology

The sampling methodologies described here are based on those described by Nelson and Smith (1980) and Towns (1987).

Sampling stations should be selected based on (1) being representative of the particular river reach, (2) having reasonable access, and (3) having velocities sufficient to carry fish downstream to the barrier net. Stations should be approximately 600-700 feet in length, although longer and shorter lengths may be used to accommodate differences in stream size and unusual channel structure or habitat. Measurements should be taken at each station to describe the morphology of the river and to allow calculation of rotenone and potassium permanganate concentrations. Measurements should include water temperature, stream discharge, and station length and average width. Stream discharge can either be measured using a current meter or extrapolated from discharge measured at a nearby U.S. Geological Survey gaging station.

At the downstream end of the station, a blocking net is placed across the river. Where possible, it is best to add a second net approximately half-way through the station. This mid-station net will collect upstream fish which might otherwise settle to the stream bottom and be lost. An additional net is set across the upstream end of the station to prevent migration of fish out of the station. Nets of several lengths and depths may be needed to accommodate the various station morphologies encountered. Mesh sizes may range from small mesh (3/16 inch stretch), which can be used with low current velocities, to larger mesh (2 inch stretch), which can be used at higher velocities. Small mesh nets can be assumed to capture all fish of 2 inches in total length and larger and should be used whenever possible. Larger mesh nets will allow small fish to pass through; these are subsampled using several small-mesh fyke nets placed just downstream from the blocking net at random intervals across the river. The catch of these fyke nets cn be extrapolated across the total cross-sectional area of the river to yield an estimate of the total number of small fish which pass through the blocking net.

The float line of the barrier net should be attached to a head rope which had been previously set across the river and pulled taut. At most stations braided dacron line can be used for this head rope, however, steel aircraft cable should be substituted at stations where the river is wide and the current is swift. The lead line of the net is held in place with trap net anchors. The lead line should not be anchored until the treatment is ready to begin. This helps to minimize the build-up of debris in the net which will tend to pull the float line under the water's surface. In high velocity situations, it may be necessary to attach additional lines to the head rope to prevent downstream sag of the net. These lines should be directed upstream and attached to overhead tree limbs or similar structures.

Rotenone should be applied in most warmwater rivers at a concentration of 3 ppm. For this concentration apply 5 gallons of rotenone per each 100 cfs of river discharge; this amount should be metered into the river to provide a constant concentration throughout an exposure time of 35 minutes. Other concentrations may be calculated on a straight-line proportional basis (3 ppm/5 gallons). Two ppm of rotenone is suggested for clear headwater streams that have low turbidity, low amounts of silt substrate, and where rotenone-resistant fish species are expected to be absent. Even lower concentrations should be used if this method is employed in cold-water trout streams. In rivers with high turbidity, where silt and organic detritus are the predominant substrates, and where large numbers of resistant fish (for example carp and bullheads) are expected, up to 5 ppm of rotenone may be applied. Silt and organic detritus absorb rotenone and thus reduce its effectiveness. Rotenone concentrations higher than 5 ppm should be avoided. In stations with large slow-water pools the leading edge of the rotenone plume is rapidly diluted by the static water volume and either the concentration or exposure time of rotenone must be increased to ensure adequate results. The addition of fluorescein dye at the beginning of rotenone application is useful for tracking the progress of the treated water mass.

The method used to apply rotenone is based upon water depth at the upstream limit of the station. When the river is shallow and easily wadable, rotenone can be applied by spraying with one or more water pumps. Where the water is too deep to wade, rotenone can be applied from a boat; the rotenone is gravity fed into the outboard motor back-wash while the boat moves back and forth across the river.

Immediately downstream from the blocking net, the rotenone is neutralized by adding potassium permanganate to the river. In most warmwater rivers a concentration of 5 ppm permanganate is sufficient to detoxify 3 ppm rotenone. The permanganate should be metered into the river to provide a constant concentration for 45 minutes. In other situations the concentration of potassium permanganate needed can be calculated using the ratio of 5 parts permanganate to 3 parts rotenone. Permanganate amounts can also be determined according to the ratio of 15 pounds of permanganate to 1 gallon of rotenone. When the flow of rotenone through the station is impeded by a large static water volume, additional application time will be required. In situations where 5 ppm of rotenone has been employed, up to 8.5 ppm of potassium permanganate should be used. Permanganate concentrations above 12 ppm are likely to cause fish mortalities. Extra potassium permanganate or longer exposure times may be used in trout streams where there is great public concern over inadvertent downstream fish mortalities; in warmwater streams the use of extra permanganate is generally not necessary.

The potassium permanganate is first dissolved in river water placed in spray barrels and then sprayed into the river with water pumps. In this instance a double-intake pumping system is required. The smaller intake hose (approximately 3/4" to 1", with shut-off valve) is placed in the spray barrel and the main intake in placed in the river. The rate of permanganate addition is controlled by regulating the small intake valve. Alternatively, the permanganate may be pumped directly from a perforated spray barrel placed directly in the river. In this case, dry permanganate is added to the perforated barrel at a predetermined pound-per-minute rate. At large-river stations several detoxification units are necessary. Two workers are needed per detoxification unit--one to spray and one to add permanganate throughout the spraying period. To ensure detoxification in the event of a pump failure, it is essential to have at least one back-up pump at the detoxification station, pre-tested, primed, and ready.

As many fish as possible should be collected from the station. Dead and distressed fish can be immediately collected with hand nets. Dead fish that accumulate on the barrier net may be allowed to remain. Several sweeps of the entire study area should be made by boat and/or wading to collect fish that settle to the bottom, are washed ashore, or become lodged in obstructions. When it is determined that no additional dead fish are accumulating on the barrier net, the net can be lifted and the fish removed.

Data collection

The following data collection procedures should be followed:

(1) Count and identify to species all fish. If necessary, ice can be used to help preserve fish during identification.

(2) Weigh fish in aggregate by species.

(3) Measure total length (round down to the nearest inch) of all gamefish, sucker species, and carp. For extremely abundant sucker species, individuals should be separated into "less than or equal to 3 inch" and "larger than 3 inch" groups. Individuals in the first group can simply be counted and weighed in aggregate. A random subsample of 400 individuals of the latter group should be measured. The length range of individuals of other species should be recorded.

(4) Take scale samples for age analysis from ten fish per inch group for all gamefish (take pectoral spines from channel catfish). In typical swift-water reaches, "gamefish" include

Temperatures: Centigrade to Fahrenheit and Fahrenheit to Centigrade.

Centigrade to Fahrenheit[a]

| Temp. °C | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 32.0 | 33.8 | 35.6 | 37.4 | 39.2 | 41.0 | 42.8 | 44.6 | 46.4 | 48.2 |
| 10 | 50.0 | 51.8 | 53.6 | 55.4 | 57.2 | 59.0 | 60.8 | 62.6 | 64.4 | 66.2 |
| 20 | 68.0 | 69.8 | 71.6 | 73.4 | 75.2 | 77.0 | 78.8 | 80.6 | 82.4 | 84.2 |
| 30 | 86.0 | 87.8 | 89.6 | 91.4 | 93.2 | 95.0 | 96.8 | 98.6 | 100.4 | 102.2 |
| 40 | 104.0 | 105.8 | 107.6 | 109.4 | 111.2 | 113.0 | 114.8 | 116.6 | 118.4 | 120.2 |
| 50 | 122.0 | 123.8 | 125.6 | 127.4 | 129.2 | 131.0 | 132.8 | 134.6 | 136.4 | 138.2 |

[a] Temperatures in degrees Centigrade expressed in left vertical column and in top horizontal row; corresponding temperatures in degrees Fahrenheit in body of table.

Fahrenheit to Centigrade[a]

| Temp. °F | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 30 | -1.11 | -0.56 | 0.00 | 0.56 | 1.11 | 1.67 | 2.22 | 2.78 | 3.33 | 3.89 |
| 40 | 4.44 | 5.00 | 5.56 | 6.11 | 6.67 | 7.72 | 7.78 | 8.33 | 8.89 | 9.44 |
| 50 | 10.00 | 10.56 | 11.11 | 11.67 | 12.22 | 12.78 | 13.33 | 13.89 | 14.44 | 15.00 |
| 60 | 15.56 | 16.11 | 16.67 | 17.22 | 17.78 | 18.33 | 18.89 | 19.44 | 20.00 | 20.56 |
| 70 | 21.11 | 21.67 | 22.22 | 22.78 | 23.33 | 23.89 | 24.44 | 25.00 | 25.56 | 26.11 |
| 80 | 26.67 | 27.22 | 27.78 | 28.33 | 28.89 | 29.44 | 30.00 | 30.56 | 31.11 | 31.67 |
| 90 | 32.22 | 32.78 | 33.33 | 33.89 | 34.44 | 35.00 | 35.56 | 36.11 | 36.67 | 37.22 |
| 100 | 37.78 | 38.33 | 38.89 | 39.44 | 40.00 | 40.56 | 41.11 | 41.67 | 42.22 | 42.78 |

[a] Temperatures in degrees Fahrenheit expressed in left vertical column and in top horizontal row; corresponding temperatures in degrees Centigrade in body of table.

Meters to feet and feet to meters

Meters to feet [a]

| Meters | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.00 | 3.28 | 6.56 | 9.84 | 13.12 | 16.40 | 19.69 | 22.97 | 26.25 | 29.53 |
| 10 | 32.81 | 36.09 | 39.37 | 42.65 | 45.93 | 49.21 | 52.49 | 55.78 | 59.06 | 62.34 |
| 20 | 65.62 | 68.90 | 72.18 | 75.46 | 78.74 | 82.02 | 85.30 | 88.58 | 91.87 | 95.15 |
| 30 | 98.43 | 101.71 | 104.99 | 108.27 | 111.55 | 114.83 | 118.11 | 121.39 | 124.67 | 127.96 |
| 40 | 131.24 | 134.52 | 137.80 | 141.08 | 144.36 | 147.64 | 150.92 | 154.20 | 157.48 | 160.76 |
| 50 | 164.04 | 167.33 | 170.61 | 173.89 | 177.17 | 180.45 | 183.73 | 187.01 | 190.29 | 193.57 |
| 60 | 196.85 | 200.13 | 203.42 | 206.70 | 209.98 | 213.26 | 216.54 | 219.82 | 223.10 | 226.38 |
| 70 | 229.66 | 232.94 | 236.22 | 239.51 | 242.79 | 246.07 | 249.35 | 252.63 | 255.91 | 259.19 |
| 80 | 262.47 | 265.75 | 269.03 | 272.31 | 275.60 | 278.88 | 282.16 | 285.44 | 288.72 | 292.00 |
| 90 | 295.28 | 298.56 | 391.84 | 305.12 | 308.40 | 311.69 | 314.97 | 318.25 | 321.53 | 324.81 |
| 100 | 328.09 | 331.37 | 334.65 | 337.93 | 341.21 | 344.49 | 347.78 | 351.06 | 354.34 | 357.62 |

[a] Length in meters expressed in left vertical column and in top horizontal row; corresponding lengths in feet in body of table.

Feet to meters [a]

| Feet | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.000 | 0.305 | 0.610 | 0.914 | 1.219 | 1.524 | 1.829 | 2.134 | 2.438 | 2.743 |
| 10 | 3.048 | 3.353 | 3.658 | 3.962 | 4.267 | 4.572 | 4.877 | 5.182 | 5.486 | 5.791 |
| 20 | 6.036 | 6.401 | 6.706 | 7.010 | 7.315 | 7.620 | 7.925 | 8.229 | 8.534 | 8.839 |
| 30 | 9.144 | 9.449 | 9.753 | 10.058 | 10.363 | 10.668 | 10.972 | 11.277 | 11.582 | 11.887 |
| 40 | 12.192 | 12.496 | 12.801 | 13.106 | 13.411 | 13.716 | 14.020 | 14.325 | 14.630 | 14.935 |
| 50 | 15.239 | 15.544 | 15.849 | 16.154 | 16.459 | 16.763 | 17.068 | 17.373 | 17.678 | 17.983 |
| 60 | 18.287 | 18.592 | 18.897 | 19.202 | 19.507 | 19.811 | 20.116 | 20.421 | 20.726 | 21.031 |
| 70 | 21.335 | 21.640 | 21.945 | 22.250 | 22.555 | 22.859 | 23.164 | 23.469 | 23.774 | 24.079 |
| 80 | 24.383 | 24.688 | 24.993 | 25.298 | 25.602 | 25.907 | 26.212 | 26.517 | 26.822 | 27.126 |
| 90 | 27.431 | 27.736 | 28.041 | 28.346 | 28.651 | 28.955 | 29.260 | 29.565 | 29.870 | 30.174 |
| 100 | 30.479 | 30.784 | 31.089 | 31.394 | 31.698 | 32.003 | 32.308 | 32.613 | 32.918 | 33.222 |

[a] Length in feet expressed in left vertical column and in top horizontal row; corresponding lengths in meters in body of table.

Inches to millimeters
(1 inch = 25.40005 millimeters)

| Inches | 0 | .1 | .2 | .3 | .4 | .5 | .6 | .7 | .8 | .9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 3 | 5 | 8 | 10 | 13 | 15 | 18 | 20 | 23 |
| 1 | 25 | 28 | 30 | 33 | 35 | 38 | 40 | 43 | 45 | 48 |
| 2 | 51 | 53 | 56 | 58 | 61 | 64 | 66 | 69 | 71 | 74 |
| 3 | 76 | 79 | 81 | 84 | 86 | 89 | 91 | 94 | 97 | 99 |
| 4 | 102 | 104 | 107 | 109 | 112 | 114 | 117 | 119 | 122 | 124 |
| 5 | 127 | 130 | 132 | 135 | 137 | 140 | 142 | 145 | 147 | 150 |
| 6 | 152 | 155 | 157 | 160 | 163 | 165 | 168 | 170 | 173 | 175 |
| 7 | 178 | 180 | 183 | 185 | 188 | 190 | 193 | 196 | 198 | 201 |
| 8 | 203 | 206 | 208 | 211 | 213 | 216 | 218 | 221 | 224 | 226 |
| 9 | 229 | 231 | 234 | 236 | 239 | 241 | 244 | 246 | 249 | 251 |
| 10 | 254 | 257 | 259 | 262 | 264 | 267 | 269 | 272 | 274 | 277 |
| 11 | 279 | 282 | 284 | 287 | 290 | 292 | 295 | 297 | 300 | 302 |
| 12 | 305 | 307 | 310 | 312 | 315 | 318 | 320 | 323 | 325 | 328 |
| 13 | 330 | 333 | 335 | 338 | 340 | 343 | 345 | 348 | 351 | 353 |
| 14 | 356 | 358 | 361 | 363 | 366 | 368 | 371 | 373 | 376 | 378 |
| 15 | 381 | 384 | 386 | 389 | 391 | 394 | 396 | 399 | 401 | 404 |
| 16 | 406 | 409 | 411 | 414 | 417 | 419 | 422 | 424 | 427 | 429 |
| 17 | 432 | 434 | 437 | 439 | 442 | 445 | 447 | 450 | 452 | 455 |
| 18 | 457 | 460 | 462 | 465 | 467 | 470 | 472 | 475 | 478 | 480 |
| 19 | 483 | 485 | 488 | 490 | 493 | 495 | 498 | 500 | 503 | 505 |
| 20 | 508 | 511 | 513 | 516 | 518 | 521 | 523 | 526 | 528 | 531 |
| 21 | 533 | 536 | 538 | 541 | 544 | 546 | 549 | 551 | 554 | 556 |
| 22 | 559 | 561 | 564 | 566 | 569 | 572 | 574 | 577 | 579 | 582 |
| 23 | 584 | 587 | 589 | 592 | 594 | 597 | 599 | 602 | 605 | 607 |
| 24 | 610 | 612 | 615 | 617 | 620 | 622 | 625 | 627 | 630 | 632 |
| 25 | 635 | 638 | 640 | 643 | 645 | 648 | 650 | 653 | 655 | 658 |
| 26 | 660 | 663 | 665 | 668 | 671 | 673 | 676 | 678 | 681 | 683 |
| 27 | 686 | 688 | 691 | 693 | 696 | 699 | 701 | 704 | 706 | 709 |
| 28 | 711 | 714 | 716 | 719 | 721 | 724 | 726 | 729 | 732 | 734 |
| 29 | 737 | 739 | 742 | 744 | 747 | 749 | 752 | 754 | 757 | 759 |
| 30 | 762 | 765 | 767 | 770 | 772 | 775 | 777 | 780 | 782 | 785 |
| 31 | 787 | 790 | 792 | 795 | 798 | 800 | 803 | 805 | 808 | 810 |
| 32 | 813 | 815 | 818 | 820 | 823 | 826 | 828 | 831 | 833 | 836 |
| 33 | 838 | 841 | 843 | 846 | 848 | 851 | 853 | 856 | 859 | 861 |
| 34 | 864 | 866 | 869 | 871 | 874 | 876 | 879 | 881 | 884 | 886 |
| 35 | 889 | 892 | 894 | 897 | 899 | 902 | 904 | 907 | 909 | 912 |
| 36 | 914 | 917 | 919 | 922 | 925 | 927 | 930 | 932 | 935 | 937 |
| 37 | 940 | 942 | 945 | 947 | 950 | 953 | 955 | 958 | 960 | 963 |
| 38 | 965 | 968 | 970 | 973 | 975 | 978 | 980 | 983 | 986 | 988 |
| 39 | 991 | 993 | 996 | 998 | 1001 | 1003 | 1006 | 1008 | 1011 | 1013 |
| 40 | 1016 | 1019 | 1021 | 1024 | 1026 | 1029 | 1031 | 1034 | 1036 | 1039 |

Ounces to grams
(1 ounce = 28.3495 grams)

| Ounces | .0 | .1 | .2 | .3 | .4 | .5 | .6 | .7 | .8 | .9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 3 | 6 | 9 | 11 | 14 | 17 | 20 | 23 | 26 |
| 1 | 28 | 31 | 34 | 37 | 40 | 43 | 45 | 48 | 51 | 54 |
| 2 | 57 | 60 | 62 | 65 | 68 | 71 | 74 | 77 | 79 | 82 |
| 3 | 85 | 88 | 91 | 94 | 96 | 99 | 102 | 105 | 108 | 111 |
| 4 | 113 | 116 | 119 | 122 | 125 | 128 | 130 | 133 | 136 | 139 |
| 5 | 142 | 145 | 147 | 150 | 153 | 156 | 159 | 162 | 164 | 167 |
| 6 | 170 | 173 | 176 | 179 | 181 | 184 | 187 | 190 | 193 | 196 |
| 7 | 198 | 201 | 204 | 207 | 210 | 213 | 215 | 218 | 221 | 224 |
| 8 | 227 | 230 | 232 | 235 | 238 | 241 | 244 | 247 | 249 | 252 |
| 9 | 255 | 258 | 261 | 264 | 266 | 269 | 272 | 275 | 278 | 281 |
| 10 | 283 | 286 | 289 | 292 | 295 | 298 | 301 | 303 | 306 | 309 |
| 11 | 312 | 315 | 318 | 320 | 323 | 326 | 329 | 332 | 335 | 337 |
| 12 | 340 | 343 | 346 | 349 | 352 | 354 | 357 | 360 | 363 | 366 |
| 13 | 369 | 371 | 374 | 377 | 380 | 383 | 386 | 388 | 391 | 394 |
| 14 | 397 | 400 | 403 | 405 | 408 | 411 | 414 | 417 | 420 | 422 |
| 15 | 425 | 428 | 431 | 434 | 437 | 439 | 442 | 445 | 448 | 451 |
| 16 | 454 | 456 | 459 | 462 | 465 | 468 | 471 | 473 | 476 | 479 |
| 17 | 482 | 485 | 488 | 490 | 493 | 496 | 499 | 502 | 505 | 507 |
| 18 | 510 | 513 | 516 | 519 | 522 | 524 | 527 | 530 | 533 | 536 |
| 19 | 539 | 541 | 544 | 547 | 550 | 553 | 556 | 558 | 561 | 564 |
| 20 | 567 | 570 | 573 | 575 | 578 | 581 | 584 | 587 | 590 | 593 |
| 21 | 595 | 598 | 601 | 604 | 607 | 610 | 612 | 615 | 618 | 621 |
| 22 | 624 | 627 | 629 | 632 | 635 | 638 | 641 | 644 | 646 | 649 |
| 23 | 652 | 655 | 658 | 661 | 663 | 666 | 669 | 672 | 675 | 678 |
| 24 | 680 | 683 | 686 | 689 | 692 | 695 | 697 | 700 | 703 | 706 |
| 25 | 709 | 712 | 714 | 717 | 720 | 723 | 726 | 729 | 731 | 734 |
| 26 | 737 | 740 | 743 | 746 | 748 | 751 | 754 | 757 | 760 | 763 |
| 27 | 765 | 768 | 771 | 774 | 777 | 780 | 782 | 785 | 788 | 791 |
| 28 | 794 | 797 | 799 | 802 | 805 | 808 | 811 | 814 | 816 | 819 |
| 29 | 822 | 825 | 828 | 831 | 833 | 836 | 839 | 842 | 845 | 848 |
| 30 | 850 | 853 | 856 | 859 | 862 | 865 | 867 | 870 | 873 | 876 |
| 31 | 879 | 882 | 885 | 887 | 890 | 893 | 896 | 899 | 902 | 904 |
| 32 | 907 | 910 | 913 | 916 | 919 | 921 | 924 | 927 | 930 | 933 |
| 33 | 935 | 938 | 941 | 944 | 947 | 950 | 953 | 955 | 958 | 961 |
| 34 | 964 | 967 | 970 | 972 | 975 | 978 | 981 | 984 | 987 | 989 |
| 35 | 992 | 995 | 998 | 1001 | 1004 | 1006 | 1009 | 1012 | 1015 | 1018 |
| 36 | 1021 | 1023 | 1026 | 1029 | 1032 | 1035 | 1038 | 1040 | 1043 | 1046 |
| 37 | 1049 | 1052 | 1055 | 1057 | 1060 | 1063 | 1066 | 1069 | 1072 | 1074 |
| 38 | 1077 | 1080 | 1083 | 1086 | 1089 | 1091 | 1094 | 1097 | 1100 | 1103 |
| 39 | 1106 | 1108 | 1111 | 1114 | 1117 | 1120 | 1123 | 1125 | 1128 | 1131 |
| 40 | 1134 | 1137 | 1140 | 1142 | 1145 | 1148 | 1151 | 1154 | 1157 | 1159 |

Oxygen saturation at different temperatures

| Temp. °C | Parts per million | Cc per liter (at 0° C and 760 mm) | Temp. °C | Parts per million | Cc per liter (at 0° C and 760 mm) |
|---|---|---|---|---|---|
| 0 | 14.62 | 10.23 | 16 | 9.95 | 6.96 |
| 1 | 14.23 | 9.96 | 17 | 9.74 | 6.82 |
| 2 | 13.84 | 9.68 | 18 | 9.54 | 6.68 |
| 3 | 13.48 | 9.43 | 19 | 9.35 | 6.54 |
| 4 | 13.13 | 9.19 | 20 | 9.17 | 6.42 |
| 5 | 12.80 | 8.96 | 21 | 8.99 | 6.29 |
| 6 | 12.48 | 8.73 | 22 | 8.83 | 6.18 |
| 7 | 12.17 | 8.52 | 23 | 8.68 | 6.07 |
| 8 | 11.87 | 8.31 | 24 | 8.53 | 5.97 |
| 9 | 11.59 | 8.11 | 25 | 8.38 | 5.86 |
| 10 | 11.33 | 7.93 | 26 | 8.22 | 5.75 |
| 11 | 11.08 | 7.75 | 27 | 8.07 | 5.65 |
| 12 | 10.83 | 7.58 | 28 | 7.92 | 5.54 |
| 13 | 10.60 | 7.42 | 29 | 7.77 | 5.44 |
| 14 | 10.37 | 7.26 | 30 | 7.63 | 5.34 |
| 15 | 10.15 | 7.10 | | | |

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# MICHIGAN DEPARTMENT OF NATURAL RESOURCES

Fisheries Division

LIMNOLOGY

Water: Example L. T. 1 R. 1 Sec. 15 Date: 8/16/80

County: Washtenaw Id. ______ Station: Middle of lake

| Depth M | Temp. °C | O2 ppm | Depth M | Temp. °C | O2 ppm |
|---|---|---|---|---|---|
| 1 | 24 | 8.2 | | | |
| 2 | 23 | 8.2 | | | |
| 3 | 23 | 8.1 | | | |
| 4 | 22 | 8.0 | | | |
| 5 | 22 | 8.0 | | | |
| 6 | 21 | 9.3 | | | |
| 7 | 19 | 8.2 | | | |
| 8 | 16 | 5.6 | | | |
| 9 | 14 | 4.0 | | | |
| 10 | 12 | 1.3 | | | |
| 11 | 12 | 0.8 | | | |
| 12 | 11 | 0.0 | | | |

| Time AM PM | Temp. Air °C | Sky | Wave condition[1] | Preceding weather | Maximum depth of vegetation | Percent shoal (< 5M) | Water color[2] | Secchi disc (0.1m) | Chlorophyll a |
|---|---|---|---|---|---|---|---|---|---|
| 2:30 | 28 | clear | choppy | clear | 3 m | 60 | clear | 3.2 | |

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

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

Comments: No development, watershed stable old fields

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

Submergent 30 C, 60 A, 10 E Emergent 90N, 10S

Floating 80N, 20 C Chara 90N, 10A

| Parameter | Surface | Mid-depth (____ M) | Bottom (within 1M) |
|---|---|---|---|
| pH | 8.2 | 8.0 | 7.8 |
| Alkalinity | pHth 0.0 MO 92 | pHth 0.0 MO 93 | pHth 0.0 MO 102 |
| Conductivity | | | |
| Chlorides | 4.7 | 4.5 | 4.8 |
| Suspended solids | | | |
| Total solids | | | |
| Total phosphorus | .024 | .016 | .034 |
| Ortho-phosphorus | .006 | .003 | .009 |
| Nitrate | | | |
| Nitrite | | | |
| Ammonia | | | |
| Organic nitrogen | | | |

Maximum depth at station: 12 M Prepared by I.M. Biologist Sec. Dist 27

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

(over)

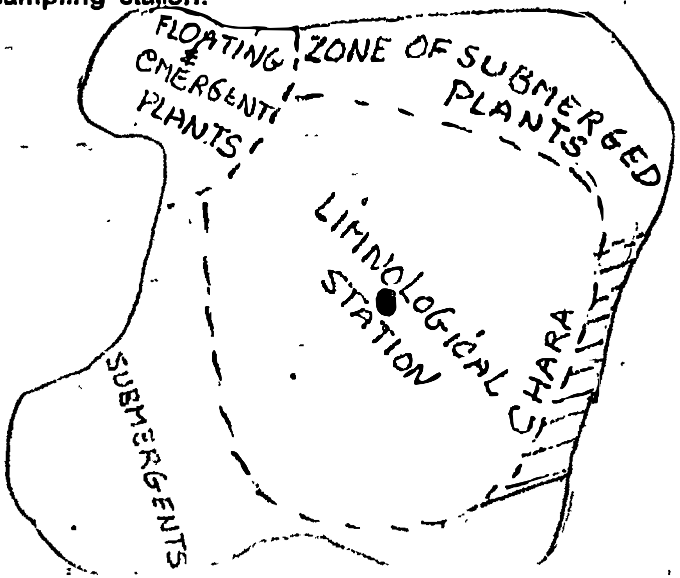
Optional observations:

1. Additional parameters analyzed by Inland Lake Management Unit:

| Parameter | Surface | Mid-depth (____ M) | Bottom (within 1M) |
|---|---|---|---|
| Iron | .040 | .034 | .040 |
| Sulfate | 10.0 | 8.4 | 8.3 |
| Sodium | 4.1 | 4.1 | 4.1 |
| Potassium | 0.84 | 0.84 | 0.84 |
| | | | |
| | | | |
| | | | |
| | | | |

2. Additional comments on condition of lake: No problems with water quality

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

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MICHIGAN DEPARTMENT OF NATURAL RESOURCES
Fisheries Division

R8059-1
Rev. 3/82

# LENGTH-WEIGHT REGRESSION

Water Example L T. 1 R. 1 Sec. 15

County Washtenaw Id.

Collection date June 8-10, 1982

Gear Electrofish, 220V AC

Units of Measurement (✓): (XX) inches or ( ) mm; ( ) pounds or (X) grams

| Species | Number Measured | Length range | Equation: log W = log c + n log L |
|---|---|---|---|
| Bluegill | 49 | 1.5 - 8.2 | Log W = -.63468 + 3.1709 Log L |
| Brook Trout | 25 | 6.2 - 8.7 | Log W = -.64753 + 2.91450 Log L |

Analysis: Bluegill condition is very slightly better than average.
Brook trout in good condition compared to stream-grown fish.

Prepared by J. C. Schneider Section IFR

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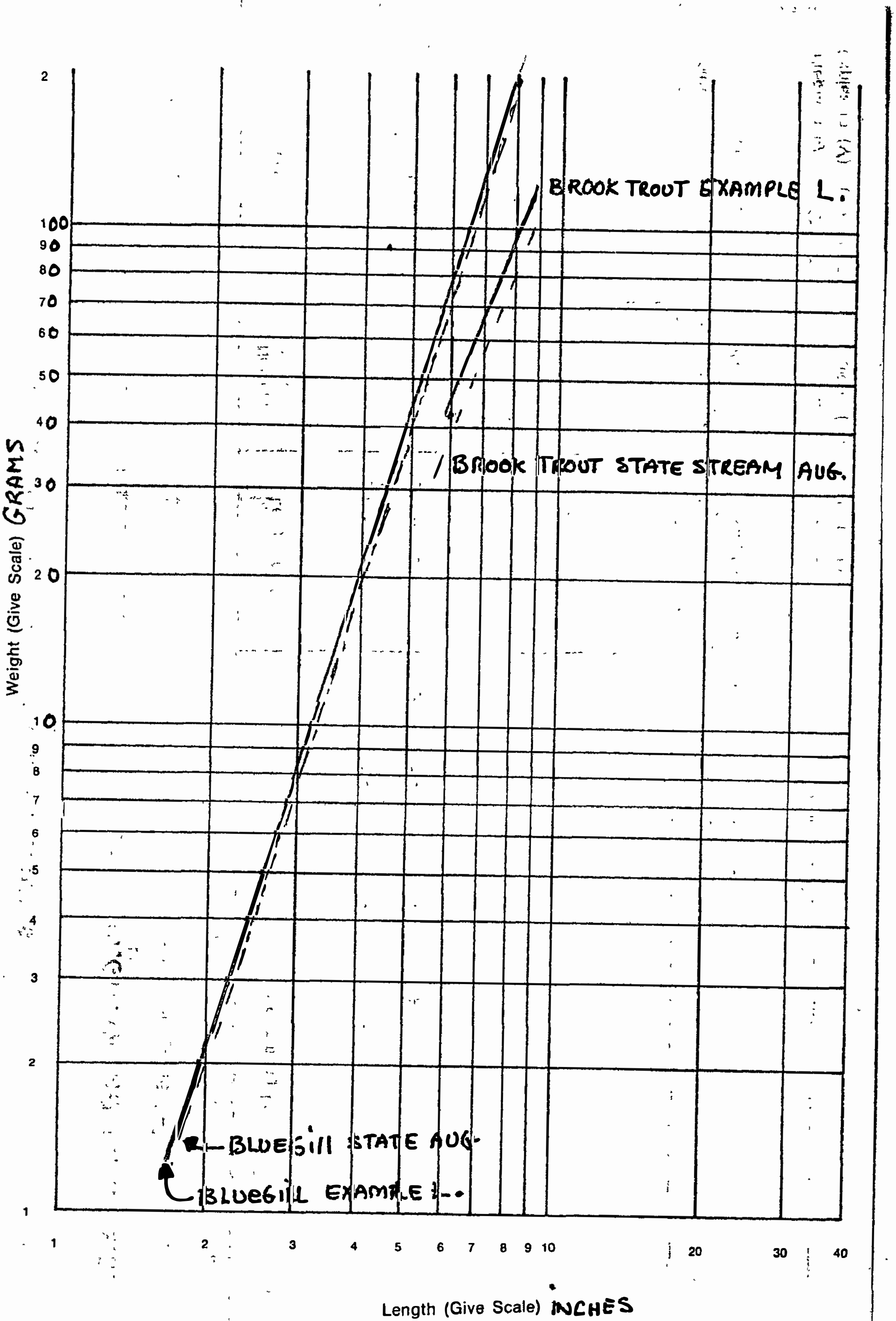

Weight (Give Scale) GRAMS
Length (Give Scale) INCHES
BROOK TROUT EXAMPLE L.
BROOK TROUT STATE STREAM AUG.
BLUEGILL STATE AUG.
BLUEGILL EXAMPLE L.
1
2
3
4
5
6
7
8
9
10
20
30
40
50
60
70
80
90
100

R8057
Rev. 3/82

# MICHIGAN DEPARTMENT OF NATURAL RESOURCES
Fisheries Division

## LAKE PHYSICAL DESCRIPTION

Lake Example L. T. 1 R. 1 Sec. 15
County Washtenaw
Id. ______ Prepared by J. Schneider Date 8/13/82

1. Lake: Area (ha) 109.4 Perimeter (km) 42.1 Shape factor ↓ 1.13 Ref. 6
2. Watershed: Area (km) 314 Perimeter (km) 70 Shape factor ↓ 1.11 Lake area ÷ watershed area 2.9 Ref. 1
3. Maximum depth (m) 19.1 Mean depth (m) 3.9 Volume (1000's of m³) 4,299 Ref. 6
4. Heating degree days (base 55°F) 2100
5. Flushing rate (years) ______ Ref. 11
6. Drainage type (✓): Seepage ______ Intermittent outlet ______ Permanent outlet X
7. Inlets: Names Fish Creek
   Mean annual discharge (m³/sec) about 1 Ref. ______
8. Outlet: Name Fish Creek
   Mean annual discharge (m³/sec) <1
   Name of main drainage system Huron River
9. Lake type (✓): Natural ______ Natural with dam X Impoundment ______
10. Dam: Height (m) 3 Boat lock (✓): No X Yes ______ Functional fish ladder (✓): No X Yes ______
    Effect on upstream fish movement (✓): None ______ Hinders ______ Completely blocks X
    Comments: Dam not used - could develop migratory walleye runs if removed.
11. Annual fluctuation in water level (✓): 0-0.5m X 0.5-1m ______ 1-2m ______ more than 2m ______
12. Maximum long-term fluctuation in water level (m) .5-1
13. Soils in 0-2m (%): Organic 80 Muck ______ Clay ______ Marl 15 Sand 5 Gravel ______ Rubble ______ Bedrock ______
14. Soils in 2m+ (%): Organic 60 Muck ______ Clay ______ Marl 30 Sand 10 Gravel ______ Rubble ______ Bedrock ______
15. Shoreline (% by type): Bog 10 Swamp 15 Marsh ______ Upland 75
16. Lake use (✓): Private ______ Semiprivate ______ Public X
17. Approximate number of: Cottages and houses none Resorts none Boat liveries 1
18. Surrounding land use (%): Undeveloped 50 Agricultural 50 Urban ______
19. Describe topography, soil, vegetation: Rolling upland, sandy loam, old fields and hardwoods

↓Shape factor formerly called shore development factor. Equals perimeter ÷ 3.5449 √area.

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

Ref. code:

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

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

Reference for item 4

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

Continuations (use item numbers):

R-8069 4/81

# MICHIGAN DEPARTMENT OF NATURAL RESOURCES

Fisheries Division

## LAKE AREA & VOLUME

Lake Example L.

County Washtenaw T. 1 R. 1 Sec. 15 Id.

Map: Date June 8, 1982

Area 270 acres

Surf. el. not given.

Metric Summary:

Area 109.4 % Shoal[1] 40

Volume 4,299 Avg. depth[2] 3.9 m (12.9 ft.)

Computation in (✓):

☒ Acres, feet, acre-feet

☐ Hectares, meters, 1000's m³

| Part of Map | Area enclosed by contour line | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0 | 10 | 20 | 30 | 40 | 50 | 60 |
| E. Bay | 122.3 | 84.1 | 62.8 | 50.3 | 30.7 | 20.6 | 5.0 |
| W. Bay | 148.1 | 99.9 | 77.2 | 56.8 | 44.1 | 25.5 | 8.7 |
| Total | 270.4 | 184.0 | 140.0 | 107.1 | 74.8 | 46.1 | 13.7 |
| % | 100 | 68 | 52 | 40 | 28 | 17 | 5 |

| Part of Map | Volume in depth strata | | | | | | | Total | % |
|---|---|---|---|---|---|---|---|---|---|
| | 0-10 | 10-20 | 20-30 | 30-40 | 40-50 | 50-60 | 60-62 | | |
| E. Bay | 516.0 | 367.2 | 282.8 | 202.5 | 128.2 | 64.0 | 5.0 | | |
| W. Bay | 620.0 | 442.8 | 335.0 | 252.2 | 174.0 | 85.5 | 8.7 | | |
| Total | 1136.0 | 810.0 | 617.8 | 454.8 | 302.2 | 149.5 | 13.7 | 3484 | 100 |
| % | 33 | 23 | 18 | 13 | 9 | 4 | .4 | 100 | |

Prepared J.C. Schneider Section IFR Date Jan 17, 1983

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[1] % shoal = percent of lake area < 5M (15 ft.) deep. [2] Average depth = volume ÷ area.

MICHIGAN DEPARTMENT OF NATURAL RESOURCES

Fisheries Division

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# POPULATION ESTIMATES

Water: Example L.

County: Washtenaw T. 1 R. 1 Sec. 15 Sheet 1 of 1

Site: - Id. Date: Mark 6/8/82 Recap 6/9/82

Gear: M: 220V AC; R:Gill net Formula: $EST = \frac{M(R+U+1)}{R+1}$ Acres: 270

Species: Brook trout Estimated: No./acre 0.76 Lb./acre 0.14 % L-A: By No. 100* By Lb. 100*

| Inch Group | No. Marked | Recapture run: Recaps | Recapture run: Unmark | Estimates: No. | Estimates: 95% limits | Estimates: Lb. | No. Aged | Estimates by age group: I | II | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 8 | 5 | 15 | 28 | 17-99 | 3.2 | 23 | 28 | | | | | | |
| 7 | 14 | 10 | 90 | 128 | 79-283 | 22.9 | 30 | 64 | 64 | | | | | |
| 8 | 7 | 5 | 35 | 48 | 26-179 | 12.0 | 30 | | 48 | | | | | |
| Total | | | | 204 | | 38.1 | | 92 | 112 | | | | | |
| | | | | | | | % survival | | - | | | | | |

Methods, analysis, remarks: Limits from Clopper - Pearson chart
Too few fish marked for good estimate. Better survival (112/1000 = 11%) from 1980 plant than 1981 plant (92/1000 = 9%).

*No size limit at this lake.

Prepared by: J.C. Schneider Sec. IFR COPIES TO: ( ) LANSING ( ) REGION ( ) DISTRICT (✓) I.F.R.

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

| Inch Group | No. Marked | Recapture run | | Estimates | | |
|---|---|---|---|---|---|---|
| | | Recaps | Unmark | No. | 95% limits | Lb. |
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| Total | | | | | | |

| No. Aged | Estimates by age group | | | | | | |
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| % survival | | | | | | | |

Methods, analysis, remarks:

R-8070 4/81

# MICHIGAN DEPARTMENT OF NATURAL RESOURCES

**FISH GROWTH ANALYSIS**

Water: Example L. T. 1 R. 1 Sec. 15

County: Washtenaw Id.

Collection Date: June 9, 1981

Gear and Methods: Electrofishing, gillnet, trapnet, Mean length of Brook Tr. weighted by pop est.

Collected By: J. Schneider, Latta Section: Res. Aged By: Schneider Section: Res.

| Species ↓ [1] | Age Group [2] | Number of fish | Lenth range in inches | Mean length in inches | State avg. length | Growth index (by age group) | Mean growth index for species |
|---|---|---|---|---|---|---|---|
| Brook trout | I | 38 | 6.2 - 7.9 | 6.9 | 5.3* | +1.6 | |
| | II | 45 | 7.1 - 8.7 | 7.9 | 8.1* | -0.2 | +0.7 |
| | | | | | | | |
| Bluegill | I | 15 | 2.0 - 3.9 | 3.2 | 3.0 | +0.2 | |
| | II | 3 | 4.1-5.0 | 4.5 | 4.2 | - | |
| | III | 6 | 4.0 - 5.9 | 5.2 | 5.3 | -0.1 | |
| | IV | 17 | 4.8 - 6.3 | 5.5 | 6.2 | -0.7 | |
| | V | 15 | 5.6 - 7.1 | 6.4 | 6.9 | -0.5 | |
| | VI | 5 | 6.5 - 8.2 | 7.0 | 7.4 | -0.4 | -0.3 |

* State averages for stream populations

[1] Several species may be listed on one sheet.
[2] Age in years. Fish become one year older on January 1.

(over)

| Species [1] | Age Group [2] | Number of fish | Lenth range in inches | Mean length in inches | State avg. length | Growth index (by age group) | Mean growth index for species |
|---|---|---|---|---|---|---|---|
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**Analysis:** Brook trout grew well up to about 7 inches, then seemed to stop. Probably overstocked. Bluegill growth close to average (-0.3) but slower than in 1974.(+0.5).

**Prepared by** J. Schneider **Section** Res. **Date** Aug 10, 1979

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MICHIGAN DEPARTMENT OF NATURAL RESOURCES R8064
Fisheries Division 4/81

Stream Example Cr. T. 2S R. 4E Sec. 20, 21

County Washtenaw Id. ______

# STREAM SURVEY SUMMARY

1. Drainage system Example Cr., Honey Cr., Huron River
2. Station: Location Upstream from M-29 bridge
   Length (m) 400 m Avg. width (m) 5.68 Area (ha) 0.2272
   Avg. depth (m) 0.35 Velocity (m/sec) 0.8 Discharge 1.63 $m^3$/sec.
   Color and turbidity clear, slight
   Dredged? NO
   Classification[1] II A.2
3. Names of tributaries Sand Creek
4. Water source (springs, groundwater, etc.) groundwater
5. Stability of flow good summer low flow
6. Barriers (dams, waterfalls, wiers, etc.) None

| Location | Owner | Use | Head |
|---|---|---|---|
| | | | |

7. Surrounding country (topography, soil, cover, use) Southside of creek active agriculture. North side state land: wooded.
8. Access State land
9. Erosion (source, severity) Cattle have access to creek
10. Pollution None
11. Mortalities None reported
12. Parasites Not checked
13. Diseases None
14. Predators Great Blue Herons
15. Beaver None

16. Shade North bank wooded - south open

17. Pools (✓): Size -- large ____ medium X ____ small ____; Type -- deep ____ moderate ____ shallow X ____
Frequency -- many ____ frequent ____ infrequent X

18. Bottom types²: Pools 80% clay, 20% gravel
Riffles 90% gravel, 10% sand

19. Spawning grounds gravel riffles

20. Aquatic vegetation (% of stream bed): Abundant 0 Moderate 20 Sparse 80

21. Fish food organism abundance (✓): Exceptional ____ Average X Poor ____

22. Fishing (reputation, history) Little fishing reported

23. Recent stocking None

24. Recent management

25.

| Fish species | Relative abundance | Predominate size | Growth (good, avg., poor) |
|---|---|---|---|
| Rock bass | moderate | 6" | average |
| smallmouth bass | sparse | 4" | good |
| P. Seed | sparse | 5" | average |

26. Notes and continuations (use item number) cattle are causing serious erosion.
Should furnish limited fishery for rock bass and smallmouth bass.

Prepared by I.M. Biologist Sec. Dist. 27 Date of survey 6/22/82

¹See Michigan Stream Classification System (Appendix VI A15).

²Bedrock, boulder (10"), cobble (3-10"), gravel (⅛-3"), sand, silt, clay, muck, detritus

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MICHIGAN DEPARTMENT OF NATURAL RESOURCES
Fisheries Division

R8063
4/81

Lake Example

T. 1 R. 1 Sec. 15

County Washtenaw

Id.

# LAKE SURVEY SUMMARY

1. Other names of lake MUD
2. Accessibility (how reached, condition of roads) Take 2-track north off M50, ¼ mile east of US 12. 4-wheel drive required when wet.
3. Outlet (immediate and main drainage) Fish Creek to Huron River.
   Permanency Permanent — Size 6 ft wide x 0.5 ft. deep
4. Dam in outlet yes — Distance from lake — Height 3 feet
   Effect on level stabilizes — Owner U.R. Snell — Use level control
   Effect on fish movements blocks walleye run
5. Inlets (name, size) Fish creek, about 4 ft x 0.5 ft.
   Drainage area approx. 119 sq. miles
6. Pollution (kind, source, severity) None
7. Shoreline type (%): Bog 10 — Swamp 15 — Marsh — Upland 75
8. Surrounding country (topography, soil, cover) Rolling upland, sand, old fields and hardwoods
9. Use (private, public, semi-private) public — Public fishing site yes
10. Approximate number Cottages 0 — Homes 0 — Resorts 0 — Boat Liveries 1
11. Intensity of fishing (heavy, medium, light, or angler days) Summer medium — Winter light
12. Other uses Goose refuge,; swimming
13. Area 270 acres — Shore Development 1.13 — Maximum depth 62 ft.
14. Area of Vegetation (acres) about 70 — Per cent shoal (less than 15 ft.) 40
15. Slope at drop-off (gradual, steep) steep
16. Bottom Soil: Shoal mostly organic, some sand — Deep water peat and marl
17. Color clear — Secchi disk (range) ± 10 feet.
18. Temperature (range): Surface 24 c — Bottom 11C
19. Thermocline Location 6-10m — Temperature (range) 19-12C
20. Dissolved oxygen (range): Above thermocline (in upper 20 feet if absent) 8.0 - 8.3 ppm
    In Thermocline 9.3 - 4.0 ppm — Below thermocline (near bottom if absent) 1.3 - 0
    Depth range where temperature is below 70° F., and $O_2$ above 4 ppm. 6-10M — Oxygen-thermal type 3
21. pH (range) 7.8 - 8.2 — $CO_2$ - — Methyl Orange Alk. (range) 92-102

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(Over)

22. Cover (kind, abundance) vegetation plentiful; logs sparse

23. Vegetation (type, abundance) submergent abudant, floating sparse; emergent sparse. Some chara.

24. Food (abundance, dominant organisms): Plankton Some large clodocera seen

Bottom: Shoal Burrowing mayfly holes evident Depths Not sampled.

Vegetation

25. Spawning grounds (summarize observations and reports) Adequate for all species excpet trout.

26. Predators (kind and abundance) A pair of blue herons seen on every trip to lake.

27. Fish parasites None noticed

Fish mortalities (observed or reported) No reports

28. Fishing: general reputation Good most years

History Trout stocked periodically since 1950's.

Reported by U.R. Snell

29. Recent stocking 1,000 brook trout fingerlings in 1978 and in 1979.

30.

| Fish species | Abundance | Predominant size | Growth rate (poor, average, good) |
|---|---|---|---|
| Brook trout | Common (est. = 204) | 6-8" | good up to 7" |
| Bluegill | Abundant | 3-8: | average |
| Carp | Common | 15-25" | |
| Common shiner | rare | | |

Continuations (use item numbers):

Prepared by J.C. Schneider Section IFR Date of survey(s) June 8-10, 1982
Aug. 16, 1980

MICHIGAN DEPARTMENT OF NATURAL RESOURCES

Fisheries Division

# FISH COLLECTION

Water: Example L.

County: Washtenaw    T. 1    R. 1    Sec. 15    Date: June 8-10, 1982

I.D. ______    Sheet 1 of 2

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

Sample site(s): Number of 8    Depth Range 0-62 feet    Temperature range 25.7 - 10.2 C

Location(s) (describe or map below): Electrofished entire edge and netted as mapped below.

Cover (abundance, type): Moderate to dense pond weeds, sparse logs.

Fish foods: Crayfish and burrowing mayflies plentiful in lake and in trout stomachs.

Water clarity, level, etc. clear, normal    Cond.: 200    Electro. eff.: Good

Weather: Present Hot, sunny    Preceding Stormy

Temperature: Air 28.1c    Water surface 25.7c    Time of day 1400

Stream: Length    Avg. width    Avg. depth

Velocity: Ave.    Surface    Discharge

Bottom type:

Gear Description: Boom shocker 220V, AC, 7amp, 5 electrodes, after sunset; 1 exp Gill; seine 50 ft x 6 ft x 1 in bag; 1 fyke 4 ft x 1 in; 2 trap 3 ft x 1.5 in.

Effort: Net lifts 2F, 4T, 2G    Net nights 2F, 4T, 2G    Area covered S = .5ac    Hours shocked 2.3

Purpose of collection: Reports of poor fishing - basic survey. Estimate trout.

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

Analysis, map, remarks, fishing reports:

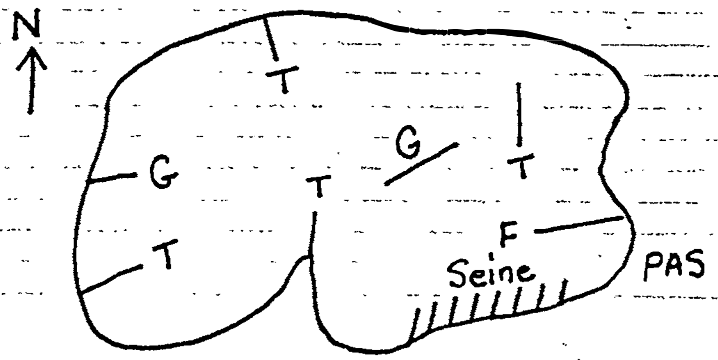
Bluegill CPE by electrofishing has increased from 41/hr in 1974 to 87 now; L-A down from 50% to 11%. Recruitment OK now but should be checked again in 2 years. Most carp were large and only 1 small one was seen while electrofishing. The carp population may be waning, but it still comprises 53% of trap net catch by weight.

FOLD HERE

The brook trout population appears to small but the estimates have wide confidence limits (See Population Estimates form).

Growth analysis is pending.

Gillnet CPE not computed because net had been tampered with. Fishing was poor all last year, good in May, poor in June (4 anglers).




Analysis by: J. Schneider    Sec. IFR

Collection by: J. Schneider, W. Latta    Sec. IFR    Identification by: R. Bailey    Sec. UM Museum

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R8058 Rev. 3/82

CATCH SUMMARY BY GEAR Gear = ______________, or as indicated.

| Species | Bluegill | | Carp | | Bluegill | | Brook Trout | | Carp | | Common Shiner | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gear | Trap | | Trap | | Elect. | | Elect. | | Elect. | | Elect. | | | |
| Length | 6.6 | | 19.7 | | 4.2 | | 7.5 | | 11.4-22.1 | | 1.8 | | | |
| Avg. Wt. | .21 | | 4.09 | | .06 | | .18 | | 1.30 | | - | | | |
| | No. | Lb. | No. | Lb. | No. | Lb. | No. | Lb. | No. | Lb. | No. | Lb. | No. | Lb. |
| Total | 309 | 66 | 18 | 74 | 200 | 13.0 | 29 | 5.1 | 4 | 5.2 | 1 | - | | |
| % | 94 | 47 | 6 | 53 | 85 | 56 | 12 | 22 | 2 | 22 | .1 | - | | |
| CPE | 77 | 16.4 | 4.5 | 18.5 | 87 | 5.7 | 12.6 | 2.2 | 1.7 | 2.2 | .4 | - | | |
| % L-A | 75 | 88 | - | - | 11 | 38 | 100* | 100* | - | - | - | - | | |
| **LENGTH-FREQUENCY & LENGTH-BIOMASS SAMPLE** — Inches | | | | | | | | | | | | | | |
| 1 | | | | | 4 | - | | | | | 1 | - | | |
| 2 | | | | | 50 | .4 | | | | | | | | |
| 3 | | | | | 45 | 1.2 | | | | | | | | |
| 4 | 8 | .5 | | | 44 | 2.6 | | | | | | | | |
| 5 | 49 | 5.5 | | | 35 | 3.9 | | | | | | | | |
| 6 | 111 | 21.3 | | | 15 | 2.9 | 8 | .9 | | | | | | |
| 7 | 37 | 11.1 | | | 6 | 1.6 | 14 | 2.4 | | | | | | |
| 8 | 22 | 9.9 | | | 1 | .4 | 7 | 1.8 | | | | | | |
| 9 | | | | | | | | | | | | | | |
| 10 | | | | | | | | | | | | | | |
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| 14 | | | | | | | | | | | | | | |
| 15 | | | 1 | | | | | | | | | | | |
| 16 | | | 3 | | | | | | | | | | | |
| 17 | | | 2 | | | | | | | | | | | |
| 18 | | | | | | | | | | | | | | |
| 19 | | | 3 | | | | | | | | | | | |
| 20 | | | 6 | | | | | | | | | | | |
| 21 | | | | | | | | | | | | | | |
| 22 | | | | | | | | | | | | | | |
| 23 | | | 2 | | | | | | | | | | | |
| 24 | | | | | | | | | | | | | | |
| 25 | | | 1 | | | | | | | | | | | |
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| 38 | | | | | | | | | | | | | | |
| 39 | | | | | | | | | | | | | | |
| 40 | | | | | | | | | | | | | | |
| Sample total | 227 | 48.3 | | | | | | | | | | | | |

**ALL SPECIES TOTAL**

| Gear | No. | Lb. |
|---|---|---|
| Trap net | 327 | 140 |
| Electrofishing | 234 | 23.3 |
| Seine | 86 | 2.0 |
| Fyke net | 20 | 12.1 |
| Gillnet | 162 | 26.2 |
| All | 829 | 203.6 |

- Record average length or range in length of fish.
- Total % = percent contribution of the species to the total catch in the gear.
- L-A = Legal- or acceptable- size game fish: bluegill, sunfish, rock bass-6"+ ; crappie, perch, bullhead-7"+ ; bass-12"+ ; walleye-15"+; pike-20"+ muskie-30"+ ; trout-7"+ in U.P. streams, 8"+ in L.P. streams, 10"+ in lakes.
  OR: * No size limit on brook trout here.
- Inch groups: 1=1.0-1.9, 2=2.0-2.9, etc.

MICHIGAN DEPARTMENT OF NATURAL RESOURCES

Fisheries Division

# FISH COLLECTION (CON'T.)

Water Example L.　　T. 1 R. 1 Sec. 15　　Date June 8-10, 1982

County Washtenaw　　I.D. ______　　Sheet 2 of 2

Summary of: (X) All sites ( ) Coll. site No.____ ( ) Index site No.____ (X) All gear ( ) Gear ____

| Species | Bluegill | | Carp | | Carp | | Bluegill | | Brook Trout | | Bluegill | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gear | Seine | | Seine | | Fyke | | Fyke | | Gillnet | | Gillnet | | | |
| Length | 2.8 | | 10.4 | | 15.2 - 25.6 | | 5.5 | | 7.6 | | 5.1 - 5.9 | | | |
| Avg. Wt. | .02 | | .60 | | 3.33 | | .12 | | .19 | | .10 | | | |
| | No. | Lb. | No. | Lb. | No. | Lb. | No. | Lb. | No. | Lb. | No. | Lb. | No. | Lb. |
| Total | 85 | 1.4 | 1 | .6 | 3 | 10.0 | 17 | 2.1 | 160 | 26 | 2 | .2 | | |
| % | 99 | 70 | 1 | 30 | 15 | 83 | 85 | 17 | 99 | 99 | 1 | 1 | | |
| CPE | 170 | 2.8 | 2 | 1.2 | 1.5 | 5.0 | 8.5 | 1.0 | - | - - | - | - | | |
| % L-A | 0 | 0 | - | - | - | - | 24 | 38 | 100* | 100* | 0 | 0 | | |
| Inches | 1 | - | | | | | | | | | | | | |
| 1 | 8 | - | | | | | | | | | | | | |
| 2 | 40 | .4 | | | | | | | | | | | | |
| 3 | 36 | 1.0 | | | | | | | | | | | | |
| 4 | | | | | | | 3 | .2 | | | | | | |
| 5 | | | | | | | 10 | 1.1 | | | 2 | .2 | | |
| 6 | | | | | | | 4 | .8 | 20 | 2.0 | | | | |
| 7 | | | | | | | | | 100 | 15 | | | | |
| 8 | | | | | | | | | 40 | 9.0 | | | | |
| 9 | | | | | | | | | | | | | | |
| 10 | | | 1 | .6 | | | | | | | | | | |
| 11 | | | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | | | |
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| 36 | | | | | | | | | | | | | | |
| 37 | | | | | | | | | | | | | | |
| 38 | | | | | | | | | | | | | | |
| Sample total | | | | | | | | | | | | | | |

LENGTH-FREQUENCY & LENGTH-BIOMASS SAMPLE

R8058-1
Rev. 3/82

CATCH SUMMARY BY GEAR Gear = ALL or as indicated.

| Species | Bluegill | | Carp | | Brook trout | | Common Shiner | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gear | | | | | | | | | | | | | | |
| Length ↓ | 5.0 | | 19.1 | | 7.1 | | 1.8 | | | | | | | |
| Avg. Wt. | .14 | | 3.46 | | .16 | | - | | | | | | | |
| | No. | Lb. | No. | Lb. | No. | Lb. | No. | Lb. | No. | Lb. | No. | Lb. | No. | Lb. |
| Total | 613 | 83 | 26 | 90 | 189 | 31.1 | 1 | - | | | | | | |
| % ↓ | 74 | 41 | 3 | 44 | 23 | 15 | .1 | - | | | | | | |
| CPE | | | | | | | | | | | | | | |
| % L-A ↓ | 37 | 74 | - | - | 100 | 100 | - | - | | | | | | |
| Inches ↓ | 1 | | | | | | | | | | | | | |
| 1 | 12 | | | | | | | | | | | | | |
| 2 | 90 | .8 | | | | | | | | | | | | |
| 3 | 81 | 2.2 | | | | | | | | | | | | |
| 4 | 55 | 3.3 | | | | | | | | | | | | |
| 5 | 96 | 10.7 | | | | | | | | | | | | |
| 6 | 130 | 25 | | | 28 | 2.9 | | | | | | | | |
| 7 | 43 | 12.7 | | | 114 | 17.4 | | | | | | | | |
| 8 | 23 | 10.3 | | | 47 | 10.8 | | | | | | | | |
| 9 | | | | | | | | | | | | | | |
| 10 | | | 1 | | | | | | | | | | | |
| 11 | | | | | | | | | | | | | | |
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| 18 | | | | | | | | | | | | | | |
| 19 | | | 3 | | | | | | | | | | | |
| 20 | | | 6 | | | | | | | | | | | |
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| 22 | | | | | | | | | | | | | | |
| 23 | | | 2 | | | | | | | | | | | |
| 24 | | | | | | | | | | | | | | |
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| 40 | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| Sample total | 531 | 65 | 19 | | 189 | 31.1 | | | | | | | | |

LENGTH-FREQUENCY & LENGTH-BIOMASS SAMPLE

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

Field Sheets

# MICHIGAN DEPARTMENT OF NATURAL RESOURCES
Fisheries Division

## FISH COLLECTION

Water: Exaple L.

County: Wash. T. 1 R. 1 Sec. 15 Date: June 8-10 '82

I.D. ______ Sheet 1 of ______

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

Sample site(s): Number of ______ Depth Range ______ Temperature range: 25.7 surf, 10.2 at 62'

Location(s) (describe or map below): Electrofished all shoreline

Cover (abundance, type): moderate to dense pondweeds, sparse logs

Fish foods: Hexagenia and crayfish everywhere. Also in stomachs of gilled trout

Water clarity, level, etc.: Clear, normal Cond.: 200 Electro. eff.: good

Weather: Present: Hot, Sunny Preceding: ______

Temperature: Air: 28.1C Water surface: 25.7 Time of day: 1400 on 6/9

Stream: Length ______ Avg. width ______ Avg. depth ______

Velocity: Ave. ______ Surface ______ Discharge ______

Bottom type: ______

Gear Description: Boom Shocker 7 amp; 1 Fyke 1" mesh; 2 Trap 1.5" mesh; 1 exp gill. Bag Seine 50 X 6 X 1"

Effort: Net lifts ______ Net nights ______ Area covered: S = 1.0 ac Hours shocked: 2.3

Purpose of collection: ______

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

Analysis, map, remarks, fishing reports:

Gillnet catch not pilfered on 10th

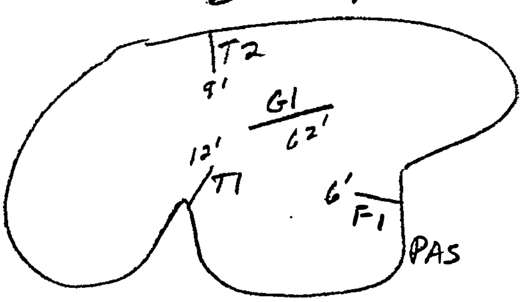
Carp mostly large – 1 small one seen stocking but not caught.

4 anglers said fishing poor last year, good in May, poor in June

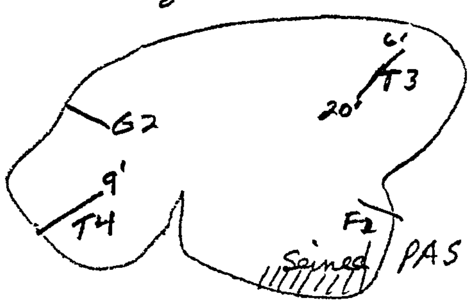
Brook trout marked with top caudal clip while electrofishing.

FOLD HERE

Sets 6/8




Sets 6/9




Analysis by ______ Sec. ______

Collection by: Schneider, Lotta Sec. ______ Identification by ______ Sec. ______

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R8058
Rev 3/82

June 8, 9-11:30 pm Shocker

CATCH SUMMARY BY GEAR    Gear = ____________________ , or as indicated.

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | B Gill | | Brook T. | | Carp | | Common Shiner | | | | | | | |
| Gear | | | | | | | | | | | | | | |
| Lengths | | | | | 11.4-22.1 | | | | | | | | | |
| Avg. Wt | | | | | | | | | | | | | | |
| | No. | ~~Lb.~~ | No. | ~~Lb.~~ | No. | Lb. | No. | Lb. | No. | Lb. | No. | Lb. | No. | Lb. |
| Total | 129 | | 4 | | 4 | 5.2 | 1 | — | | | | | | |
| ~~%~~ + | +71 | | +25 | | | | | | | | | | | |
| ~~CPE~~ | 200 | | 29 | | | | | | | | | | | |
| % L-A | | | | | | | | | | | | | | |
| Inches | | | | | | | | | | | | | | |
| 4 — 1 | | | | | | | 1.8" | | | | | | | |
| 20 — 2 | 卌 卌 卌 卌 卌 | | | | | | | | | | | | | |
| 10 — 3 | 卌 卌 卌 卌 卌 卌 | | | | | | | | | | | | | |
| 10 — 4 | 卌 卌 卌 卌 卌 卌 ||| | | | | | | | | | | | | | |
| 10 — 5 | 卌 卌 卌 卌 | | | | | | | | | | | | | |
| 10 — 6 | 卌 | | | 8 | | | | | | | | | | |
| 6 — 7 | | | |||| | 10 | | | | | | | | | | |
| 1 — 8 | | | | 7 | | | | | | | | | | |
| 9 | | | | 25 | | | | | | | | | | |
| 71 — 10 | | | | scaled | | | | | | | | | | |
| 11 | | | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | | | |
| 14 | | | all given | | | | | | | | | | | |
| 15 | | | top tail | | | | | | | | | | | |
| 16 | | | | | | | | | | | | | | |
| 17 | | | clip for | | | | | | | | | | | |
| 18 | | | | | | | | | | | | | | |
| 19 | | | M&Recapt. | | | | | | | | | | | |
| 20 | | | | | | | | | | | | | | |
| 21 | | | | | | | | | | | | | | |
| 22 | | | | | | | | | | | | | | |
| 23 | Calculate weights | | | | | | | | | | | | | |
| 24 | per inch group | | | | | | | | | | | | | |
| 25 | from scale envelopes | | | | | | | | | | | | | |
| 26 | | | | | | | | | | | | | | |
| 27 | | | | | | | | | | | | | | |
| 28 | | | | | | | | | | | | | | |
| 29 | | | | | | | | | | | | | | |
| 30 | | | | | | | | | | | | | | |
| 31 | | | | | | | | | | | | | | |
| 32 | | | | | | | | | | | | | | |
| 33 | | | | | | | | | | | | | | |
| 34 | | | | | | | | | | | | | | |
| 35 | | | | | | | | | | | | | | |
| 36 | | | | | | | | | | | | | | |
| 37 | | | | | | | | | | | | | | |
| 38 | | | | | | | | | | | | | | |
| 39 | | | | | | | | | | | | | | |
| 40 | | | | | | | | | | | | | | |
| Sample total | | | | | | | | | | | | | | |

Scale samples

LENGTH-FREQUENCY & LENGTH-BIOMASS SAMPLE

ALL SPECIES TOTAL

| Gear | No. | Lb. |
|---|---|---|
| | | |

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

MICHIGAN DEPARTMENT OF NATURAL RESOURCES

Fisheries Division

Field Sheet

**FISH COLLECTION (CON'T.)**

Water: Example    T.____ R.____ Sec.____    Date: 6/9/82

County: Wash    I.D. ____    Sheet ___ of ___

Summary of: ( ) All sites ( ) Coll. site No.____ ( ) Index site No.____ ( ) All gear ( ) Gear: Trap, Fyke, gill

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | B. Gill | | Carp | | B Gill | | B Gill | | brook T | | B Gill | | Carp | |
| Gear | Trap #1 | | T #1 | | T #2 | | Fyke #1 | | Gill #1 | | Seine 50'x 6'x 1" Bag | | | |
| Length | | | | | | | | | | | 0.7-2.9 | | 10.4 | |
| Avg. Wt | | | | | | | | | | | | | | |
| | No. | Lb. | No. | Lb. | No. | Lb. | No. | Lb. | No. | Lb. | No. | Lb. | No. | Lb. |
| Total | 89 | 19.7 | 18 | 73.6 | 75 | 15.7 | 17 | 2.1 | 160 | [illegible] | 85 | 1.4 | 1 | .6 |
| % | | | | | | | | | | | | | | |
| CPE | | | | | | | | | | | | | | |
| % L-A | | | | | | | | | | | | | | |
| Inches | | | | | | | | | no clip | clip | / | | | |
| 1 | | | | | | | | | | | LHT /// | | | |
| 2 | | | | | | | | | | | LHT LHT LHT LHT LHT LHT | | | |
| 3 | | | | | | | | | | | LHT LHT LHT LHT / | | | |
| 4 | /// | | | | // | | /// | | | | | | | |
| 5 | LHT LHT LHT LHT LHT | | | | LHT LHT | | LHT LHT | | | | / | | | |
| 6 | LHT LHT LHT LHT LHT LHT LHT /// | | | | LHT LHT LHT LHT // | | //// | | LHT LHT | LHT | | | | |
| 7 | LHT // | | | | LHT LHT | | | | LHT LHT LHT LHT LHT | LHT LHT | | | | |
| 8 | LHT / | | | | LHT LHT / | | | | LHT LHT | LHT | | | | |
| 9 | | | | | | | | | | | | | | |
| 10 | | | | | | | | | | | | | / | .6 lb |
| 11 | | | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | | | |
| 14 | | | | | | | | | LHT LHT LHT LHT LHT LHT LHT (more 7") | | 1.4 lb | | | |
| 15 | | | / | | | | | | | | | | | |
| 16 | | | /// | | | | | | LHT LHT | | | | | |
| 17 | | | // | | | | | | LHT | | | | | |
| 18 | | | | | | | | | | | | | | |
| 19 | | | /// | | | | | | | | | | | |
| 20 | | | LHT / | | | | | | LHT LHT (more 8") | | | | | |
| 21 | | | | | | | | | LHT LHT | | | | | |
| 22 | | | // | | | | | | LH | | Seined about 870' of beach | | | |
| 23 | | | | | | | | | | | | | | |
| 24 | | | | | | | | | | | | | | |
| 25 | Bulk wts | | / | | | | | | | | | | | |
| 26 | | | Bulk wts | | | | | | No bulk wts taken - estimate from L-W regr. | | | | | |
| 27 | | | | | 5.3 | | 2.1 lb | | | | | | | |
| 28 | | | | | 4.9 | | | | | | | | | |
| 29 | 9.6 | | 24.1 | | | | | | | | | | | |
| 30 | | | | | 5.5 | | | | | | | | | |
| 31 | 3.4 | | 14.4 | | | | | | | | | | | |
| 32 | | | 20.1 | | 15.7 | | | | | | | | | |
| 33 | 5.7 | | 15.0 | | | | | | | | | | | |
| 34 | 18.7 | | | | | | | | | | | | | |
| 35 | | | 73.6 | | | | | | | | | | | |
| 36 | | | | | | | | | | | | | | |
| 37 | | | | | | | | | | | | | | |
| 38 | | | | | | | | | | | | | | |
| Sample total | 89 | | | | 75 | | | | | | | | | |

LENGTH-FREQUENCY & LENGTH-BIOMASS SAMPLE

R8058-1
Rev. 3/82

June 10 nets pulled

CATCH SUMMARY BY GEAR Gear = ______________ or as indicated

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | Carp | | B Gill | | | | B Gill | | | | | | | |
| Gear | Fyke #2 | | T #3 | | T #4 | | G #2 | | | | | | | |
| Length | | | | | | | | | | | | | | |
| Avg. Wt. | | | | | | | | | | | | | | |
| | No. | Lb. | No. | Lb. | No. | Lb. | No. | Lb. | No. | Lb. | No. | Lb. | No. | Lb. |
| Total | 3 | 10.0 | 145 | 49.0 | | | 2 | .2 | | | | | | |
| % | | | | | | | | | | | | | | |
| CPE | | | | | | | | | | | | | | |
| % L-A | | | | | | | | | | | | | | |
| Inches | | | | | | | | | | | | | | |
| 1 | | | | | | | | | | | | | | |
| 2 | | | | | empty | | | | | | | | | |
| 3 | | | | | | | | | | | | | | |
| 4 | | | \|\|\| | | | | | | | | | | | |
| 5 | | | 卌 卌 \|\|\|\| | | | | \|\| | | | | | | | |
| 6 | | | 卌 卌 卌 卌 卌 卌 卌 \| | | | | | | | | | | | |
| 7 | | | 卌 卌 | | | | | .2 lb | | | | | | |
| 8 | | | 卌 | | | | | | | | | | | |
| 9 | | | | | | | | | | | | | | |
| 10 | | | 13.2 lb | | | | | | | | | | | |
| 11 | | | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | | | |
| 13 | | | +82 | | | | | | | | | | | |
| 14 | | | not | | | | | | | | | | | |
| 15 | 1 - 15.6 | | measured | | | | | | | | | | | |
| 16 | | | | | | | | | | | | | | |
| 17 | | | = 13.6 lb | | | | | | | | | | | |
| 18 | | | | | | | | | | | | | | |
| 19 | | | | | | | | | | | | | | |
| 20 | | | | | | | | | | | | | | |
| 21 | 1 | | | | | | | | | | | | | |
| 22 | | | | | | | | | | | | | | |
| 23 | | | | | | | | | | | | | | |
| 24 | | | | | | | | | | | | | | |
| 25 | 1 - 25.6 | | | | | | | | | | | | | |
| 26 | | | | | | | | | | | | | | |
| 27 | | | | | | | | | | | | | | |
| 28 | | | | | | | | | | | | | | |
| 29 | 10.0 lb | | | | | | | | | | | | | |
| 30 | | | | | | | | | | | | | | |
| 31 | | | | | | | | | | | | | | |
| 32 | | | | | | | | | | | | | | |
| 33 | | | | | | | | | | | | | | |
| 34 | | | | | | | | | | | | | | |
| 35 | | | | | | | | | | | | | | |
| 36 | | | | | | | | | | | | | | |
| 37 | | | | | | | | | | | | | | |
| 38 | | | | | | | | | | | | | | |
| 39 | | | | | | | | | | | | | | |
| 40 | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| Sample total | | | | | | | | | | | | | | |

LENGTH-FREQUENCY & LENGTH-BIOMASS SAMPLE

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

## MICHIGAN DEPARTMENT OF NATURAL RESOURCES

Fisheries Division

SURVEY PLANNING

Water: EXAMPLE L. Date: MARCH 10, 1979

County: WASHTENAW T. 1 R. 1 Sec. 15

Objective: REPORTS OF POOR FISHING. CHECK ABUNDANCE, GROWTH, AND SURVIVAL OF PLANTED TROUT. CHECK GROWTH OF BLUEGILL. OBTAIN CPE INDICES OF ABUNDANCE FOR ALL SPECIES. CHECK RECRUITMENT.

Previous surveys:

Gear types and dates

TRAPNETS, GILLNETS, ELECTROFISHING (220 AC) - JUNE 12-15, 1974

TRAPNETS - APRIL 1966.

Comparison of results

CPE, GROWTH INDEX, % L-A INDICATED BLUEGILLS MAYBE STARTING TO STUNT.

Fish population changes: CARP APPEARED IN THE LAKE IN EARLY 1970'S.

BROOK TROUT STOCKED IN 1977 & 1978.

Limnological data and dates: COMPLETE LIMNOLOGICAL SURVEY AUGUST 8, 1974.

LAKE STATIFIES AND THERMOCLINE RETAINS ENOUGH OXYGEN FOR TROUT.

Recommendations:

Gear type

TRAPNET, GILLNET, FYKENET, ELECTROFISHING GEAR (220-V AC) SMALL SEINE.

Timing

2nd OR 3rd WEEK IN JUNE.

Limnological measurements

TEMPERATURE & DEPTH RANGE WHERE GEAR IS FISHED.

Special studies: ——

Units of measurement: INCHES & POUNDS

Data to collect

CATCH SUMMARY: ALL SPECIES

LENGTH-FREQUENCY: " " "

LENGTH-BIOMASS: GAME SPECIES

LENGTH-WEIGHT: BLUEGILL & TROUT

GROWTH: BLUEGILL - 10 SAMPLES/INCH GROUP; TROUT - 30 SAMPLES/INCH GROUP.

MARK & RECAPTURE ESTIMATES: BROOK TROUT

AGE-FREQUENCY & SURVIVAL: BROOK TROUT.

# MICHIGAN DEPARTMENT OF NATURAL RESOURCES

Fisheries Division

Off Scale Envelopes

Water: Example L. T. 1 R. 1 Sec. 15 LENGTH-WEIGHT FIELD DATA

County: Washtenaw Gear: Electrofish Date: June 9, 1982

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

Fish length (Define inch groups)

Bluegill

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| .0 | | 11 | 8, 7 | 19 | 37 |
| .1 | | 11 | 9 | | |
| .2 | | 11 | | 21 | |
| .3 | | 11 | 11 | 24, 23 | 44, 41 |
| .4 | | | | 28 | 45, 49 |
| .5 | 11 | 𝍸 1 | 13, 12, 14 | 27, 30 | 51 |
| .6 | | | 15 | | 57 |
| .7 | 1 | 111 | | 33, 35 | 61 |
| .8 | 1 | | 16 | | 63, 61 |
| .9 | | 11 | 18 | 36 | |
| Total | 3.6g | 82g | | | |
| Avg. | 3.6/4 = .91 avg | 82/20 = 4.1g avg | 123/10 = 12.3g avg | 276/10 = 27.6g avg | 509/10 = 50.9g avg |

Bluegill

| | 6 | 7 | 8 | | |
|---|---|---|---|---|---|
| .0 | | 108 | | | |
| .1 | 64 | 111, 114 | | | |
| .2 | | | 183 | | |
| .3 | 75 | 123 | | | |
| .4 | 82, 84, 81 | 130 | | | |
| .5 | 87 | 136 | | | |
| .6 | 96 | | | | |
| .7 | 94, 101 | | | | |
| .8 | | | | | |
| .9 | 105 | | | | |
| Avg. | 869/10 = 86.9 avg | 722/6 = 120 avg | 183/1 = 183 avg | | |

Brook Trout

| | | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|
| .0 | | | 65 | | |
| .1 | | | 69, 70 | | |
| .2 | | 45, 48 | 72, 75 | | |
| .3 | | | | 107 | |
| .4 | | 50 | | 111 | |
| .5 | | 52, 50 | 81 | 114, 117, 113 | |
| .6 | | 54 | | 118 | |
| .7 | | | 88, 86 | 121 | |
| .8 | | 60, 59 | 90 | | |
| .9 | | | 93 | | |
| Avg. | | 418/8 = 52.2 avg | 789/10 = 78.9 | 801/7 = 114.4g avg | |

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

R8059 4/81

Fish length (Define inch groups)

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

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

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

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