MICHIGAN DEPARTMENT OF NATURAL RESOURCES

FISHERIES DIVISION

Fisheries Research Report No. 1794

June 12, 1973

THE STANDING CROP OF FISH IN MICHIGAN LAKES [1]

By James C. Schneider

ABSTRACT

Estimates of the standing crops of fish in 64 lakes and ponds in Michigan were summarized. The estimates were adjusted, when necessary, to include fish which were not estimated originally. Lakes with slow-growing bluegills had the highest total standing crops of fish, 182 pounds per acre. Lakes with only slow-growing yellow perch had the smallest fish crops, 46 pounds per acre. Lakes with fish populations of normal species diversity and growth averaged 88 pounds per acre. Other lakes, with poor or unusual fish populations, contained 104 pounds per acre.

Multiple regression-correlation analyses were performed. Lake alkalinity, area, depth, alkalinity divided by depth (index), and the logarithm of each of these variables--these factors accounted for only 25% of the variation in the logarithm of fish standing crop when data from all lakes were pooled. Stratifying the data according to type of fish, and to trout lake versus warmwater lake, resulted in significant regressions. However, application of these results is limited because: (1) sample size was small in certain strata, (2) performance of particular variables in different regressions was inconsistent, and (3) the range in variables was relatively narrow.

[1] A contribution from Dingell-Johnson Project F-29-R-7, Michigan.

Introduction and methods

Numerous studies have been made on the fish populations of Michigan lakes. This report will summarize those studies for which the entire fish crop, or major portion of the crop, was estimated, or can be estimated from data at hand. Data have been obtained from published papers, from reports of the Institute for Fisheries Research, and from unpublished material collected by Institute personnel (Table 1). In addition to describing these populations, I have attempted to relate standing crops of fish to the physical and chemical characteristics of the lakes.

The earliest estimates of total fish populations were simply counts of the number of dead fish recovered after rotenone treatments. Ball (1948a) summarized 32 of these estimates which were made between 1934 and 1942. These estimates, plus four additional studies from that period which Ball did not cite, are included in this report.

After 1942, many other lakes were treated with toxicants. Lists of lakes which were treated were compiled by Taube et al. (1954), Scott (1961), and Spitler (unpublished) for the periods 1942-1953, 1947-1961, and 1957-1967, respectively. To my knowledge, intensive population studies were made at only a few of these lakes by research personnel. Estimates were made at certain other lakes by field biologists; however these are not included here because their precision cannot be ascertained.

In the population estimates based on fish recovered at poisoning, it was generally assumed that all, or nearly all, of the fish in the lake were recovered (especially on a weight basis); however the few checks which have been made (by noting the recovery rate of fin-clipped fish liberated before treatment) suggest that a variable, but substantial portion of the fish may not be recovered. This is because some fish dive into the bottom, or simply lie on the bottom until they decompose.

Krumholz (1944) recovered 86% of the fin-clipped bluegills (<u>Lepomis macrochirus</u>) and largemouth bass (<u>Micropterus salmoides</u>)

from Twin Lake. From Ford Lake, another relatively clear and deep lake, Ball (1948b) recovered 59% of the bluegills and 45% of the brook trout (Salvelinus fontinalis). Other data for Michigan lakes, unpublished, have been supplied by Institute personnel.

Mercer H. Patriarche provided excellent data for Jewett Lake, a small, relatively shallow lake of average clarity. The recovery rates varied with the species of fish and, also, with size of the fish, but they were mostly less than 40%. For bluegills in the inch groups 3, 4, 5, 6, 7 and 8+ (8 inches and larger), the percent recovery rates were 18, 40, 56, 39, 40, and 39, respectively. Largemouth bass 2-4 inches long were recovered at a rate of 32%, the same as bass 5 inches and longer. Recovery rates for rock bass (Ambloplites rupestris), pumpkinseed (Lepomis gibbosus), and hybrid sunfish were each 19%. Only 4% of the black crappies (Pomoxis nigromaculatus) and 1% of the bullheads (Ictalurus spp.) were found.

Other unpublished data on recovery of marked fish at poisoning were available from Center Lake (C. M. Taube) and Cassidy Lake (J. C. Schneider). In these two studies a complete census of dead fish was not attempted; however we estimated that a majority of the fish, especially of the large ones, were picked up. Center Lake is relatively deep, but it is clear. Cassidy Lake is shallow and clear, but it has an extensive mat of Chara which may have concealed dead fish. At Center Lake recovery rates for fin-clipped fish were 6, 8 and 4% respectively for bluegills, yellow perch (Perca flavescens), and pumpkinseed. At Cassidy Lake, recovery rate was a function of fish size, because collectors concentrated on the larger fish. For bluegills in the inch groups 3, 4, 5, 6, 7+ (7 inches and larger), the recovery rates were 0.3, 5, 9, 17, and 22%, respectively; for pumpkinseed of the same sizes the recovery rates were 1.6, 7, 16, 18, and 18%; and for yellow perch of these sizes, 0.6, 3, 3, 7, and 24% were recaptured. No marked large-mouth bass under 6.0 inches long were recovered; 47% of the 6- to 9-inch bass were found, and 26% of the legal-sized bass (larger than 10 inches) were recaptured. Few black crappies (4%) and bullheads (13%) were recovered.

Several studies on the recovery rate of fish killed by toxicants in lakes and ponds have been made in other states. Rupp and De Roche (1965) found that less than one-half of the dead fish in three small, deep, clear lakes floated into shore. Their divers found most of the fish on the bottom; however some of these fish might have surfaced eventually. Krumholz (1950) recovered 91% of the green sunfish (Lepomis cyanellus) and 87% of the largemouth bass from ponds. Carlander and Lewis (1948), on the other hand, recovered only 38%, 33%, 14%, 80%, and 91% of the bluegills, largemouth bass, white crappie (Pomoxis annularis), black bullheads (Ictalurus melas), and golden shiners (Notemigonus crysoleucas), respectively, from a small, shallow, turbid pond. From other ponds, Moorman and Ruhr (1951) recovered 22-65% of the black bullheads.

In contrast with the studies cited above, Parker (1970) concluded that virtually all fish will surface within a week of treatment if temperatures exceed 60 F and if rooted aquatic plants are not abundant. In his laboratory tests, large numbers of fish did not surface when water temperatures were less than 60 F. His field tests were conducted in ponds less than 10 feet deep.

The disparity between the results of Parker and the other studies cannot be reconciled on the basis of temperature. From water temperatures given by the authors, or judged on the time of year in which the treatments were made, surface temperatures probably exceeded 60 F in all these studies, except that by Patriarche in which the water temperature was only 42 F. However, it is likely that many of the lakes were stratified and that the water in the hypolimnion was less than 60 F at the time of treatment. Cassidy Lake, and probably also Ford Lake, were not stratified and had temperatures in excess of 60 F. In these lakes recovery may have been hindered by extensive mats of Chara.

Other factors which may affect the recovery of dead fish are the nature of the shoreline, the species of fish and their distribution within the lake, and the abundance of crayfish, turtles, birds, and predacious fish which may consume large numbers of dying or dead fish. Krumholz (1950) noted that greater numbers of fish were picked up from lakes which had well defined shorelines than from lakes with encroaching or brushy edges. Rupp and De Roche (1965) reported that most smelt (*Osmerus mordax*) sank to the bottom, whereas most white suckers (*Catostomus commersoni*) floated. Perhaps the smelt were in deep, cold water and the suckers in shallow, warm water when the treatment was made.

In summary, the recovery of fish after chemical treatment seems to be a function of: (1) temperature (and consequently lake depth and stratification), (2) abundance of weeds, (3) nature of the shoreline, (4) distribution of fish within the lake, and (5) numbers of predators and scavengers. It is unlikely that complete recovery of dead fish is possible except in warm, shallow ponds free of weeds. Recovery rates from typical shallow lakes (which are usually weedy) or typical deep lakes (which contain some water colder than 60 F all year) will usually be much less, even when surface temperatures exceed 60 F. Therefore most of the estimates of fish crops based on "complete" recovery of fish after poisoning should be revised upwards.

It is difficult to determine how large the adjustment should be since reported recovery rates have ranged from 86% to 45% and less, but even a crude adjustment is probably better than none at all. In those studies in which the author estimated recovery rate (Ford Lake, and the north basin of Twin Lake), or those studies in which the author has already modified the population estimate to take into account fish remaining on the bottom (Daggett), the estimates have been adjusted accordingly. For lakes and ponds less than 10 feet deep (Clear, De Bruin's, Pond 4), I assumed 100% recovery. For waters greater than 10 feet deep (all other lakes), I assumed that 60% of the fish were picked up. The original estimates and the adjusted estimates are given in Table 2. Only the adjusted data are used in the subsequent discussion.

Most of the lakes which were chemically treated had poor quality or unusual fish populations. Many were potential trout lakes which were dominated by slow-growing warmwater fish such as yellow perch, pumpkin-seed, white sucker, and various species of minnows. Relatively normal populations of warmwater fish were present only in Howe, Walsh, Third Sister, and Deep lakes. Howe was poisoned because it contained carp (<u>Cyprinus carpio</u>); Walsh, because the fish were heavily parasitized; and the other two lakes, as part of experiments.

A second method, in which the water was drained and the fish trapped and counted, has been used to estimate the fish in certain reservoirs and ponds (Table 3). This is the most accurate method of estimating fish abundance, and no adjustment of the figures reported by the authors was necessary. Unfortunately, these fish populations were not typical in that they were relatively young (Pond 24), or unbalanced (Upper and Lower Loch Alpine), or consisted only of bluegills (Belmont Ponds).

A third method of estimating fish populations is the mark-and-recapture technique (Tables 4 and 5). A sample of fish is caught, given a distinctive fin clip, and released. Subsequent samples of fish are taken and inspected for marked fish. From these data an estimate of the fish population is calculated, using the Petersen, Schnabel or Schumacher formulas. Fish may be captured in trap nets or seines, or by electro-fishing or angling, or with the aid of toxicants.

Mark-and-recapture estimates necessarily apply only to those species of fish and sizes of fish which are sampled by the gear employed. Often such estimates are restricted to "legal-sized" fish. I have adjusted these estimates to include species and sizes not reported by the author. In determining the adjustment, I took into account all information on recruitment, growth and structure of the fish population supplied by the author or by Institute files. When these data were inadequate, I made comparisons to other lakes, especially Mill Lake (Schneider, 1971) and to theoretical models. For instance, in adjusting the estimates to include small fish, I used the following guidelines for populations with stable recruitment: (1) 60% of the biomass of bluegill populations exceeds 6.0 inches when they are growing at an average rate, 50% when growing slowly; (2) 90% of the biomass of black crappies exceeds 7.0 inches; (3) 90% of the biomass of largemouth bass exceeds 10.0 inches under conditions of average growth, 80% under slow growth; (4) 50% of the biomass of pumpkinseeds exceeds 6.0 inches when growth is average; (5) 30% of the yellow perch biomass exceeds 7.0 inches under average growth, 4% under poor growth; and (6) 78% of the bullhead standing crop is larger than 6.0 inches in typical populations.

The mark-and-recapture estimates of standing crops of fish in Michigan lakes were divided into two groups. In the first group (Table 4), enough data were given so that an adjusted estimate of total standing crop could be made with only a few assumptions. In the second group (Table 5), the data were not so complete. Numerical estimates of some of the larger fish were given, but their total weight or average size were not. An important component of these populations, the yellow perch, was estimated at only one lake, and then probably underestimated. Consequently, the approximations I have made of total fish crop are quite rough. Some other studies of fish populations reported by Crowe (1956) were too sketchy to be used to estimate total standing crop.

The mark-and-recapture technique has been used on a variety of fish populations. Most of the biomass estimates we have for normal populations were made with this technique. Wintergreen Lake at the Kellogg Bird Sanctuary (Table 4), had an excellent fish population, but the lake was unusual in that it was enriched by the droppings of thousands of waterfowl. The estimate for Craig Lake is believed to be inflated because fish migrated to other lakes via the Coldwater River (Table 5). A number of experimental or unusual populations have been studied also. Dix and Rash ponds contained only slow-growing largemouth bass (Table 4). Katherine Lake, an unproductive lake in Gogebic County, had only smallmouth bass (Micropterus dolomieui). Cub and Marsh lakes, also in Gogebic County, contained only largemouth bass and yellow perch, and smallmouth bass and white suckers, respectively. These populations were not being exploited appreciably.

North Twin Lake (stunted pumpkinseeds), and Devoe Lake (predominantly white suckers) had poor fish populations. East Twin Lake and Grebe Lake had poor fish populations, mostly white suckers and black bullheads, respectively; however they are not so atypical as most other lakes in this group. Scaup and Lodge lakes were atypical because they winterkilled periodically. Partial kills may have occurred in these lakes 2-3 years prior to the estimates. Mill, Jewett, and Center lakes typically have slow-growing bluegills; however they contained a good variety of species and sizes, and their fish populations resemble many others in lower Michigan.

Cassidy Lake in 1966-68 and Jewett Lake in 1969 contained experimental populations of slow-growing yellow perch. The estimate was made at Jewett Lake when the perch population was at its maximum size; the estimate for Cassidy Lake is an average. The Sand lakes and Ford Lake contained experimental populations of bluegills (over-abundant, stunted) or green sunfish x bluegill hybrids (under-abundant, fast-growing).

In this broad review, data collected by all methods were stratified into categories for analysis. First, the lakes were classified according to their fish populations: those composed only of yellow perch (invariably slow-growing), or of yellow perch plus forage species (Table 6); those composed mostly of slow-growing bluegills, but other species may have been abundant also (Table 7); and those which were normal (Table 8) as compared to those which were poor or unusual (Table 9) in terms of species diversity, growth, and the fishery. Second, the total standing crop of fish (the adjusted estimate), region of occurrence, total alkalinity, area, mean depth, and the ratio of alkalinity to mean depth were determined for each lake. In addition, each lake was classified as to whether it was physically suited for trout management ("trout," in Table headings), or to warmwater species ("bass" in Table headings). Finally, these data were analyzed, principally by multiple linear and polynomial (second-degree) regression-correlation techniques, using an additive model, to determine if fish biomass was related to these variables. Three lakes were excluded from the analyses. De Bruin's Pond was excluded because its alkalinity was not known. Wintergreen and Craig lakes were excluded for reasons cited above (however, I found that inclusion of the Craig Lake data had almost no effect on the results of the analyses). Data from 61 lakes were analyzed.

Results

The standing crop of fish varied from 10 to 360 pounds per acre in the 64 Michigan lakes considered. Lakes in which slow-growing bluegills predominated had the highest standing crops of fish, an average of 182 pounds per acre. Bluegills made up 36-100% (average, 82%) of the total poundage. Lakes with normal fish populations (excluding Wintergreen and Craig lakes) averaged 88 pounds of fish per acre. Among the normal lakes in southern Michigan, the bluegill comprised 28-62% (average, 44%) of the total standing crop. Lakes in which yellow perch were the only sport fish present had total standing crops of 46 pounds per acre. The remaining lakes, classified as having poor or unusual fish populations, had 104 pounds of fish per acre. Three of these lakes were unusual in that they contained only bass. Katherine, a soft-water lake in the Upper Peninsula, had 10 pounds of smallmouth bass per acre. Dix and Rash, hard-water ponds in southern Michigan, contained 128 and 96 pounds per acre of largemouth bass, respectively.

The most pertinent results of the multiple linear regression analyses are summarized in Table 10. Second-degree polynomial regressions were made on certain sets of data for certain variables, but the fit was generally no better than that obtained by a linear or logarithmic model. The highest coefficients of determination (R^2) occurred when $\log_{10}$ fish standing crop was regressed upon all of the variables used in the analyses--alkalinity, area, mean depth, index, and $\log_{10}$ of each of these variables. By stepwise elimination of the variables with the smallest partial correlation coefficients, those variables which accounted for the greatest amount of variation in log fish crop were determined (the "best" equations in Table 10).

Only 25% of the variation in log fish standing crop could be attributed to all eight variables, when data from all 61 lakes were pooled. Index alone accounted for 20% of the variation. The predictive value of the variables was enhanced by stratifying the data by lake type. For lakes physically suited for trout, an R^2 of 43% was obtained; for lakes suited only for warmwater fish, R^2 was 34%.

Additional improvement in the fit of the regressions was obtained by stratifying the data according to type of fish population. Coefficients of determination for normal, slow-growing perch and slow-growing bluegill populations were 92%, 99.9%, and 96%, respectively. The R^2 for the poor fish populations was only 44%. When stratified according to trout and bass lakes, R^2 for the poor populations increased to 77% and 56%, respectively.

Unfortunately, these correlations form no clear-cut pattern which can be explained in biological terms. Some of the variables were correlated with each other, yet sometimes all were needed to strengthen a particular regression. For example, alkalinity, log alkalinity, index, and log index all contributed to the regression for all types of fish populations in warmwater lakes. Simple correlations using only independent variables were weak. For example, the R^2 of log fish standing crop versus log index for all strata ranged from less than 1% to 38%. Addition of area or log area, the only other independent variable, increased R^2 only slightly (range 3-44%). Interpretation of these correlations is complicated further because the algebraic signs of the variables were inconsistent. Log index, for example, was strongly positive in five analyses and strongly negative in two analyses. Considering all nine of the analyses in Table 10, log index, log depth and log alkalinity appear to be the most important physical parameters for predicting fish crops.

The equations which may be formed from the regression coefficients in Table 10 were used to predict the total standing crop of fish in the lakes used in the analyses (Table 11). Three predictions were made for each lake. One prediction was based on the equation formed from all data (equation No. 1); another prediction was made from the equation for trout-type lakes (equation No. 2) or the equation for bass-type lakes (equation No. 3); and a third prediction was made using the equation which best described the type of fish population and type of lake (equations No. 4-9). The latter equations had the highest coefficients of determination and, therefore, should give the most accurate prediction.

As may be seen in Table 11, the best equations did predict standing crops reasonably close to the adjusted estimates of standing crop which I derived from field data. The largest deviations between the adjusted and predicted estimates occurred among the heterogeneous group I call the "poor" and "unusual" fish populations. The fish population in North Twin Lake (predominantly pumpkinseeds) was overestimated by 80 pounds per acre. Three other lakes in this group, Kimes No. 3 and Upper and Lower Loch Alpine, with extraordinarily high populations of white suckers or minnows, were underestimated by 62-173 pounds per acre. Sand No. 3 (1971), with an unusual concentration of bluegills, was underestimated by 133 pounds.

Additional data are needed to determine if these descriptive equations can give reasonably accurate predictions of fish crops in other lakes. The predictive value of this model was tested, to a limited extent, when I inadvertently overlooked Grebe Lake and East Twin Lake while compiling data for analysis. I discovered the data for Grebe and East Twin after a first set of regressions had been computed and was able, therefore, to use them to test some of the first equations. I classified both lakes as "poor, bass," realizing, however, that they were more normal than most other lakes I had included in that group. Using the best equations available at that time I predicted a standing crop of 18,435 pounds per acre in East Twin Lake and 117 pounds per acre in Grebe Lake. By comparison, the adjusted estimates for these lakes were 48 and 192 pounds per acre, respectively. The deviation of 75 pounds between predicted and adjusted estimates of crop for Grebe Lake was not too disturbing since there was an unusually large number of black bullheads present--83 pounds per acre. By classifying the population of East Twin as normal and using the appropriate equation, or by using the equation for all types of fish populations in warmwater lakes, reasonable estimates of crop were obtained--33 and 66 pounds per acre.

The ridiculously high prediction of 18,435 pounds per acre I obtained for East Twin was due to the fact that no data from large lakes had gone into the first equation for poor populations in bass-type lakes. The two equations which gave reasonable estimates had included data from large (up to 1,150 acres) lakes. To improve the model, a second set of analyses was made which included the data from Grebe Lake and East Twin Lake. These are the analyses given in Table 10. Addition of these data lowered the R^2 values but the revised equations (No. 1, 3, 9) now encompass a broader variety of fish populations and lakes. The revised prediction of the fish population in East Twin is 115 pounds per acre (Table 11).

Craig Lake was not included in the analyses because the estimate of the fish population was believed to be inflated due to fish migration during the mark-and-recapture study. My adjusted estimate of 300 pounds per acre took into account the species and sizes of fish which were not estimated directly but does not take into account the effect of migration. Therefore it too, is probably inflated. However, I will use the physical data of Craig Lake to illustrate how the equations in Table 10 may be used to predict fish standing crop.

Craig Lake has a fish population typical of southern Michigan lakes. The bluegill is the predominant species. Largemouth bass, northern pike (Esox lucius), yellow perch, and a variety of other species are well represented. Fish grow at average rates and fishing could be called good or average. Therefore I would classify this population as "normal." The total standing crop of fish in Craig Lake may be predicted best from equation 4:

$$\begin{aligned}\log_{10} \text{Crop} = & -11.081 - 0.036 \text{ alkalinity } - 0.001 \text{ area} \\ & -0.070 \text{ depth } + 9.698 \log_{10} \text{depth } + 8.192 \\ & \log_{10} \text{index}\end{aligned}$$

Substituting data for Craig Lake found in Table 8:

$$\begin{aligned}\log \text{Crop} = & -11.081 - 0.036\ (165) - 0.001\ (122) - 0.070 \\ & (8.4) + 9.698\ (0.92428) + 8.192\ (1.29226) \\ & = 1.81886\end{aligned}$$

Standing Crop = 66 pounds per acre.

If equation 1 had been used instead, the predicted crop would have been 59 pounds per acre. Both predictions are lower than the adjusted estimate of 300 pounds per acre and lower than I expected intuitively.

Discussion

A number of other attempts have been made to relate the standing crop of fish to the physical characteristics of lakes. Using some of the same data from Michigan which I used, Ball (1948a) also described fish crops in relation to the alkalinity of the water and whether or not the lake was suited for trout management. Carlander (1955) obtained statistically significant correlations between fish crops and methyl orange alkalinity for trout lakes, warmwater lakes and reservoirs throughout North America. Alkalinity, or associated factors, accounted for 28%, 41% and 69% of the variation in standing crop within these three groups of lakes, respectively.

Carlander also noted a weak negative relationship between fish crop and depth. Rawson (1952) and Hayes (1957), on the other hand, considered depth to be the most important physical factor. All three authors concluded that the negative relationship between fish productivity and area proposed by Rounsefell (1946) was in fact due to depth.

Northcote and Larkin (1956) in British Columbia, were the first to use multiple correlation techniques to test the statistical significance of two physical factors simultaneously. They concluded that total dissolved solids (T. D. S.) were much more important than depth in predicting "bio-index," their index of biological productivity based on estimates of standing crops of fish, benthos, and plankton. Their multiple regression using the logarithms of bio-index, T. D. S., and mean depth had an R^2 of 43%.

Selcher (1971) obtained a significant simple correlation between catch of fish per hour per net and the methyl orange alkalinity for 39 lakes in Pennsylvania. He also noted some correlation between catch and an index created by dividing alkalinity by mean depth. A similar index, the "morphoedaphic index" was first proposed by Ryder (1965). Ryder found that $\log_{10}$ of morphoedaphic index (total dissolved solids divided by mean depth) explained as much as 73% of the variation in $\log_{10}$ fish production (i.e., harvest) of 34 north-temperate lakes. The lakes analyzed by Ryder were all large, the smallest was 1 square mile in area. By comparison, the 64 lakes I analyzed were small, only 5 of them exceeded 200 acres. For my data, log index (total alkalinity divided by mean depth) alone was not a satisfactory predictor of the log of fish standing crop. The index accounted for only 20% of the variation in fish crop for all lakes and only 16% of the variation in fish crop among lakes with normal fish populations.

Jenkins (1967) used multiple correlation to relate the standing crop, and sport and commercial harvest of reservoirs to area, mean depth, T.D.S., storage ratio, shoreline development, age, water level fluctuation, outlet depth, growing season, and chemical type. These variables explained less than 50% of the variation in log standing crop or log harvest in most of his analyses. The logarithm of morphoedaphic index was the best single predictor of standing crop. In a linear equation it explained only 10% of the variation in log crop; however in a second-degree polynomial equation it accounted for 40% of the variation. By contrast, the fit of my data was not improved appreciably by a second-degree polynomial. When Jenkins added shoreline development and storage ratio into the first-degree equation, the amount of variability accounted for increased to 22%. Sport harvest was predicted best (20%) by total dissolved solids, shoreline development, growing season, age, and area. Commercial harvest was predicted best (37%) by mean depth, storage ratio, and age. It is difficult to interpret these results because no one variable was important in predicting all three measures of fish productivity. I encountered a similar problem in my analysis of Michigan fish crops in that no one variable was important in all types of fish populations.

From this review of the literature we can conclude that alkalinity, total dissolved solids, area, depth, and an index of alkalinity or T.D.S. divided by mean depth, are all related to fish standing crops or fish production. Shoreline development, age, and growing season are additional factors which seem to be important to reservoir fisheries. My analysis indicates that alkalinity, area, depth or alkalinity divided by mean depth alone are not strongly correlated with fish standing crop. Apparently, these parameters interact and all, or most of them, are needed for a good predictive equation.

In addition, the analysis can be improved by stratifying the data according to the type of fish population present. Fish populations dominated by slow-growing bluegills were distinctly larger than those where slow-growing yellow perch were the only sport fish. Normal populations, with intermediate standing crops, achieved a better balance between number of species and abundance. This allowed fuller use of the various trophic levels while allowing individual fish to grow at a normal rate. The analysis of poor and unusual fish populations was not as satisfactory due to the heterogeneity of fish species and populations included. The regression for poor and unusual fish populations was improved considerably by stratifying into lake types (R^2 of 77% for potential trout lakes, and 56% for lakes unsuited for trout).

Hayes and Anthony (1964) used a different method to adjust standing crop estimates for type of fish present. They computed a "productivity index," which was the ratio of the observed standing crop of fish of a given trophic level (short, medium, long food chains) divided by the average standing crop of fish in that trophic level as determined by Carlander (1955). When more than one productivity index could be computed for a given lake, the largest one was selected. In their multiple regression analysis, area, log of mean depth and log of methyl orange alkalinity explained 67% of the variation in log of productivity index. I considered using a similar approach with my data from Michigan, however, the assumptions involved with this method appear to be too formidable.

Although some of my multiple regressions appear to have high predictive value, they should be extrapolated to other lakes carefully. The number of lakes included in some strata was small relative to the number of variables included in the analysis, and the biological and statistical interpretation of these regressions was obscure. It should be pointed out also that the estimates of fish crops, and the adjustments made to them, were subject to large errors. Additional variability can be anticipated because, in general, standing crops of fish are not stable entities but fluctuate through time as weak and strong year classes move through the population. Natural fluctuations of three-fold and more magnitude have been observed (Beyerle, 1972; Schneider, 1972). Consequently, correlation of fish crops with physical parameters cannot be expected to be extremely high. The regressions in Table 10 are surprisingly good. Their accuracy and usefulness need to be tested with additional data.

Table 1. Summary of studies on the fish populations of lakes in Michigan

Lake	County	Date	Method[1]	Reference
Airport	Marquette	8/20/40	Treat	Ball (1948a)
Bear	Hillsdale	5/40-41	M & R	IFR (unpublished)
Belmont No. 1	Kent	10/65-69	Drain	Beyerle (1972)
Belmont No. 2	Kent	10-65-69	Drain	Beyerle (1972)
Belmont No. 3	Kent	10-68-69	Drain	Beyerle (1972)
Big Bear	Otsego	1940-46	M & R	Crowe (1953)
Booth	Otsego	9/6/37	Treat	Ball (1948a)
Burke	Clinton	9/1/42	Treat	Ball (1948a)
Cadillac	Wexford	6/47-48	M & R	Beckman (1949)
Cassidy	Washtenaw	6/64	M & R	Schneider (unpub.)
Cassidy	Washtenaw	9/66-68	M & R	Schneider (1972)
Center	Osceola	7/47	M & R	Taube (unpublished)
Clear	Alcona	8/26/37	Treat	Ball (1948a)
Craig	Branch	5/40-41	M & R	Beckman (1948)
Cub	Gogebic	1967	M & R	Clady (1970)
Daggett	Barry	10/2/62	Treat	Beyerle (unpub.)
Daggett	Barry	9/12/66	Treat	Beyerle (1971)
DeBruin's	Kalamazoo	5/27/41	Treat	Ball (1948a)
Deep	Oakland	9/12/41	Treat	Ball (1948a)
Devoe	Ogemaw	5/61	M & R	Patriarche (unpub.)
Dix Pond	Washtenaw	8/62	M & R	Westers (1963)
East Fish	Montmorency	8/25/41	Treat	Ball (1948a)
East Twin	Montmorency	6-8/39	M & R	Crowe (1940)
Emerald	Calhoun	9/13/68	Treat	Beyerle (1971)
Fife	Gr. Traverse	5/58	M & R	Christensen (1960)
Fife	Gr. Traverse	6/50	M & R	Cooper (1951)
Fitzek	Otsego	8/15/39	Treat	Ball (1948a)
Ford	Otsego	10/71	M & R	Laarman (unpub.)
Ford	Otsego	8/26/46	Treat	Ball (1948b)
Ford	Otsego	9/9/36	Treat	Ball (1948a)
Grebe	Ogemaw	5/66	M & R	Patriarche (1973)
Holland	Luce	9/10/41	Treat	Ball (1948a)
Howe	Crawford	9/7/37	Treat	Ball (1948a)
Jewett	Ogemaw	10/68-69	M & R	Schneider (1972)
Jewett	Ogemaw	4/58	M & R	Patriarche (1961)
Katherine	Gogebic	1967	M & R	Clady (1970)
Kimes No. 3	Newaygo	9/5/41	Treat	Ball (1948a)
Linnbeck	Menominee	9/11/40	Treat	Ball (1948a)
Lodge	Ogemaw	6/58	M & R	Patriarche (unpub.)
Lower Loch Alpine	Washtenaw	10/50	Drain	Lagler/DeRoth (1953)
Marsh	Gogebic	1967	M & R	Clady (1970)
Mill	Washtenaw	1965-69	M & R	Schneider (1971)
North Basin Twin	Oscoda	8/29/41	Treat	Krumholz (1944)

(continued, next page)

Table 1. (cont.)

Lake	County	Date	Method[1]	Reference
North Twin	Cheboygan	7/46	M & R	Crowe (1947)
O'Brian	Alcona	8/9/39	Treat	Ball (1948a)
Pike No. 4	Oscoda	8/6/39	Treat	Ball (1948a)
Pond No. 4	Otsego	8/15/39	Treat	Ball (1948a)
Pond No. 24	Van Buren	9/48	Drain	Taube (unpublished)
Rash Pond	Washtenaw	8/62	M & R	Westers (1963)
Sand No. 2	Gr. Traverse	10/71	M & R	Laarman (unpub.)
Sand No. 3	Gr. Traverse	10/71	M & R	Laarman (unpub.)
Sand No. 2	Gr. Traverse	5/20/69	Treat	Schneider (unpub.)
Sand No. 3	Gr. Traverse	5/20/69	Treat	Schneider (unpub.)
Scaup	Ogemaw	10/57	M & R	Patriarche (unpub.)
Section Four	Otsego	9/19/35	Treat	Eschmeyer (1938)
South Pond	Ogemaw	10/57	M & R	Patriarche (unpub.)
South Twin	Otsego	9/20/34	Treat	Eschmeyer (1938)
Sugarloaf	Washtenaw	1948-50	M & R	Cooper (1952)
Swanzy	Marquette	9/11/40	Treat	Ball (1948a)
Third Sister	Washtenaw	5/6/41	Treat	Ball (1948a)
Twin	Marquette	7/23/41	Treat	Ball (1948a)
Upper Loch Alpine	Washtenaw	10/51	Drain	Lagler/DeRoth(1953)
Walsh	Washtenaw	4/25/38	Treat	Ball (1948)
Whitmore	Washtenaw	5/53	M & R	Cooper/Schafer(1954)
Wintergreen	Kalamazoo	4-9/51	M & R	Fetterolf (1952)

[1] Treat = census of fish killed following chemical treatment.
Drain = census of fish by draining of reservoirs.
M & R = mark and recapture estimate.

Table 2. Estimates of the standing crop of fish (pounds per acre) in Michigan lakes, based on "complete" recovery of dead fish following chemical treatment.

(The upper figures were given by the source authors; the lower figures are adjusted estimates.)

Lake	Bass[1]	Rock bass	Blue-gill	Sun-fish[2]	Yellow perch	Pike, walleye	Minnows	Other fish	Total
Airport	...	...	...	...	14	...	...	1	15
	...	...	...	...	23	...	...	1	24
Booth	...	3	...	...	9	...	4	6	22
	...	6	...	...	15	...	7	10	36
Burke	9	...	22	2	...	...	...	27	60
	16	...	36	4	...	...	...	44	100
Clear	...	...	5	38	...	...	2	156	201
	...	...	...	...	...	...	...	...	...
Daggett	...	...	197	...	...	1	...	...	198
(1966)	...	...	...	...	...	...	...	...	...
Daggett	10	...	92	3	15	1	4	26	151
	...	...	...	...	...	...	...	...	...
DeBruin's	...	...	...	81	...	...	4	216	301
	...	...	...	...	...	...	...	...	...
Deep	7	2	17	5	1	...	...	6	38
	12	3	29	8	2	...	...	9	63
East Fish	...	...	...	...	19	...	2	9	30
	...	...	...	...	31	...	4	15	50
Emerald	...	...	158	...	...	1	...	...	159
	...	...	...	...	...	...	...	...	...
Fitzek[3]	4	6	...	...	5	...	3	1	19
	7	10	...	...	8	...	4	3	32
Ford	...	...	114	...	...	3	...	3	120
(1946)	...	...	194	...	...	5	...	5	204
Ford	...	...	...	...	35	...	16	1	52
(1936)	...	...	...	...	58	...	26	2	86
Holland	...	...	...	15	...	...	28	39	82
	...	...	...	25	...	...	46	66	137
Howe	12	...	...	2	1	...	tr	23	38
	19	...	...	3	2	...	1	38	63
Kimes	19	...	69	...	7	...	5	37	137
No. 3	32	...	116	...	12	...	8	60	228
Linnbeck	tr	1	...	3	7	...	13	5	29
	tr	2	...	4	11	...	21	10	48

(continued, next page)

Table 2 (cont.)

Lake	Bass[1]	Rock bass	Blue-gill	Sun-fish[2]	Yellow perch	Pike, walleye	Minnows	Other fish	Total
N. Basin	6	...	63	6	...	...	...	...	75
Twin	8	...	72	7	...	...	...	...	87
O'Brien[3]	tr	4	...	1	1	1	6	14	27
	tr	6	...	2	2	2	10	23	45
Pike No. 4	5	3	...	7	14	1	2	12	44
	8	5	...	11	24	2	3	20	73
Pond No. 4	8	26	...	...	18	...	16	45	113
	...	...	...	...	...	...	...	...	...
Sand No. 2	...	...	...	...	8	...	9	...	17
(1969)[4]	...	...	...	...	13	...	15	...	28
Sand No. 3	...	...	44	...	tr	...	...	...	44
(1969)[4]	...	...	73	...	...	...	...	...	73
Section	...	...	...	...	28	...	...	...	28
Four[3]	...	...	...	...	47	...	...	...	47
South	...	...	...	...	35	...	...	...	35
Twin[3]	...	...	...	...	58	...	...	...	58
Swanzy	3	...	2	...	25	...	1	...	31
	6	...	3	...	41	...	2	...	52
Third	13	...	54	3	...	...	3	14	87
Sister	22	...	90	5	...	...	5	23	145
Twin	3	...	...	...	6	...	1	...	10
	5	...	...	...	10	...	2	...	17
Walsh[3]	15	...	57	3	2	...	1	14	92
	25	...	95	5	3	...	1	24	153

[1] Includes largemouth and smallmouth bass.

[2] Includes pumpkinseed and hybrid Lepomis.

[3] A few fish may have survived treatment.

[4] Total kill estimated from partial counts.

Table 3. Estimates of the standing crop of fish (pounds per acre) in Michigan reservoirs, derived from complete recovery of fish at draining.

Lake	Bass[1]	Rock bass	Blue-gill	Sun-fish[2]	Yellow perch	Pike, walleye	Minnows	Other fish	Total
Belmont No. 1	...	...	305	...	...	...	...	...	305
Belmont No. 2	...	...	239	...	...	...	...	...	239
Belmont No. 3	...	...	233	...	...	...	...	...	233
Lower Loch Alpine	30	11	...	51	...	...	...	98	190
Pond No. 24	42	...	77	22	6	2	...	35	184
Upper Loch Alpine	12	24	...	52	...	...	...	213	301

[1] Includes largemouth and smallmouth bass.

[2] Includes pumpkinseed and hybrid *Lepomis*.

Table 4. Estimates of the standing crop of fish (pounds per acre) in Michigan lakes, based on the mark-and-recapture technique.

(The upper figures were given by the source authors; the lower figures are adjusted estimates.)

Lake	Bass[1]	Rock bass	Blue-gill	Sun-fish[2]	Yellow perch	Pike, walleye	Minnows	Other fish	Total
Cassidy	...	...	...	...	35	...	...	...	35
(1966-68)	...	...	...	...	...	...	...	...	...
Cassidy[2]	...	...	...	...	...	...	...	...	...
(1964)	10	tr	67	14	24	...	...	30	145
Center[3]	...	...	...	...	...	...	...	...	...
	6	tr	255	12	11	tr	...	tr	284
Cub	30	...	...	...	10	...	...	22	62
	...	...	...	...	...	...	...	...	...
Devoe[3]	...	...	...	...	...	...	...	...	...
	1	1	1	tr	4	tr	...	50	57
Dix Pond[3]	...	...	...	...	...	...	...	...	...
	128	...	...	...	...	...	...	...	128
East	2	tr	...	1	...	6	...	3	12
Twin[5]	3	1	...	4	20	12	2	6	48
Fife[4]	17	2	23	6	...	...	...	14	62
(1950)	18	4	37	11	9	...	...	16	95
Ford	...	...	1	39	...	...	...	...	40
(1971)	...	...	...	...	...	...	...	...	...
Grebe[3]	...	...	...	...	...	...	...	...	...
	...	...	...	...	43	32	...	117	192
Jewett	...	...	...	...	62	...	...	...	62
(1969)	...	...	...	...	...	...	...	...	...
Jewett	14	1	32	2	1	...	...	11	61
(1958)	17	1	60	3	3	...	...	16	100
Katherine	10	...	...	...	...	...	...	...	10
	...	...	...	...	...	...	...	...	...
Lodge[3]	...	...	...	...	...	...	...	...	...
	8	1	56	25	3	...	...	28	121
Marsh	5	...	...	...	47	...	...	...	52
	...	...	...	...	...	...	...	...	...
Mill	10	...	44	12	14	7	...	...	87
	12	1	44	12	14	9	3	21	116
North	1	...	2	12	...	...	...	1	16
Twin	2	...	4	24	5	...	...	1	36

(continued, next page)

Table 4 (cont.)

Lake	Bass[1]	Rock bass	Blue-gill	Sun-fish[2]	Yellow perch	Pike, walleye	Minnows	Other fish	Total
Rash Pond[3]	...	...	...	...	...	...	...	...	...
	96	...	...	...	...	...	...	...	96
Sand No. 2	...	...	1	11	...	...	...	...	12
(1971)	...	...	...	...	...	...	...	...	...
Sand No. 3	...	...	241	...	...	...	...	2	243
(1971)	...	...	...	...	...	...	...	...	...
Scaup[3]	...	...	...	...	...	...	...	...	...
	6	...	3	5	3	3	...	25	45
South Pond[3]	...	...	...	...	...	...	...	...	...
	3	2	45	2	3	...	...	3	58
Sugarloaf	7	1	19	1	...	2	...	13	43
	8	3	31	3	30	2	...	18	95
Whitmore	8	tr	10	1	...	2	...	14	35
	9	1	16	1	10	3	...	17	57
Wintergreen	48	...	149	39	19	...	...	9	264
	60	...	200	52	32	...	5	11	360

[1] Includes largemouth and smallmouth bass.

[2] Includes pumpkinseed and hybrid Lepomis.

[3] The source author did not give standing crop. I computed an adjusted estimate from the data.

[4] Fish estimates were adjusted for revision of the estimated area of the lake from 575 to 619 acres in 1954.

[5] Fish estimates were adjusted for revision of the estimated area of the lake from 974 to 830 acres in 1960.

Table 5. Mark-and-recapture estimates of the number of larger-sized fish per acre, and approximate estimates of total pounds per acre, in studies where the source author did not give data on fish weights or lengths.

Lake	Number per acre								Lb/ acre total crop
	Bass[1]	Rock bass	Blue-gill	Sun-[2] fish	Yellow perch	Pike, walleye	Minnows	Other fish	
Bear	10	1	142	7	...	...	...	...	90
Big Bear	8	5	4	7	...	...	...	22	100
Cadillac	1	1	3	1	3	5	...	3	25
Craig	33	...	411	8	...	...	...	9	300
Fife(1958)	7	17	26	...	...	6	...	6	80

[1] Includes largemouth and smallmouth bass.

[2] Includes pumpkinseed and hybrid _Lepomis_.

Table 6. Physical characteristics and fish standing crops (pounds per acre) in lakes in which slow-growing yellow perch were the only sport fish present.

Lake	Lake type	DNR region[1]	Alkalinity (ppm)	Area (acres)	Mean depth (feet)	Alk. / Mean depth	Pounds per acre
Airport	trout	1	5	6.8	10.5	0.5	25
Cassidy (1966-68)	bass	3	127	46.2	3.7	34.3	35
Ford (1936)	trout	2	127	10.7	9.0	14.1	73
Jewett (1969)	bass	2	33	12.9	7.5	4.4	62
Sand No. 2 (1969)	bass	2	71	17.3	9.9	7.2	28
Section Four	trout	2	149	2.7	29.6	5.0	47
South Twin	trout	2	105	4.3	17.8	5.9	58
Average							46

[1] DNR Region: Designated geographical areas of Department of Natural Resources. Region 1 is the upper peninsula of Michigan, Region 2 is approximately the northern half of the lower peninsula, and Region 3 is the southern half.

Table 7. Physical characteristics and fish standing crops (pounds per acre) in lakes dominated by slow-growing bluegills.

Lake	Lake type	DNR region[1]	Alkalinity (ppm)	Area (acres)	Mean depth (feet)	Alk./ Mean depth	Pounds per acre
Belmont No. 1	bass	3	212	4.4	3.9	54.4	305
Belmont No. 2	bass	3	216	6.4	4.9	44.1	239
Belmont No. 3	bass	3	208	2.5	4.9	42.4	233
Burke	trout	3	175	1.8	24.4	7.2	100
Center	trout	2	2	38.8	20.5	0.1	284
Daggett (1962)	bass	3	16	15.0	7.4	2.2	151
(1966)	bass	3	16	15.0	7.4	2.2	198
Emerald	bass	3	114	5.6	6.0	19.0	159
Ford (1946)	trout	2	127	10.7	9.0	14.1	204
Jewett (1958)	bass	2	33	12.9	7.5	4.4	100
Mill	bass	3	140	136.0	5.3	26.4	116
Sand No. 3 (1969)	bass	2	55	14.9	5.2	10.6	73
Average							182

[1] See Table 6.

Table 8. Physical characteristics and fish standing crops (pounds per acre) in lakes with "normal" fish populations.

Lake	Lake type	DNR region[1]	Alkalinity (ppm)	Area (acres)	Mean depth (feet)	Alk. / Mean depth	Pounds per acre
Bear	bass	3	150	117.0	15.1	9.9	90
Cadillac	bass	2	64	1150.0	11.0	5.8	25
Cassidy (1964)	bass	3	127	46.2	3.7	34.3	145
Craig	bass	3	165	122.0	8.4	19.6	300
Deep	trout	3	84	14.8	26.7	3.1	63
Fife (1950)	bass	2	108	619.0	14.7	7.3	80
Howe	bass	2	51	13.4	10.8	4.7	63
South Pond	bass	2	168	1.3	7.9	21.3	58
Sugarloaf	bass	3	115	180.0	3.4	33.8	95
Third Sister	bass	3	95	10.0	23.2	4.1	145
Walsh	bass	3	145	10.2	11.0	13.2	153
Whitmore	bass	3	106	677.0	14.1	7.5	57
Winter-green	bass	3	169	39.3	7.6	22.3	360
Average (excluding Wintergreen and Craig)							88

[1] See Table 6.

Table 9. Physical characteristics and fish standing crops (pounds per acre) in lakes with "poor" or "unusual" fish populations.

Lake	Lake type	DNR region[1]	Alkalinity (ppm)	Area (acres)	Mean depth (feet)	Alk. / Mean depth	Pounds per acre
Big Bear	bass	2	45	362.0	14.6	3.1	100
Booth	bass	2	125	16.0	13.6	9.2	37
Clear	bass	2	165	11.3	4.1	40.2	195
Cub	bass	1	10	28.0	10.8	0.9	62
DeBruin's	bass	3	--	0.8	4.5	--	301
Devoe	trout	2	198	130.0	21.7	9.1	57
Dix Pond	bass	3	172	1.2	5.5	31.3	128
East Fish	trout	2	190	13.5	20.6	9.2	50
East Twin	bass	2	--	830.0	6.7	--	48
Fitzek	trout	2	180	6.2	27.4	6.6	32
Ford (1971)	trout	2	127	10.2	9.0	14.1	40
Grebe	bass	2	73	72.5	6.0	12.2	192
Holland	trout	1	18	5.3	11.0	1.6	137
Katherine	bass	1	3	48.0	14.1	0.2	10
Kimes No. 3	trout	2	102	6.8	8.6	11.9	228
Linnbeck	trout	1	211	5.1	11.7	18.0	48
Lodge	bass	2	97	17.2	6.7	14.5	121
Lower Loch Alpine	bass	3	210	12.5	5.6	37.5	190
Marsh	bass	1	6	65.0	16.8	0.4	52
No. Basin Twin	bass	2	76	7.8	15.4	4.9	87
North Twin	bass	2	54	27.1	5.1	10.6	36
O'Brien	trout	2	172	10.4	19.2	9.0	45
Pike No. 4	trout	2	148	4.6	12.0	12.3	73
Pond No. 4	trout	2	183	1.6	3.4	53.8	113
Pond No. 24	bass	3	165	33.7	4.3	38.4	184

(continued, next page)

Table 9 (cont.)

Lake	Lake type	DNR region[1]	Alaklinity (ppm)	Area (acres)	Mean depth (feet)	Alk. / Mean depth	Pounds per acre
Rash Pond	bass	3	202	0.2	3.9	51.8	96
Sand No. 2 (1971)	bass	2	71	17.3	9.9	7.2	12
Sand No. 3 (1971)	bass	2	55	14.9	5.2	10.6	241
Scaup	bass	2	121	5.8	6.6	18.3	45
Swanzy	trout	1	15	20.3	17.1	0.9	52
Twin	trout	1	5	21.5	30.8	0.2	17
Upper Loch Alpine	bass	3	178	10.9	5.4	33.0	301
Average							104

[1] See Table 6.

Table 10. Summary of multiple regression analyses, stratified by type of fish population and lake, of $\log_{10}$ fish standing crop on alkalinity, area, mean depth, alkalinity divided by mean depth (index), and $\log_{10}$ of each of these variables.

Factors in analysis	All populations		
	All lakes	Trout lakes	Bass lakes
Sample size	61	21	40
R^2: All variables	0.253	0.429	0.373
Best variables	0.205	0.402	0.344
Regression coefficients for the best equations:			
Constant	1.749	2.654	4.291
Alkalinity			0.007
Area			
Depth			0.098
Index	0.010		-0.026
Log alkalinity		9.348	-3.684
Log area			
Log depth		-9.891	
Log index		-9.549	3.404
Equation number	1	2	3

Factors in analysis	Normal populations	Stunted populations	
		Perch	Bluegill
Sample size	11	7	12
R^2: All variables	0.925	0.999*	0.964
Best variables	0.910	0.999	0.950
Regression coefficients for the best equations:			
Constant	-11.081	4.214	2.024
Alkalinity	-0.036		
Area	-0.001	-0.011	
Depth	-0.070		
Index			
Log alkalinity		15.767	-71.236
Log area		-0.932	-0.142
Log depth	9.698	-17.315	70.886
Log index	8.192	-15.597	71.670
Equation number	4	5	6

Factors in analysis	Poor populations		
	All lakes	Trout lakes	Bass lakes
Sample size	31	13	18
R^2: All variables	0.438	0.769	0.561
Best variables	0.382	0.711	0.492
Regression coefficients for the best equations:			
Constant	1.651	4.008	2.336
Alkalinity	-0.002		
Area		0.008	
Depth			
Index		-0.022	
Log alkalinity			-7.743
Log area		-0.631	0.101
Log depth		-1.312	6.830
Log index	0.514		7.961
Equation number	7	8	9

* All 8 variables could not be analyzed simultaneously because there were only 7 samples.

Table 11.--Adjusted and predicted estimates of the total standing crop of fish, in pounds per acre, in lakes used in the present multiple regression analyses

Lake class, Lake name	Adjusted (Tables 2-5)	Predicted by equations in Table 10			
		Best[1]	No. 3	No. 2	No. 1
Normal, all lakes		No. 4			
Bear	90	80	103	...	72
Cadillac	25	21	44	...	64
Cassidy	145	121	152	...	128
Deep	63	70	...	69	60
Fife	80	78	63	...	67
Howe	63	67	41	...	63
South Pond	58	67	123	...	94
Sugarloaf	95	108	163	...	127
Third Sister	145	124	95	...	62
Walsh	153	137	92	...	77
Whitmore	57	77	62	...	67
Stunted perch, all lakes		No. 5			
Airport	25	25	...	91	57
Cassidy (1966-68)	35	35	152	...	128
Ford (1936)	73	73	...	81	78
Jewett (1969)	62	62	57	...	62
Sand No. 2 (1969)	28	28	51	...	67
Section Four	47	47	...	55	63
South Twin	58	58	...	66	65
Stunted bluegills, all lakes		No. 6			
Belmont No. 1	305	301	148	...	208
Belmont No. 2	239	247	169	...	162
Belmont No. 3	233	213	164	...	156
Burke	100	101	...	51	67
Center	284	280	...	110	56
Daggett (1966)	198	175	65	...	59
Daggett (1962)	151	175	65	...	59
Emerald	159	130	103	...	89
Ford (1946)	204	198	...	81	78
Jewett (1958)	100	106	57	...	62
Mill	116	133	126	...	106
Sand No. 3 (1969)	73	67	104	...	72

(continued, next page)

Table 11.--concluded.

Lake class, Lake name	Adjusted (Tables 2-5)	Predicted by equations in Table 10 Best[1]	No. 3	No. 2	No. 1
Poor, trout lakes		No. 8			
Devoe	57	56	...	56	70
East Fish	50	30	...	57	70
Fitzek	32	34	...	49	66
Ford (1971)	40	79	...	81	79
Holland	137	156	...	137	58
Kimes No. 3	228	113	...	82	75
Linnbeck	48	65	...	67	87
North Basin Twin	87	70	...	79	63
O'Brien	45	37	...	56	70
Pike No. 4	73	88	...	72	75
Pond No. 4	113	109	...	104	205
Swanzy	52	50	...	77	57
Twin	17	24	...	14	56
Poor, bass lakes		No. 9			
Big Bear	100	46	37	...	60
Booth	37	43	76	...	70
Clear	195	170	146	...	147
Cub	62	27	37	...	57
Dix	128	99	142	...	119
East Twin	48	115	69	...	67
Grebe	192	115	87	...	75
Katherine	10	13	36	...	56
Lodge	121	92	85	...	80
Lower Loch Alpine	190	128	170	...	138
Marsh	52	50	57	...	57
North Twin	36	116	106	...	72
Pond No. 24	184	183	146	...	142
Rash	96	126	147	...	195
Sand No. 2 (1971)	12	57	51	...	67
Sand No. 3 (1971)	241	108	104	...	72
Scaup	45	86	98	...	87
Upper Loch Alpine	301	128	146	...	124

[1] By equation number indicated for each lake class.

Literature cited

Ball, Robert C. 1948a. A summary of experiments in Michigan lakes on the elimination of fish populations with rotenone, 1934-1942. Trans. Amer. Fish. Soc., 75(1945): 139-146.

Ball, Robert C. 1948b. Recovery of marked fish following a second poisoning of the population in Ford Lake, Michigan. Trans. Amer. Fish. Soc., 75(1945): 36-42.

Beckman, William C. 1948. The Craig Lake population investigation for the summer of 1947. Mich. Dep. Conserv., Inst. Fish. Res., Rep. No. 1160, 10 p.

Beckman, William C. 1949. Population studies during 1948. Mich. Dep. Conserv., Inst. Fish. Res., Rep. No. 1229, 9 p.

Beyerle, George B. 1971. A study of two northern pike-bluegill populations. Trans. Amer. Fish. Soc., 100(1): 69-73.

Beyerle, George B., and John E. Williams. 1972. Survival, growth, and production by bluegills subjected to population reduction in ponds. Mich. Dep. Nat. Res., Res. Develop. Rep. No. 273, 28 p.

Carlander, Kenneth D. 1955. The standing crop of fish in lakes. J. Fish. Res. Bd. Canada, 12(4): 543-570.

Carlander, Kenneth D., and William M. Lewis. 1948. Some precautions in estimating fish populations. Prog. Fish-Cult., 10(3): 134-137.

Clady, Michael D. 1970. Regulation of fish populations in three lightly exploited lakes in northern Michigan. PhD thesis, Univ. Mich., Ann Arbor, 86 p.

Cooper, Gerald P. 1952. Estimation of fish populations in Michigan lakes. Trans. Amer. Fish. Soc., 81(1951): 4-16.

Cooper, Gerald P., and Robert N. Schafer. 1954. Studies on the population of legal-size fish in Whitmore Lake, Washtenaw and Livingston counties, Michigan. Trans. 19th N. Amer. Wildl. Conf.: 239-259.

Crowe, Walter R. 1940. Population analysis of East Twin Lake. Mich. Dep. Conserv., Inst. Fish. Res., Rep. No. 590, 10 p.

Crowe, Walter R. 1947. A fish population analysis of North Twin Lake, Cheboygan County. Mich. Dep. Conserv., Inst. Fish. Res., Rep. No. 1090, 9 p.

Crowe, Walter R. 1953. An analysis of the fish population of Big Bear Lake, Otsego County, Michigan. Pap. Mich. Acad. Sci., 38(1952): 187-207.

Crowe, Walter R. 1956. Fish population reconnaissance of Hamlin Lake, Mason County, Michigan. Mich. Dep. Conserv., Inst. Fish. Res., Rep. No. 1490, 13 p.

Eschmeyer, R. W. 1938. The significance of fish population studies in lake management. Mich. Dep. Conserv., Inst. Fish. Res., Rep. No. 452, 18 p.

Fetterolf, Carlos de la Mesa, Jr. 1952. A population study of the fishes of Wintergreen Lake, Kalamazoo County, Michigan: with notes on movement and effect of netting on condition. MS thesis, Dep. Zool., Mich. State Univ., East Lansing, 127 p.

Hayes, F. R. 1957. On the variation in bottom fauna and fish yield in relation to trophic level and lake dimensions. J. Fish. Res. Bd. Canada, 14(1): 1-32.

Hayes, F. R., and E. H. Anthony. 1964. Productive capacity of North American lakes as related to the quantity and the trophic level of fish, the lake dimensions, and the water chemistry. Trans. Amer. Fish. Soc., 93(1): 53-57.

Jenkins, Robert M. 1967. The influence of some environmental factors on standing crop and harvest of fishes in U. S. reservoirs, p. 298-321. In Reservoir Comm. Southern Div. Amer. Fish. Soc.

Krumholz, Louis A. 1944. A check on the fin-clipping method for estimating fish populations. Pap. Mich. Acad. Sci., 29(1943): 281-291.

Krumholz, Louis A. 1950. Some practical considerations in the use of rotenone in fisheries research. J. Wildl. Mgmt., 14(4): 413-424.

Lagler, Karl F., and Gerardus C. DeRoth. 1953. Populations and yield to anglers in a fishery for largemouth bass, Micropterus salmoides (Lacepede). Pap. Mich. Acad. Sci., 38(1952): 235-253.

Moorman, Robert B., and C. E. Ruhr. 1951. Suggestions for improving the collection of fish with rotenone. Prog. Fish-Cult., 13(3): 149-152.

Parker, Richard O. Jr. 1970. Surfacing of dead fish following application of rotenone. Trans. Amer. Fish. Soc., 99(4): 805-807.

Patriarche, Mercer H. 1961. An appraisal of methods for estimating the fish population of a lake. Mich. Dep. Conserv., Inst. Fish. Res., Rep. No. 1631, 23 p.

Patriarche, Mercer H. 1973. Final report on the controlled harvest of pike. Mich. Dingell-Johnson Proj. F-29-R-6, Study II.

Rawson, D. S. 1952. Mean depth and the fish production of large lakes. Ecology, 33: 513-521.

Rounsefell, George A. 1946. Fish production in lakes as a guide for estimating production in proposed reservoirs. Copeia, 1946(1): 29-40.

Ryder, R. A. 1965. A method for estimating the potential fish production of north-temperate lakes. Trans. Amer. Fish. Soc., 94(3): 214-218.

Rupp, Robert S., and Stuart E. DeRoche. 1965. Standing crops of fishes in three small lakes compared with C^{14} estimates of net primary productivity. Trans. Amer. Fish. Soc., 94(1): 9-25.

Schneider, James C. 1971. Characteristics of a population of warm-water fish in a southern Michigan lake, 1964-1969. Mich. Dep. Nat. Res., Res. Devel. Rep. No. 236, 158 p.

Schneider, James C. 1972. Dynamics of yellow perch in single-species lakes. Mich. Dep. Nat. Res., Res. Devel. Rep. No. 184, 47 p.

Scott, John A. 1961. Summary of lake and stream reclamation projects completed by the Lake and Stream Improvement Section, Fish Division, 1947-1961. Mich. Dep. Conserv., unpublished rep. Dec. 1961, 10 p.

Selcher, John William. 1971. Statistical modeling for prediction of growth rates of Pennsylvania fishes using selected physical, chemical, and biological indices. MS thesis, Dep. Fish., Univ. Mich., Ann Arbor, 71 p.

Taube, Clarence M., Kiyoshi G. Fukano, and Frank F. Hooper. 1954. Further studies on the use of fish poisons in Michigan lakes. Mich. Dep. Conserv., Inst. Fish. Res., Rep. No. 1414, 29 p.

Westers, Harmannus. 1963. An evaluation of population estimate procedures in two ponds, containing only largemouth bass (Micropterus salmoides). MS thesis, Dep. Fish., Univ. Mich., Ann Arbor, 55 p.

Report approved by G. P. Cooper

Report typed by M. S. McClure and
B. A. Lowell