Manual of Fisheries Survey Methods II: with periodic updates

Chapter 21: Interpreting Fish Population and Community Indices

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TOC
NEXT PAGE
PREVIOUS PAGE
CITATION

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Chapter 21: Interpreting Fish Population and Community Indices

James C. Schneider

A variety of statistics about fish populations and communities are collected during surveys (Chapter 2). Some guidelines for their interpretation will be reviewed here to complement the professional judgement of fisheries biologists.

There are three major questions in the interpretation of survey statistics:

- Is the sample representative of the species and sizes present;
- What biological attributes and processes are revealed by the statistics; and
- Exactly how do the statistical values relate to average expectations and to the quality of populations, communities, and fishing?

The first assumes that a representative ("fair") sample has been obtained or that biases caused by gear or season are recognized; the second that we can agree on the interpretation of population and community characteristics; and the third that within the continuous array of possible statistics, groups can be recognized that we can agree represent poor, average, or good conditions.

TOC
NEXT PAGE
PREVIOUS PAGE
CITATION

These questions are partially addressed in Table 21.1. This table summarizes some important population and community indicators, associated sampling concerns, and biological interpretations. Further elaboration follows.

Population indices reflect many important characteristics of a species population. Length-frequency distribution, length-biomass distribution, and average length and weight of the sample reflect population size structure. Age and growth analysis reflects recruitment, mortality, and longevity patterns as well as growth rate. Length-weight relationships also indicate growth rate and food conditions. Recruitment surveys focus on reproductive success within the last year or two. Catch-per-effort (CPE) statistics are a rough index of population abundance. Growth, length-weight relationships, and recruitment are discussed in Chapters 2, 9, 13, 15, 17, and 23 so will not be discussed further here.

Community indices are based on species composition of the catch sample. Species ratios and predator-prey ratios are statistics that may be derived. Community composition on a weight basis is a less variable and more useful statistic than community composition on a numbers basis (Schneider 1981). While the catch of one large fish can skew the proportion by weight in a small sample, erratic catches of small fish can more often have an even greater effect on the proportion by number.

21.1 Population indices

21.1.1 Size and age structure

Size structure and age structure of fish populations result from interactions among additions (recruitment), growth, and losses (natural plus fishing mortality). True size and age distributions of populations, by both numbers and weight, can be mathematically simulated if the many possible combinations of the variables are known. Figure 21.1 is an example based on recruitment, growth, and natural mortality patterns observed at Blueberry Pond (data in Schneider 1993). This lake is a best case example because virtually no fishing mortality occurs, growth is very good up to 8 inches, standing crop is high, and size structure is excellent. Figure 21.1

demonstrates that numbers of fish rapidly decline with age so that old and large fish are quite rare. On the other hand, standing crop biomass reaches a peak at an intermediate age (4) and size (6 1/2”).

Our perception of true population structure is clouded by the size selectivity of our sampling gear. Figure 21.2 demonstrates the selectivity of three types of gear for bluegill in Mill Lake. Generally, angling, gill net, trap net and large-mesh fyke nets are biased towards large fishes, whereas seine, electrofishing, and small-mesh fyke nets are biased toward small or medium-sizes (Laarman and Ryckman 1980; Schneider 1990, 1997). Table 21.2 summarizes an analysis of trap net and electrofishing selectivity based on comparison of catches to “true” population size structure, as derived from intensive mark-and-recapture studies at a small number of lakes (Schneider 1997).

21.1.1.1 Size structure.–Standards for interpretation of fish population size structure in Michigan are partially developed. Possible approaches to standardization are to adopt proposed national systems or to develop systems tailored to Michigan conditions. The latter could be based either on empirical data from large data sets, recognition of “type” waters, or mathematical models computed from average statistics.

The national systems (see Gabelhouse 1984) begin with defining a “stock” size, which is the minimum size of fish to be included in the analysis (“the stock”). Proportions of larger fish in the stock may then be computed and are given such terms as PSDs, RSDs, quality size, etc. It is presumed that the sampling gear gives an unbiased picture of size distribution above this stock size. Stock (minimum) sizes have been defined as 3” for bluegill and pumpkinseed, 8” for largemouth bass, 5” for black crappie and yellow perch, and 10” for walleye. Comparison of these sizes to the gear selectivity data in Table 21.2 indicates electrofishing data can meet the minimum criteria for all species, so those systems potentially could be used. However, electrofishing may not catch representative samples of large fish when they inhabit deep water (Table 2.2). Trap nets do not catch small stock size well (Table 21.2), and small-mesh fyke nets may catch small enough sizes but still be biased towards larger panfish (Schneider 1997).

TOC
NEXT PAGE
PREVIOUS PAGE
CITATION

For Michigan bluegill, Schneider (1990) devised an empirical scoring system based on length-frequency statistics of bluegill sampled with several types of gear used in Michigan. The length-frequency indices incorporated were average length and proportions of the catch larger than 6”, 7”, and 8”. The scoring system has been reproduced here as Table 21.3. Resulting scores of 3 to 4 indicate average population size structures, scores of 1 to 2 indicate populations lacking large fish (and usually slow-growing, but possibly short-lived), and scores of 5 to 7 indicate unusually high proportions of relatively large bluegill (which are fast-growing or long-lived). Application of the system to 303 lakes in 1990, and more lakes since then (Schneider and Lockwood 1997), indicated it is useful for classifying bluegill populations and lakes. The score for any lake can be converted to a percentile relative to the 303 lakes.

21.1.1.2 Age structure.–Information about large and old fish is especially valuable. It reflects the important interaction between growth and mortality, which determines potential angling quality (abundance of large fish) and longevity (maximum age). Mortality rate is best determined from intensive sampling of population age structure, however, it can be inferred from our conventional low-intensity sampling for age and growth as follows.

Table 21.4 shows state average length at ages 3 and 4 (in spring) for some important sport fish. Very generally, trap and fyke nets with conventional 1.5” mesh pots will sample quite well black crappie, largemouth and smallmouth bass, and northern pike of sizes equivalent to age 3 and older. The same gear catches bluegill, pumpkinseed, and yellow perch of sizes equivalent to age 4 and older. If we assume age 3 and older fish of all species typically have a combined natural and angling mortality rate of 60% per year, which is reasonable based on cumulative information, then we can calculate the probabilities of finding old fish in our samples as shown in Table 21.4.

For example, for all species in the top group (age 3 base), for every 100 fish age 3 and older *randomly* sampled, about 1 (0.6) should be age 8. For species in the lower group, the ratio of age 8 to all age 4 and older fish is also about 1 (1.5). The same age distribution could apply to other rates of growth if the distributions of mortality rate and gear age selectivity are adjusted appropriately.

I propose as a rule of thumb for all these species: if the maximum age taken in a good random sample (approximately 100 fish) is about age 8, that indicates a typical mortality rate probably exists within the population. If fish age 10 or older are found, that suggests mortality is relatively low. If the maximum age is less 7 or less, mortality rate is probably relatively high (or we can't age the fish reliably). If old fish are found in smaller samples, that likewise indicates mortality must be low. Walleye have a growth pattern which places them in the top group, however on average they have a lower mortality rate than the other species so usually reach at least age 10 in good samples.

Note that to determine maximum age, scale samples need not be taken on a strictly random basis. Our usual technique of sampling only 10-15 fish per inch group (stratified sampling) has two advantages: (1) it is highly likely that the oldest fish in the sample will be discovered; and (2) we don't have to age so many age 3 and 4 fish to obtain the statistical power of a larger random sample. For example, for bluegills 5- to 8-inches long, aging 10 fish per inch group (40 fish) will give approximately the same information about longevity as randomly aging 100 fish.

TOC
NEXT PAGE
PREVIOUS PAGE
CITATION

Difficulties with the longevity method above are that old fish are rare (and may be missed by sampling) and they usually are slow growing (and may be hard to age from scales). The ratio of age 3 or age 4 fish to all older ages (age 4 or age 5 plus) is a potentially more reliable statistic because it is a larger number. However, it must be based on a random sample or a de-stratified sample (Chapter 15). In the 60% annual mortality example (Table 21.4), 60% of the age 3+ fish were age 3 and maximum age was about 7-8. If annual mortality were only 40%, 40% of the age 3+ fish would be age 3 and maximum age would be 10-11. If annual mortality were 80%, 80% of the age 3+ fish would be age 3 and maximum age would be 5-6.

21.1.2 Abundance

Densities of fish can be only inferred from catch data. Clearly, the presence of a species or size group is confirmed when at least one representative is caught. However, failure to catch any of a species or size does not assure absence from the lake or stream. Catch per effort (CPE) is only a rough indicator of relative abundance. Relatively large catches imply large populations, but catch rate is influenced by many factors other than population density.

Table 21.5 shows average catch rates (CPEs), by species, for several types of fishing gear used for lake surveys in Michigan. These CPEs can be used as a rough standard – analogous to state average growth rates (Chapter 9) – for evaluating, interpreting, and comparing results of future surveys. Excluded from the average CPE for a species were surveys with zero catches. Also, surveys during spring spawning runs were excluded to make the averages representative of general surveys. The CPE averages are based on representative survey data present in the electronic Fish Collection System as of mid September 1999; they should be revised periodically and stratified by region or lake type after more data accumulate in the system. Note that differences among catch rates in Table 21.5 reflect both that small mesh nets retain more smaller fish (but perhaps fewer larger fish) and that there are regional differences in net usage. Generally, fyke nets have been the preferred net in the Upper Peninsula and the northern Lower Peninsula, and trap nets have been favored in the southern Lower Peninsula. Since there are corresponding regional differences in fish communities and densities, the CPEs may reflect that also.

It appears CPE is much more reliable for reflecting changes in population density within a lake (Schneider 1998b) than differences in density between lakes. My (1998) preliminary analyses suggest some useful relationships between CPE and population density eventually may be developed for bluegill, pumpkinseed, yellow perch, and walleye. For walleye 13 inches and larger, it appears that a non-proportional relationship exists between trap net CPE and mark-and-recapture population estimates. Very roughly, a catch of two walleye per net lift implies a population density of about four walleye per acre and a catch of six walleye per lift implies a population of about seven per acre. Extensive data from Wisconsin lakes indicates walleye population per acre multiplied by 0.019 will estimate walleye catch per angler hour (Beard et al. 1997).

Densities of larger-sized sport fish have been estimated by mark-and-recapture methods at many Michigan lakes to date. Density estimates for largemouth bass, northern pike, and bluegill were compiled in recent reports and are duplicated here as Tables 21.6, 21.7, and 21.8. Generally, largemouth bass over 10 inches long number less than 10/acre, northern pike over 14 inches number less than 5/acre, and bluegill over 6 inches long usually number less than 100/acre but vary widely.

21.2 Community indices

21.2.1 Coldwater Lakes

Status of trout in these lakes is the primary management concern. In small lakes intensively managed for rainbow and brook trout, it is generally accepted that even small numbers of other species (especially predators) detracts from trout production and fishing. The more piscivorous trouts – lake, splake, and brown – often benefit from modest numbers of soft-rayed forage fish. In larger lakes with both cold, cool, and warmwater habitats and natural mixtures of species, northern pike in more than token amounts are detrimental to trout. Presence of cisco indicates potential trout habitat exists and there is an excellent forage base for lake trout.

TOC
NEXT PAGE
PREVIOUS PAGE
CITATION

In coldwater lakes trout population characteristics themselves are the best indicators of conditions. Growth can be compared to state averages for trout in lakes (Chapter 9). Survival is generally satisfactory if any trout carry over from one year to the next. Rainbow trout success is linked to the abundance of large *Daphnia* (Chapter 18).

21.2.2 Coolwater Lakes

In these lakes the typical coolwater species – yellow perch, smallmouth bass, walleye, rock bass, northern pike, and white sucker – predominate on a weight basis. Some habitat may also be available for trout and warmwater species. Characteristics of good and poor coolwater communities have been partially evaluated. White suckers should not comprise more than 50% of standing crop biomass and predators should probably comprise between 20 and 50% of the total biomass (Schneider and Crowe 1980; Schneider 1981). Relative growth and longevity of the species populations should serve as indicators of both population quality and community balance.

21.2.3 Warmwater Lakes

In these lakes typical warmwater species – bluegill, largemouth bass, crappie, carp, and bowfin – predominate. In Michigan's range of climate, some habitat will also be available for coolwater species, especially the ubiquitous yellow perch. Stocked walleye can thrive in most of these lakes if forage and predators are favorable.

Indicators of undesirable lake communities, and usually poor overall fishing quality, are these percentages on a weight basis (Schneider 1981):

- Common carp or white sucker >50%;
- Bluegill + pumpkinseed >78%;
- Minnows + chubsucker + warmouth >15%;
- Predators <20% and >50% (tentative).

The bluegill is a key species in the management of warmwater lakes. Generally, satisfactory or good bluegill characteristics will be reflected in satisfactory to good overall fishing quality (Schneider 1981). An important exception is that lakes with stunted bluegill often produce exceptionally large bass. These bluegill population indices have been recommended (Schneider 1981):

- Presence of any 8-inch bluegill indicates a relatively good population;
- Absence of 8-inch bluegill coupled with a bluegill growth index greater than 1 inch below state average indicate unsatisfactory conditions.

21.2.4 Average warmwater and coolwater lake communities

Information on average lake fish communities comes primarily from large seining operations and mark-and-recapture population studies. Large seines (over 800 feet long) were used to sample 229 lakes (Schneider 1981). This gear missed the smallest fish and underestimated total number and weight per acre. Also, poor fishing lakes may have been over-represented in the data set. However, the seine was probably relatively unbiased as to community composition on a weight basis, and this data set is the largest and most representative the Fisheries Division has systematically collected. A table from that report showing average values for northern Lower Peninsula (region II) and southern Lower Peninsula (region III) is reproduced here as Table 21.9.

TOC
NEXT PAGE
PREVIOUS PAGE
CITATION

Mark-and-recapture population estimates have been conducted at numerous lakes by research personnel. Most studies targeted the larger sizes of a few species, but for some lakes, gear was sufficiently diverse and sampling effort was intensive enough to obtain acceptable estimates for every important species and size. In Table 21.10 are fish community composition estimates which are believed to be typical of small, shallow, Lower Peninsula lakes. In Table 21.11 are similar but less reliable data for small lakes in the Upper Peninsula containing typical mixtures of warmwater species. In Table 21.12 are additional estimates from northern lakes with simple but acceptable fish communities.

The estimates based on seining (Table 21.9) indicated, on average, bluegill comprise 36% and largemouth bass 18% of the fish community standing crop biomass in northern Lower Peninsula lakes. For southern Lower Peninsula lakes sampled by seining, bluegills comprised 41% and largemouth bass 16% of the community standing crop biomass. The best mark-and-recapture data for Lower Peninsula lakes (Table 21.10) indicate more bluegill, 50%, and fewer largemouth bass, 11%. Small Upper Peninsula lakes with diverse species (Table 21.11) contained 56% bluegill, 2% largemouth bass, and none of those warmwater species which have a more southerly distribution pattern (e.g., chubsucker, bowfin, grass pickerel, warmouth). Schneider (1973a) provided estimates of community composition for many other lakes with unusual or unbalanced fish assemblages.

Other types of sampling provide imperfect snapshots of the composition of warmwater fish communities. Trap nets tend to underestimate the proportion on a weight basis of bluegill, yellow perch, and minnows, and over-sample black crappie, northern pike, and bowfin (Table 21.13). Daytime electrofishing under-samples bluegill, northern pike, and bullheads, and over-samples pumpkinseed, bowfin, grass pickerel, and chubsucker on a weight basis (Table 21.14).

Relative to trap net biases, fyke nets with the same mesh give about the same picture of populations and communities (Schneider 1999). Compared to trap and fyke nets, gill nets are the best sampling tool for pelagic and cold-water species, but tend to over-sample northern pike, walleye, yellow perch, white sucker, and the predator-prey ratio. Gill nets tend to under-sample bluegill, rock bass, and other centrachids. Night electrofishing can be very effective for adult largemouth bass and smallmouth bass as well as the small sizes of most species.

21.2.5 Standing Crops

Our best estimates of total standing crops of fish in typical lake communities are included in Tables 21.10 and 21.11. The estimates based on seine catches per acre (Table 21.9) are clearly too low to be realistic. Earlier summaries (Schneider 1973a and 1978) listed estimates from a wide variety of Michigan sources, including estimates for lakes with unbalanced populations (such as those completely dominated by severely stunted bluegill, bass, or yellow perch). Lakes with fewer species of fish generally have lower total standing crops because fewer niches are completely filled. However, stunted bluegill by themselves can develop surprisingly high standing crops because they feed low on the food chain (Schneider 1995).

The average total standing crop for the Lower Peninsula lakes included in Table 21.10 is 147 lb/acre. This figure is probably higher than the true average of all lakes because most of these lakes were relatively productive (mesotrophic) and lightly exploited. Mill Lake, for example, had an estimated standing crop of 109 lb/acre in unfished years (Table 21.10) compared to 94 lb/acre in a fished year (Schneider 1971). Standing crop estimates for small, fairly productive Upper Peninsula lakes with diverse communities (Table 21.11) were on the same order of magnitude, an average of 121 lb/acre, but this number is inflated by two suspiciously high estimates. In general, it appears that productive shallow lakes in which bluegill predominate often contain 100-150 lb/acre of all fish.

Total standing crop (lb/acre) of fish in any lake can be roughly estimated from the equation below (Schneider 1978, equation 3):

TOC
NEXT PAGE
PREVIOUS PAGE
CITATION

$$\log_{10}(Lb/acre) = 0.9840 + 0.3632(panfish\ \ index) + 0.00030(climate\ \ index) + 0.1990(1/(\log_{10} Secchi)) + 0.4342(\log_{10}(vegetation\ \ index)) - 0.1065(\log_{10} area) + 0.5204(rough\ \ fish\ \ index)$$

Where:

panfish index is approximate fraction of total weight as bluegill, pumpkinseed, and crappie combined;

climate index is average growing-degree days above a base of 55^0F (Figure 21.3);

Secchi is typical Secchi disk transparency in feet;

vegetation index is macrophyte abundance ranked 1-5, where 1 = sparse … 5 = very abundant;

area is lake area in acres;

rough fish index is estimated fraction of total weight as bullheads, carp, and suckers combined.

An example calculation for Mill Lake is as follows. Panfish and rough fish indices can be estimated from Table 21.10: *panfish index* = 0.41+0.11+0.05=0.57; *rough fish index* = 0.03 + 0.01 + tr = 0.04. (Note: for most lakes only typical survey data are available, so use ratios in trap or fyke net catches to approximate the indices). *Climate index* for western Washtenaw County is 2000 (Figure 21.3). *Secchi* disk ranges from 8 to 12 feet, so 10 feet is typical. Macrophytes, quite abundant, are ranked as 4. *Area* is 136 acres. The calculated standing crop is 111 lb/acre (antilog of 2.045), which agrees with field measurements of 94 to 109 lb/acre.

21.2.6 Angling yield

Annual catches of fish from Michigan lakes by anglers may be similarly estimated (Schneider 1975). Equation 1 from Table V of that publication is the most appropriate:

$$\log_{10}(Lb/acre) = -0.3322 + 0.9928(\textit{panfish index}) + 0.00022(\textit{climate index}) + 0.2829(1/(\log_{10} \textit{Secchi})) + 0.6151(\log_{10}(\textit{vegetation index})).$$

Terms are as defined above. Note that lake area and rough fish index are not used here.

Mill Lake can be used again as an example and required values were given above. The calculated sport catch was 21 lb/acre/year. Actual yearly catch from Mill Lake has never been estimated, but extensive creel census data from nearby and similar Sugarloaf Lake averaged 29 lb/acre/year.

21.2.7 Angling statistics

On-site census of angling effort and catch has been conducted at many Michigan lakes. Data collected from 1934 to 1982 is compiled or referenced in reports by Schneider and Lockwood (1979) and Ryckman and Lockwood (1985). It is difficult to generalize the statistics because extensive variation is caused by season, year, lake characteristics (e.g., region, area, productivity, fish species present, fish species targeted), and other factors. Estimates of fishing pressure ranged from 3 to over 200 hours/acre, estimates of total number of fish caught ranged from 1 to over 1000 fish/acre, and catch rates ranged from 0.1 to over 2.0 fish/angler-hour. Corresponding yearly averages for 22 typical Lower Peninsula lakes in a 1946-65 data set were 90 hours/acre, 106 fish/acre, and 1.0 fish/angler-hour (Schneider and Lockwood 1979).

TOC
NEXT PAGE
PREVIOUS PAGE
CITATION

Table 21.1.–Possible indicators of important characteristics of fish populations and communities and their interpretation.

A. Population level:

1. **Individual size range** – Can be detected with high bias gear and small sample size.

   Big fish present – Fishable; growth not poor and total mortality not high.

   Medium fish present – Recruits for fishery; reproduction several years ago.

   Small fish present – Recent reproduction.

   In combination, all three indicate uniformity of reproduction and recruitment.

2. **Size frequency** – Requires large sample and unbiased or corrected distribution, or standard gear plus expectations. A better measure of recruitment and potential fishing quality than size range.

   Large predominate – Potential fishing quality is high.

   Small predominate – Possible stunting, over-fishing, community imbalance, food limitation.

3. **CPE** – Requires standard effort, index sites, and season. Indicates both abundance and catchability.

4. **Age frequency and longevity** – Require unbiased or corrected age distribution. Indicate recruitment and mortality patterns.

5. **Growth** – Requires relatively unbiased sampling by age and size or weighting procedure. Growth rate, and to a lesser extent mortality, determine size frequency. Populations with average or better growth will have large fish unless mortality is unusually high.

TOC
NEXT PAGE
PREVIOUS PAGE
CITATION

B. Community level:

1. **Presence or absence** – Requires targeted gear suitable for all species likely to be present.

2. **Species** –

   Types available to fishery.

   Suggests food chains.

   Indicates habitat types present (temperature, oxygen, pH, etc.).

3. **Rare species** – need protection.

4. **Diversity** –

   Complex interactions are likely.

   Variety of habitats are available.

   Stability implied.

   Total productivity relatively high.

5. **Relative composition** – Requires unbiased or corrected gear, or standard gear plus expectation. Measures are percent by number or weight.

   a. Predator-prey ratio.
   b. % panfish.
   c. % sucker and carp.
   d. % chubsucker and golden shiner.
   e. Winterkill indicators (over-abundance of bullhead, perch, pumpkinseed, bowfin).

Table 21.2.–General patterns of gear size selectivity (Schneider 1997).

Species and gear	Number of lakes[a]	Minimum length (in)[b]	Peak[c]	Shape[d]
Bluegill				
1.5” trap nets[e]	6	4-5	7+	increasing
Electroshocking[f]	5	1-2	4-6	dome
Pumpkinseed				
1.5” trap nets	5	4-5	7+	increasing
Electroshocking	5	2	3-7	dome
Yellow perch				
1.5” trap nets	6	5-7	7+	increasing
Electroshocking	6	2	5-7	flat
Black crappie				
1.5” trap nets	3	3	6+	increasing
Electroshocking	2	5	7-9	flat
Largemouth bass				
1.5” trap nets	5	7-10	10+	sl increasing
Electroshocking	5	2	2-11	flat?
Northern pike				
1.5” trap nets	2	13-15	16-24+	flat?
Electroshocking	3	6-19	20-24+	increasing?
Walleye				
1.5” trap nets	1	8-9	18+	increasing
Electroshocking	1	10-11	16+	increasing

[a] Number of lakes for which size distributions by gear were compared to size distributions by mark-and-recapture estimates to determine catchability curves.

[b] Range in minimum length of fish caught by the gear in various study lakes.

[c] The inch groups where the highest proportion of sizes present are caught by the gear. For example, “4-6” indicates that 4-6 inch fish were the most catchable sizes in the population, and “7+” indicates that catchability was high at 7 inches and even increased through larger sizes.

[d] Indicates shape of the catchability curve. “Increasing” indicates larger fish are increasingly catchable (as a proportion of sizes available); “dome” indicates both large and small fish are less catchable than an intermediate size; “flat” indicates no size selectivity above the minimum size caught.

[e] Trap nets with pots of 1.5-inch stretched mesh. Fyke nets with similar mesh probably have similar selectivity.

[f] Electroshocking. Data for day and night analysis is pooled, but often larger fish are caught at night. Selectivity can be caused by netters not seeing or ignoring small sizes in addition to fish behavior and distribution patterns.

TOC
NEXT PAGE
PREVIOUS PAGE
CITATION

Table 21.3.–Scores (1 - 7) for five indices of bluegill population characteristics obtained during lake surveys. The four length indices are given for two basic gear types; growth index is independent of gear type. Also given are ranks (very poor to superior) corresponding to the scores. (Reproduced from Schneider 1990).

		Trap net or fyke net[a]				Shocker or large seine[b]				Growth
Rank	Score	Avg L[c]	% >6"[d]	% >7"[e]	% >8"[f]	Avg L	% >6"	% >7"	% >8"	index[g]
Very poor	1	<5.0	0-9	0-1.9	<0.1	<3.8	0-3	0-0.7	<0.1	<-1.0
Poor	2	5.0-5.4	10-24	2-4	<0.1	3.8-4.2	4-8	0.8-1.7	<0.1	-1.0 to -0.6
Acceptable	3	5.5-5.9	25-49	5-9	<0.1	4.3-4.7	9-17	1.8-33	<0.1	-0.5 to -0.1
Satisfactory	4	6.0-6.4	50-74	10-29	0.1-0.9	4.8-5.2	18-29	3.3-9.9	0.1-0.9	0 to 0.4
Good	5	6.5-6.9	75-85	30-49	1-9	5.3-5.7	30-39	10-24	1.0-2.9	0.5 to 0.9
Excellent	6	7.0-7.5	86-95	50-79	10-39	5.8-6.2	40-49	25-39	3-19	1.0 to 1.4
Superior	7	≥7.6	≥96	≥80	≥40	≥6.3	≥50	≥40	≥20	≥1.5

[a] Impounding nets with 1.5-inch stretched mesh in pots; also gill nets.
[b] Boom shockers or large seines; also fyke or trap nets with small mesh.
[c] Average length of catch in inches.
[d-f] Percent of catch greater than 6.0, 7.0, and 8.0 inches in length, respectively.
[g] Average deviation (inches) from the seasonal state average length at age (GI).

Directions for use: Determine a score of 1 to 7 for each of the four size indices. (If the percent of the catch greater than 8 inches is <0.1, then its score = 2). Then compute "size score (SS) by averaging the scores for average length (Avg L), percent over 6 inches (% >6"), percent over 7 inches (% >7"), and percent over 8 inches (% >8"). If one or two of the length scores is unknown because of missing data, compute SS by averaging the known scores.

TOC
NEXT PAGE
PREVIOUS PAGE
CITATION

Example: Sugarloaf Lake, Washtenaw County, was sampled by electrofishing in 1977 (Table 2). Indices were: Avg L = 5.2", % >6" = 48, % >7 = 15, % >8" = ? (not required on old form). Corresponding scores derived from Table 21.3 are: Avg L = 4, % >6" = 6, % >7" = 5, % >8" = ?. The SS = (4 + 6 + 5) / 3 = 5.0.

Table 21.4.–Approximate age distribution of fish populations based on an assumed total mortality rate of 60% per year and state average growth. Species are grouped by growth rate (size) so as to have good catchability in trap or fyke nets. Some species are well sampled beginning at age 3, others beginning at age 4.

Group	Length at age		Percent of sample in age group							
and Species	Age 3	Age 4	3	4	5	6	7	8	9	10
Age 3 base:			60	24	10	3.8	1.5	0.6	0.2	0.1
Northern pike	20.8	23.4								
Black crappie	7.5	8.6								
Largemouth bass	11.6	13.2								
Smallmouth bass	10.8	12.6								
Age 4 base:			…	60	24	10	3.8	1.5	0.6	0.2
Bluegill	5.0	5.9								
Pumpkinseed	4.9	5.6								
Yellow perch	6.5	7.5								

TOC
NEXT PAGE
PREVIOUS PAGE
CITATION

Table 21.5.–Average catch per unit of effort (CPE) during inland lake surveys for 12 species of fish and 8 types of fishing gear.[a] Mesh size (stretched measure) in experimental gill nets and in pots of fyke and trap nets are indicted. Averages were derived from data in the computerized Fish Collection System as of mid-September 1999, include only surveys in which at least one fish of the species was caught, and exclude inflated samples taken during spawning runs of walleye, northern pike, and white sucker. Blank indicates insufficient number of surveys (<10) to compute an average; italics indicates sample size of 10 to 29; normal type indicates 30 to 151 surveys in average.

	Fyke nets				Trap net	Gill net	Shocker
Species	0.7”	1”	1.5”	2”	1.5”	1.5-4”	DC
Largemouth bass	*1.7*	*1.0*	*5.2*	3.4	3.5	2.3	50.0
Smallmouth bass		*1.6*	*2.6*	*1.1*	1.6	*0.8*	14.0
Walleye		*2.2*	*1.5*	*1.0*	1.0	2.1	41.7[b]
Northern pike		1.4	0.8	*1.1*	0.8	2.3	7.4
Bluegill	14.1	*14.5*	*14.0*	10.6	56.6	4.5	165.2
Pumpkinseed	*2.7*	14.1	6.2	*1.8*	8.1	1.1	30.7
Yellow perch	*32.3*	*22.9*	14.7	*1.6*	1.0	9.5	33.0
Black crappie		*2.2*	*3.3*	*2.2*	23.3	5.3	15.8
Rock bass	*9.5*	*5.1*	7.7	*5.3*	4.0	1.3	8.5
Bullhead spp.	*7.1*	*10.2*	*13.7*	*1.8*	7.7	2.7	6.6
White sucker	*3.7*	2.9	3.3	*2.9*	2.7	3.1	*4.2*
Bowfin				*1.3*	1.7	*0.8*	*3.7*

TOC
NEXT PAGE
PREVIOUS PAGE
CITATION

[a] Fyke nets have rigid frames 4 feet high, and the same mesh is used throughout the pot, heart, and lead. Trap nets have collapsible frames, and pots 8 feet long x 5 feet wide x 3 feet high with 1.5-inch stretched mesh; mesh in hearts, wings, and leads is generally larger. Experimental inland gill nets are 125 feet long x 6 feet deep and have panels of 1.5, 2.0, 2.5, 3.0, and 4.0-inch stretched mesh (usually multifilament nylon); they are fished on bottom. Boom shockers are primarily 220-V DC with various amperages and configurations. See Chapter 3 for more details.

[b] Nearly all walleye surveys targeted recruitment of small fish in fall or spring.

Table 21.6.–Comparative densities of largemouth bass in unexploited and exploited Michigan lakes exceeding indicated minimum sizes as estimated by mark-recapture methods. Arranged by latitude. Table reproduced from Schneider (1998a).

Lake	County	Minimum length (in)	Number per acre	Reference
		Unexploited		
Blueberry	Livingston	≥10	27	Schneider 1993
		≥14	1.6	"
Third Sister	Washtenaw	≥10	12	Schneider 1971
Mill	Washtenaw	≥10	9.4	
		≥15	1.0 - 1.4	"
Dead	Washtenaw	≥10	6.6	Schneider 1993
		≥14	1.9	"
Wakeley	Crawford	≥10	2.7-7.6	Schneider 1998
		≥15	0.3-3.8	"
Cub	Gogebic	≥10	25	Clady 1975
		≥15	0	"
		Exploited		
Whitmore	Washtenaw	≥10	3.1 - 8.1	Latta 1959; Goudy 1981
Sugarloaf	Washtenaw	≥10	2.0 - 9.5	Laarman and Schneider 1979
Pontiac	Oakland	≥10	4.9	Goudy 1981
Kent	Oakland	≥10	1.5	"
Fife	Grand Traverse	≥10	3.0 - 5.5	Schneider 1971
Lodge	Ogemaw	≥10	1	"
Jewett	Ogemaw	≥10	10.5	Schneider 1995
		≥14	2.3	
Stager	Iron	≥12	0.4	Wagner 1988
Tepee	Iron	≥12	0.8	"
Chicago	Delta	≥12	0.2	"
East	Schoolcraft	≥12	1.1	"
Anderson	Marquette	≥12	0.6	"
Big Shag	Marquette	≥12	0.6	"

TOC
NEXT PAGE
PREVIOUS PAGE
CITATION

Table 21.7.–Comparative densities of northern pike in unexploited and exploited Michigan lakes exceeding indicated minimum sizes as estimated by mark-recapture methods. Table reproduced from Schneider (2000).

Lake	County	Minimum length (in)	Number per acre	Reference
		Unexploited		
Mill	Washtenaw	≥20	1.2	Schneider 1971
Dead	Washtenaw	≥20	2.6	Schneider 1993
Wakeley	Crawford	≥17	1.7 - 10.3	Schneider 1998
		Exploited		
Sugarloaf	Washtenaw	≥14	0.4 - 5.1	Laarman and Schneider 1979
Whitmore	Washtenaw	≥14	0.8	Schneider 1971
Big Portage	Jackson	≥14	0.6	“
Fife	Grand Traverse	≥14	6.4	“
Grebe	Ogemaw	≥14	10	“
		≥20	5	“
Manistee	Kalkaska	≥20	0.4 - 2.2	Laarman and Schneider 1986

TOC
NEXT PAGE
PREVIOUS PAGE
CITATION

Table 21.8.–Comparison of bluegill population characteristics for Michigan lakes. Ranges indicate multiple years.

Lake and county	Growth index	Number per acre >6"	Number per acre >8"	Adult mortality rate Total (A)	Adult mortality rate Fishing (u)	Adult mortality rate Natural (v)
Blueberry[a] Livingston	+0.3	215–507	124–333	0.37	low	…
Dead[a] Washtenaw	+0.2	208–237	16-44	0.41	low	…
Mill[b] Washtenaw	-1.0	44–209	0.3–22	0.54	0	0.54
Cassidy[c] Washtenaw	+0.0	125–126	0.3–0.6	0.55-0.62	…	…
Third Sister[d] Washtenaw	+0.2	156	68	…	low	…
Sugarloaf[ef] Washtenaw	-0. 1 to -0.4	35–80	3	0.68	0.25–0.30	0.40–0.42
Whitmore[e] Livingston	+0.6	42	4.0	0.68[g]	…	…
Manistee[h] Kalkaska	+1.0	5–47	0.9–4.4	0.64	0.10–0.31	…
Fife[i] Kalkaska	+0.1 to +1.5	4–90	1.5	0.55[j]	…	…
Jewett[k] Ogemaw	-0.1 to -1.0	42–127	1–4.6	0.86	0.23	0.63
Lodge[k] Ogemaw	-1.6	35–72	0	0.83	0.26	0.57

[a] Schneider 1993
[b] Schneider 1971
[c] Schneeberger 1988
[d] Brown and Ball 1943
[e] Cooper et al. 1957
[f] Laarman & Schneider 1979
[g] Average total mortality calculated from 1955-56 pooled age-frequency data for ages 4 to 10 (Latta 1959).
[h] Laarman & Schneider 1986
[i] Schneider & Lockwood 1979
[j] Total mortality calculated from pooled age-frequency data for 1958-65 trap netting, ages 4 to 8.
[k] Patriarche 1968

TOC
NEXT PAGE
PREVIOUS PAGE
CITATION

Table 21.9.–Species composition in percent of total weight caught, and catch per acre in numbers and pounds, for lakes seined in Region II (<1800 growing degree days – Figure 21.3) and Region III (≥1800 growing degree days). Reproduced from Schneider (1981).

	Northern Lower Peninsula– Region II[a]				Southern Lower Peninsula– Region III[b]			
	Percent composition		Average catch per acre		Percent composition		Average catch per acre	
Species	Mean	Range	Number	Pounds	Mean	Range	Number	Pounds
Bluegill *Lepomis macrochirus*	36	0-90	284	18	41	tr-83[d]	308	20
Largemouth bass *Micropterus salmoides*	18	0-86	12	6	16	0-84	15	5
White sucker *Catostomus commersoni*	11	0-86	3	3	2	0-54	1	1
Carp *Cyprinus carpio*	3	0-51	tr	1	11	0-92	1	5
Yellow perch *Perca flavescens*	9	tr-69	76	3	7	0-41	42	3
Northern pike *Esox lucius*	6	0-37	2	2	4	0-45	1	1
Pumpkinseed *Lepomis gibbosus*	5	0-38	22	2	5	0-35	32	3
Black crappie *Pomoxis nigromaculatus*	3	0-35	12	2	6	0-49	18	3
Smallmouth bass *Micropterus dolomieu*	3	0-46	1	1	tr	0-23	tr	tr
Rock bass *Ambloplites rupestris*	2	0-13	2	tr	1	0-19	1	tr
Walleye *Stizostedion vitreum*	1	0-52	tr	tr	tr	0-5	tr	tr
Bullhead *Ameiurus* spp.	1	0-9	1	tr	1	0-11	1	tr
Minnows *Cyprinidae*[c]	1	0-22	5	tr	1	0-17	10	1
Grass pickerel *Esox americanus vermiculatus*	tr	0-2	tr	tr	1	0-4	1	tr
Warmouth bass *Lepomis gulosus*	tr	0-tr	tr	tr	1	0-12	4	tr
Lake chubsucker *Erimyzon sucetta*	tr	0-3	tr	tr	1	0-17	3	1
Bowfin *Amia calva*	tr	0-12	tr	tr	tr	0-8	tr	tr
Gar *Lepisosteus* spp.	tr	0-1	tr	tr	1	0-72	tr	tr
Total	100		422	42	100		440	45

[a] For Region II, percent composition data are for 81 lakes and catch per acre data are for 77 lakes.
[b] For Region III, percent composition data are for 148 lakes and catch per acre data are for 144 lakes.
[c] Minnows include cyprinidae (except carp) and, rarely, darters (Etheostomatinae).
[d] tr = trace = <0.5.

TOC
NEXT PAGE
PREVIOUS PAGE
CITATION

Table 21.10.–Fish community composition (percent by weight) and total fish biomass (lb/acre) for shallow, productive lakes with typical warmwater species in the southern and northern Lower Peninsula. Based on mark-recapture population estimates for all important species and sizes.

	Southern Lower Peninsula					Northern Lower Pen.		All
Species	Mill	Cassidy	Dead	Blueberry	Average	Wakeley	Jewett	average
Bluegill	41	46	46	55	47	54	60	50
Pumpkinseed	10	10	9	12	10	3	3	8
Yellow perch	12	16	5	6	10	tr	3	8
Black crappie	5	tr	1	0	2	tr	14	5
Rock bass	1	tr	0	0	tr	0	1	tr
Largemouth bass	11	7	6	11	9	11	17	11
Northern pike	8	0	6	0	4	23	0	6
Bowfin	3	4	15	0	6	0	0	4
Lake chubsucker	3	2	4	6	4	0	0	3
Brown bullhead	4	9	5	0	5	7	2	5
Yellow bullhead	1	4	3	5	3	2	0	3
Warmouth	1	0	tr	0	tr	0	0	tr
Green sunfish	tr	2	tr	1	1	0	0	tr
Grass pickerel	tr	1	tr	3	2	0	0	tr
Golden shiner	tr	0	tr	1	tr	tr	0	tr
White sucker	tr	0	tr	0	tr	0	0	tr
Other	tr	tr	tr	tr	tr	tr	tr	tr
Total %	100	100	100	100	100	100	100	100
Total lb/acre	109	144	174	197	156	160	100	147

Supplemental lake data

	Mill	Cassidy	Dead	Blueberry	Wakeley	Jewett
Years of estimates	1965-69	1964	1984-85	1984-90	1987	1958
Exploitation	none	avg	v. low	v. low	none	avg
Bluegill growth	slow	avg	fast	fast	avg	slow
Area (acres)	136	46.2	56.6	19.9	168	12.9
Max depth (ft)	25	11	32	24	9	17
Alkalinity	140	127	114	105	46	33
Secchi disk (ft)	8-12	9	10-14	7-8	5-6	4-13
Macrophyte rank	4	3	5	5	5	3
Oxygen-thermal type	4	5	4	4	5	4
Reference (Schneider)	1971	1973b	1993	1993	1998a	1973a

TOC
NEXT PAGE
PREVIOUS PAGE
CITATION

Table 21.11.–Estimated fish community composition (percent by weight) and total standing crop (lb/acre) for one coolwater (East) and five warmwater lakes with diverse species in the Upper Pennisula.[a]

	Upper Peninsula lake						
Species	Stager	Tepee	Chicago	East	Anderson	Big Shag	Average
Bluegill	57	62	63	5	79	70	56
Pumpkinseed	6	0	1	19	9	16	9
Yellow perch	4	30	0	34	8	8	14
Rock bass	0	0	1	0	0	0	0
Largemouth bass	2	3	1	1	1	4	2
Smallmouth bass	0	0	0	0	0	2	0
Northern pike	0	2	6	1	1	0	2
Northern musky	0	0	0	0	0	tr	0
Lake chubsucker	0	0	0	0	0	0	0
Bullhead spp	0	2	28	tr	0	0	6
White sucker	30	0	0	39	2	tr	14
Other	tr	tr	tr	tr	tr	tr	tr
Total	100	100	100	100	100	100	100
Total lb/acre	123	46	85	178	205	90	121

Supplemental lake data

Year of estimates	1983	1983	1984	1984	1985	1985
Exploitation	avg	avg	avg	avg	avg	avg
Bluegill growth	slow	?	?	?	?	?
Area (acres)	112	115	159	55	50	194
Max depth (ft)	55	39	16	29	29	29
Alkalinity	96	5	18-51	58	119	25

[a] I calculated from Wagner's (1988) mark-and-recapture population estimates, stratified by species into two size groups, and catch data with assumptions about average size and weight (state average). Considering the wide confidence limits on the population estimates and incomplete information, the standing crop estimates could be in error by 25% and should be considered to be tentative. The totals for East and Anderson lakes, nearly 200 lb/acre, seem too high.

TOC
NEXT PAGE
PREVIOUS PAGE
CITATION

Table 21.12.–Fish community composition (percent by weight) and total fish biomass (lb/acre) for lakes containing simple but fishable and stable fish communities. Based on mark-recapture population estimates for all important species and sizes.

	Lake			
Species	Jewett	Cub	Katherine	Marsh
Bluegill	67			
Yellow perch	16	16		
Largemouth bass		46		
Smallmouth bass		3	100	9
Walleye	17			
White sucker		35		91
Other		tr	tr	tr
Total %	100	100	100	100
Total lb/acre	71	62	10	51

Supplemental lake data

Years of estimates	1992	1967	1967	1967
Exploitation	avg	none	none	none
Bluegill growth	avg	…	…	…
Area (acres)	12.9	28	48	65
Max depth (ft)	17	20	56	40
Alkalinity	33	8	3	4
Secchi disk (ft)	4-13	10	10	10
Macrophyte rank	3	1	1	1
Oxygen-thermal type	4	5	1	2
Reference	Schneider 1973a	Clady 1970	Clady 1970	Clady 1970

TOC
NEXT PAGE
PREVIOUS PAGE
CITATION

Table 21.13.–Summary of species selectivity of 1.5" trap net, based on percent by weight, relative to mark-recapture estimates and known presence. Reproduced from Schneider (1997). s = spring sample; f = fall sample; ok = within 5% of reference; low = <5% or tr; high = >5%; 0 = not caught but present.

	Lake and date of sample					
Species	Blueberry s1987	Cassidy s1964	Dead s1984	Dead s1985	Mill f1964	**General pattern**
Bluegill	low	ok	low	v. low	v. low	**low**
Pumpkinseed	ok	high	low	low	ok	**varies**
Yellow perch	ok	low	ok	low	low	**low**
Rock bass		ok			ok	**ok**
Black crappie		ok	ok	high	high	**high**
Largemouth bass	low	ok	ok	ok	high	**ok**
Northern pike			high	high	high	**high**
Brown bullhead		ok	high	ok	ok	**ok**
Yellow bullhead	v. high	ok	high	high	ok	**high**
Warmouth			ok	ok	ok	**ok**
Green sunfish	0	ok	0	0	0	**low**
Longear sunfish			0	0		**low**
Grass pickerel	ok	0	ok	0	0	**low**
Chubsucker	ok	ok	ok	ok	ok	**ok**
Bowfin		high	low	high	v. high	**high**
Golden shiner	ok	ok	0	0	0	**low**
White sucker		ok			ok	**ok**
Iowa darter	0		0	0		**0**
Banded killifish		0				**0**
Brook silverside			0	0		**0**
Bluntnose minnow	0	0	0	0		**0**
Fathead minnow	0		0	0		**0**
Blackchin shiner	0	0				**0**
Blacknose shiner		0				**0**

TOC
NEXT PAGE
PREVIOUS PAGE
CITATION

Table 21.14.–Summary of species selectivity of day electrofishing (220-v AC) relative to mark-recapture and known presence. Reproduced from Schneider (1997). s = spring sample; f = fall sample; ok = within 5% of reference; low = <5% or tr; high = >5%; 0 = not caught but present.

	By number			By weight			
Species	Blueberry s1987	Dead s1985	**Pattern**	Blueberry s1987	Dead s1985	Mill f1964	**General pattern**
Bluegill	v. low	low	**low**	low	v. low	v. low	**v. low**
Pumpkinseed	high	high	**high**	high	high	high	**high**
Yellow perch	ok	low	**ok**	ok	ok	low	**ok**
Rock bass						ok	**ok**
Black crappie		ok	**ok**		ok	ok	**ok**
Largemouth bass	ok	ok	**ok**	ok	ok	ok	**ok**
Northern pike		ok	**ok**		ok	0	**low**
Brown bullhead		ok	**ok**		low	low	**low**
Yellow bullhead	ok	ok	**ok**	ok	ok	0	**ok**
Warmouth		ok	**ok**		ok	ok	**ok**
Green sunfish	0	ok	**ok**	ok	ok	0	**ok**
Longear sunfish		ok	**ok**		ok		**ok**
Grass pickerel	high	ok	**high**	high	ok	ok	**ok+**
Chubsucker	high	ok	**ok+**	high	ok	high	**high**
Bowfin		ok	**ok**		high	v. high	**high**
Golden shiner	ok	ok	**ok**	ok	ok	ok	**ok**
White sucker						ok	**ok**
Iowa darter	0	0	**low**	0	0		**low**
Brook silverside		0	**low**		0		**low**
Bluntnose minnow	0	ok	**low**	0	ok		**low**
Fathead minnow	0	0	**low**	0	0		**low**
Blackchin shiner	ok	0	**low**	0			**low**
Blacknose shiner		ok	**low**				

TOC
NEXT PAGE
PREVIOUS PAGE
CITATION

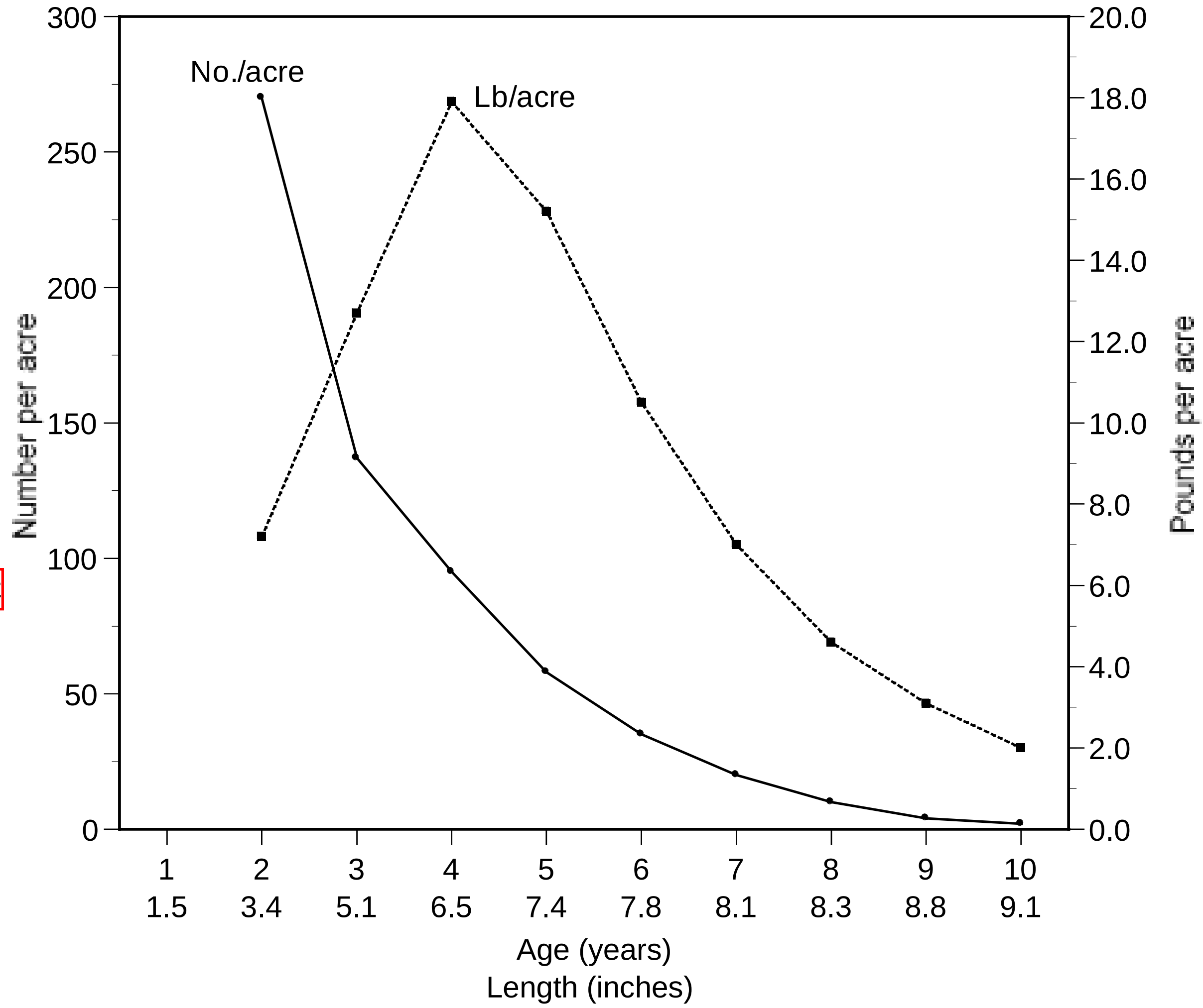

Figure 21.1.–Distributions by age and length of bluegill in Blueberry Pond based on mark-and-recapture population estimates. (Data from Schneider 1993).

TOC
NEXT PAGE
PREVIOUS PAGE
CITATION

TOC
NEXT PAGE
PREVIOUS PAGE
CITATION

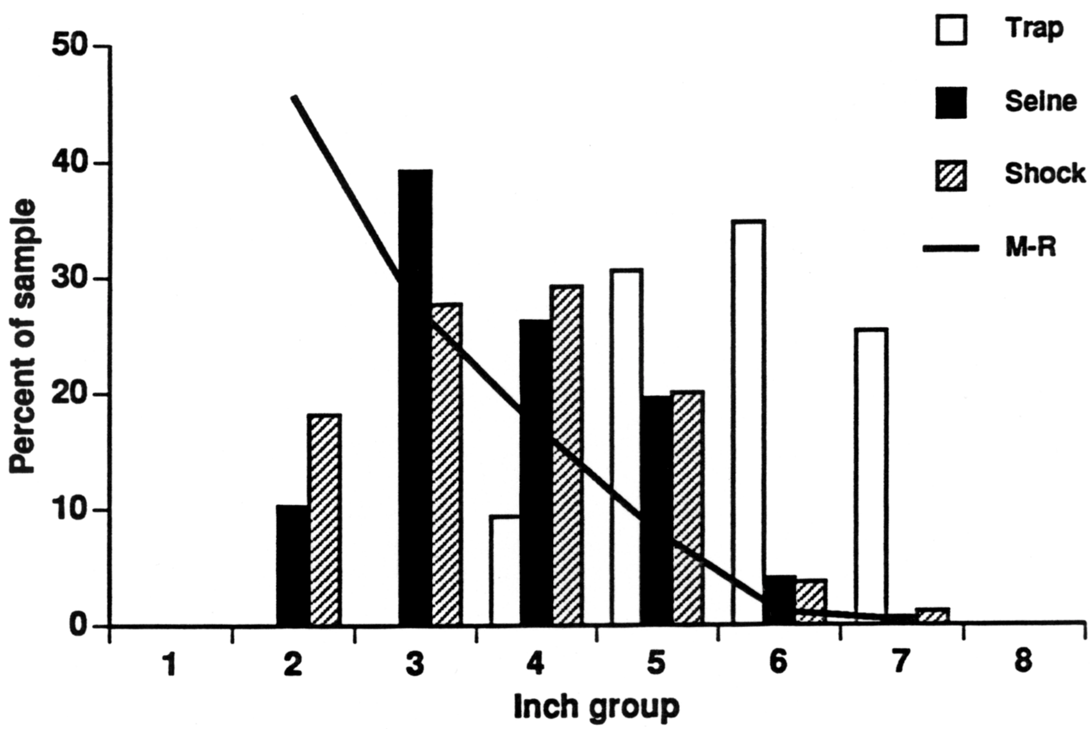

Figure 21.2–Bluegill length-frequency distributions in samples taken by 230-volt AC boom shocker, 800-foot seine (with 1-inch stretched-mesh pot) and trap net (with 1.5-inch stretched-mesh pot). The actual length distribution, based on mark-and-recapture (M-R) population estimates, is shown as a curve to illustrate gear size selectivity. Samples were taken from Mill Lake in fall 1996 (Schneider 1971 and unpublished data). Number of bluegill sampled were 4,267 by electroshocker (10 trips), 5,038 by seine (8 hauls), and 170 by trap net (42 lifts). Reproduced from Schneider (1990.)

TOC
NEXT PAGE
PREVIOUS PAGE
CITATION

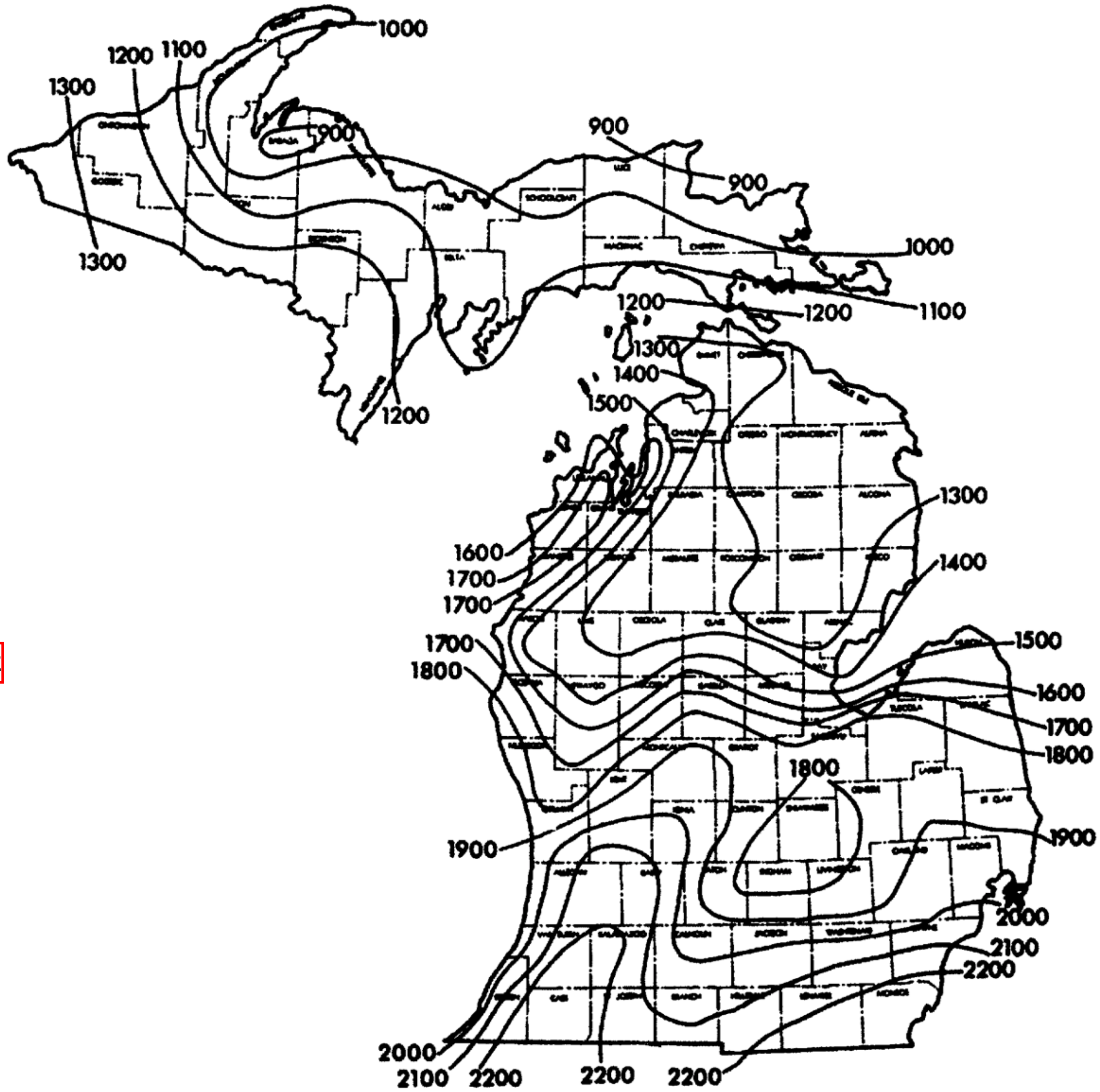

Figure 21.3–Average cumulative growing-degree-days above a base of 55°F, March 1-October 31. Reproduced from Van den Brink et al. (1971).

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TOC
NEXT PAGE
PREVIOUS PAGE
CITATION

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TOC
NEXT PAGE
PREVIOUS PAGE
CITATION

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