MICHIGAN DEPARTMENT OF NATURAL RESOURCES
FISHERIES DIVISION

Fisheries Research Report No. 1818

December 26, 1974

FISHING REGULATIONS FOR LARGEMOUTH BASS IN MICHIGAN [1]

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ABSTRACT

Fishing regulations for largemouth bass in Michigan were analyzed in Ricker's yield equation and with a review of previous fishing experiments from within the state and nationwide. Average rates for Michigan of growth, mortality, exploitation and reproduction were used in the equation. For the average rate of exploitation of 35%, the greatest harvest, in weight, occurs at a minimum size of 10 inches. However with an increase in exploitation, the greatest harvest occurs at a 12-inch minimum size. The difference in yield between 10 and 12 inches in minimum size is small, but the increase in biomass at the higher size limit is great. Although the relationship between spawning stock and progeny is not known, it seems prudent to protect the biomass of adults 12 inches and larger if exploitation is increasing. The increase in biomass with the increased size limit is unlikely to have any measurable effect on associated populations of sunfishes. In terms of numbers the increase in the minimum size to 12 inches will reduce the catch considerably. The creel limit is essentially ineffective as a regulation to limit the catch or to insure a more even distribution among anglers. A closed season in the spring has the potential for limiting the catch, as does the minimum size limit. At present a 12-inch minimum size limit, combined with the existing 5-fish creel limit and a fishing season which is open from the Saturday immediately preceding Memorial Day to December 31, seem to be appropriate fishing regulations.

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[1] Contribution from Dingell-Johnson Project F-35-R, Michigan.

Introduction

In the late 1940's there was a trend towards the liberalization of fishing regulations for largemouth bass (Micropterus salmoides) by the removal of size limits, closed seasons and sometimes creel limits (Pelton, 1950; Churchill, 1957; Mraz and Threinen, 1957; Mraz, 1964). By 1967, 35 states permitted year-round fishing without length limits for bass, with only three states eliminating the creel restrictions (Stroud and Martin, 1968). However, in the last year or two there have been publications suggesting overexploitation of largemouth bass in some waters and proposing more restrictive regulations (Clady, 1970; Rawstron and Hashagen, 1972; von Geldern, 1972; Anderson, 1973; Rawstron and Reaves, 1974). The following is an analysis of the largemouth bass in Michigan with regard to average growth, mortality, exploitation and reproduction, with the objective of deciding whether more restrictive fishing regulations are needed.

The largemouth bass is one of the larger members of the sunfish family Centrarchidae. It prefers the warm, quiet, sometimes weedy waters of lakes and impoundments. Like all sunfish the male in the spring fans a shallow depression in the lake bottom for the deposition of the eggs by the female. The eggs and then the resulting fry are guarded by the male for several days, until the brood begins to disperse throughout the lake. In southern Michigan spawning takes place from early May through mid-June (Carbine, 1948), while in the Upper Peninsula spawning occurs from late May until late June (Clady, 1973, personal communication). Nest building begins as the water temperature reaches 60 F. Young bass eat zooplankton and small insects, until they become about 2 inches long at which length fish enter their diet. Adult bass eat larger insects, fish, crayfish and frogs.

In Michigan the largest angler-caught bass on record weighed 11 pounds, 15 ounces, but a fish 6 to 8 pounds in size is noteworthy. Seldom do Michigan bass live longer than 10 years.

Population parameters

Ricker's (1958) yield equation provides a method of judging yield to the angler under different minimum size limits. The equation requires information on growth, and natural and fishing mortality rates. For an analysis to be relevant over an area as large as the state of Michigan, average rates are necessary. In addition, some attempt should be made to relate yield to fecundity, recruitment and standing crop.

Growth

In 1963, Laarman compiled all available growth data for largemouth bass in Michigan. Average growth for each age group during the months January-April, May, June, July, August, September, October-December was calculated. I fitted a line by eye to the plotted points of average growth for the monthly periods (Fig. 1). Growth in the largemouth bass has a distinct seasonal pattern, with most of the increase taking place in June through September. In the older age groups the growth points are quite variable probably because the samples are small, but presumably the seasonal growth pattern continues into the latter years. Average total length in inches for each age group of life in June and December was read from the graph in Figure 1 and used in the yield calculations (Table 1). The weight, W, in pounds to the nearest hundredth, for each average length, L, in inches to the nearest tenth, was calculated from the length-weight equation (Laarman, 1974, personal communication):

$$\text{Log } W = -3.43212 + 3.12735 \text{ Log } L$$

Mortality

The percentage decrease in largemouth bass populations from fishing and natural, or unaccounted for losses, is summarized in Table 2. Natural losses have varied nationwide from 5 to 56%. Rates of exploitation or percentage decreases attributed to fishing have varied from 8 to 65%.

Values measured in Michigan waters, although not so high as those from California, agree in general with the nationwide figures. The estimates of natural mortality in most cases apply to all bass in the population 7 to 8 inches and larger. However there are four recent studies in which the authors have estimated natural mortality by age group (Table 3). Two of these were in Michigan, one in Oklahoma, and one in Illinois. In each study (most consisted of more than one year of observation) the natural mortality was greater during the very early and the last years of life of the bass. For the yield equation I adapted Schneider's (1971) figures for the bass of Mill Lake in southern Michigan, supplemented with Clady's (1970) mortality estimates for bass of Cub Lake in the northern Upper Peninsula of Michigan. In Mill Lake the estimates of natural mortality were made in the absence of fishing; in Cub Lake no fishing was permitted, so Clady harvested with nets. The annual value of $\underline{n}$ (natural mortality rate, Ricker, 1958) used, for each age group, was: 0, 0.68; I, 0.68; II, 0.36; III, 0.33; IV, 0.33; V, 0.33; VI, 0.48; VII, 0.55; VIII, 0.58; IX, 0.58; X, 0.58.

The fishing season for largemouth bass in Michigan extends from the Saturday in May immediately preceding Memorial Day to December 31, or essentially June through December. The yield equation was therefore developed for June-December and January-May intervals for growth and mortality. Although seasonal growth estimates were available (Fig. 1), there was nothing comparable for mortality rates, so mortality was proportioned to match growth for the two intervals, June-December and January-May of each year of life (Table 1). It was assumed that most of the natural mortality occurred during the growing season rather than the winter. The fishing season at present approximates the growing season.

The rate of exploitation, $\underline{u}$, of 0.35 calculated for largemouth bass in Sugarloaf Lake (Cooper and Latta, 1954) was chosen as being most typical for Michigan. Schneider (1971) estimated average annual natural mortality, $\underline{n}$, in the absence of fishing, for legal size (10 inches and larger) largemouth, to be 0.41 in Mill Lake. Mill and Sugarloaf lakes are located near each other in southeastern Michigan. Both are about 150 acres in size and shallow; they contain typical warmwater fish populations consisting of various sunfishes, perch, pike, and minnows. Using the rate of exploitation, u, and the natural mortality rate, n, an instantaneous rate of fishing, p, of 0.581 was calculated. This value was used as the fishing rate for each age group in the fishery in the model (Table 1). With seasonal and age-specific variations in the natural mortality rate, the rate of exploitation for each age group was as follows: age-group III and IV--0.38, V--0.37, VI--0.34, VII--0.32, and VIII, IX, X--0.31.

Fecundity

Although the largemouth bass is a common, much studied species, there appears to be a lack of specific information on the age and size of bass at maturity. In Michigan, Clady (1970) recorded that females mature at age 4 or 10 inches in length. The bass that Clady studied grew very slowly, and it would not be surprising to find bass with more average growth rates maturing at a larger size. In some other states bass have been reported maturing at a size of 11.5 to 12.0 inches (Table 4).

In the largemouth bass, as in all sunfishes, it is difficult to recognize mature ova in the ovaries because they are in various stages of development. Kelley (1962) provided the most exacting estimates of fecundity for bass by using a size-frequency distribution of ova. Only two other substantial counts of eggs are available, those of Vessel and Eddy (1941) for bass in Minnesota, and of Clady (1970) in Michigan. In Figure 2 number of eggs is plotted against total length of the bass for each of these studies. A log transformation of both number of eggs and length in inches provided the best regression; log number of eggs = 2.1168 + 1.9600 log total length. The relationship between number of eggs and length was slightly less variable than between number of eggs and weight. With this relationship a 12.0-inch female largemouth bass would carry about 17,000 mature eggs. Whether all mature eggs are deposited in nests during a spawning is not known. Clady (1970) found a 58 to 90% decrease between potential number of eggs to be deposited (those carried by females) and the number actually found in nests. Only 0.1 to 0.2% of the potential resulted in fall fingerlings.

Standing crop and harvest

Estimates of standing crop and harvest are needed for a complete review of bass population parameters. Schneider (1973a) has provided the most recent compilation of standing crop figures for fish in Michigan. Although he combines largemouth and smallmouth in his tables, an average of 9 pounds per acre for lakes treated with a toxicant seems reasonable for the largemouth in Michigan waters. Carlander (1955) found a mean of about 15 pounds per acre for lakes and reservoirs of the United States.

Harvest of largemouth bass in Michigan varies from about 1 to 8 pounds per acre, with a mean of 3.4 pounds (Table 5). During the late 1940's, the 1950's, and early 1960's in Michigan many fishing regulations were tested on a group of experimental lakes. In order to evaluate the results of different regulations a continuous census of the catch was conducted on each lake. K. E. Christensen was responsible for the tabulation of census data for most of the years and much of the information in Table 5 is from his records.

The few instances where both standing crop and harvest have been measured on the same lake in Michigan are given in Table 5. The standing crop estimates for Fife, Whitmore and Sugarloaf lakes are low because they are based on only legal size bass, i.e., those 10 inches and larger; but it appears that harvest is seldom greater than one-third the standing crop, judging from the averages (3.4 pounds per acre harvest for 9 pounds standing crop) and the individual observations.

Minimum size limits

Yield

The yield equation assumes a constant recruitment to the population and that changes in density of bass are not great enough to affect growth or mortality (Ricker, 1958). In this model, recruitment consists of 1,000 pounds of 0-age bass in December. In the example in Table 1 the bass enter the catch at a minimum size of about 10 inches in June of their fourth year of life (age-group III). Yield then for this steady state population is 3,137 pounds per 1,000 pounds of recruits. This calculation was repeated using Paulik and Bayliff's (1967) computer program, for the approximate minimum size limits of 8.0, 10.0, 12.0, 14.0, 16.0, and 18.0 inches, and for fishing rates, p, of 1/2, 1, 2, and 3 times the 0.581 value used in the example (Table 6). The rate of exploitation, as explained above, varies with age group, but overall is about 0.20 for 1/2 p, 0.35 for 1 p, 0.55 for 2 p, and 0.70 for 3 p. The actual minimum sizes in June, and the corresponding age groups at which bass will enter the fishery, are as follows: for the approximate minimum size of 8.0 inches the actual minimum size is 7.6 inches for age group II; for 10.0 inches, 10.1, age group III; 12.0 inches, 11.8, IV; 14.0 inches, 14.8, VI; 16.0 inches, 16.4, VII; and 18.0 inches, 18.4, IX.

The rate of exploitation, 0.35, used in the calculations was an average for the years 1948-1952 (Cooper and Latta, 1954). More recent estimates in California have placed the rate as high as 0.65 (but with a mean for 5 years of 0.55) (Rawstron and Hashagen, 1972). Doubling the fishing rate, p, in the model places the rate of exploitation as high as the mean observed in California, and tripling p takes the rate to an extreme of 0.70. A halving of p results in a rate of 0.20 which is close to the average of 0.24 measured by Patriarche on Jewett Lake, Michigan (Table 2), and the 0.22 reported by Cooper and Schafer (1954) for Whitmore Lake, Michigan. For a rate of exploitation of 0.35, a minimum size limit of 10.0 inches yields the greatest weight (Table 6). A minimum size limit of 12.0 inches results in a slight decrease in poundage, and going to higher size limits results in increasingly greater drops in poundage. However if the rate of exploitation is as high as 0.55, then the maximum yield is obtained with a minimum size of 12.0 inches. For neither rate is the difference in weight very great. At the rate of 0.35, comparing the 10-inch minimum with the 12-inch, the weight decreases only from 3,137 to 2,990, or 5%; at the 0.55 rate the weight increases slightly from 3,590 to 3,675, or 2%.

The point at which a population in a steady state reaches its maximum biomass is called the critical size (Ricker, 1958). Largemouth bass in Michigan reach this point at age IV at a size of about 12 inches. The biomass without harvest, and with harvest at the 0.35 rate for the 10.0- and 12.0-inch minimum sizes, is plotted in Figure 3.

The biomass or standing crop remaining after harvest is of concern if the size of the spawning stock becomes critically low. It is also of concern if the bass is considered an effective predator, say on the bluegill (Lepomis macrochirus). And thirdly, the biomass is of concern if the fishery is being developed as a recreational catch-and-release activity. The biomass of bass in June, age III and older (or 10.0 inches and larger), for each minimum size and rate of exploitation proposed is given in Table 7. For a very small change in yield, the biomass or standing crop can change dramatically. In the present model at the 0.35 (1 p) rate of exploitation, increasing the size limit from 10.0 to 12.0 inches increases the biomass from 6,961 pounds to 9,977 pounds. This is a 43% increase in biomass for a 5% decrease in yield. Likewise at the 0.55 (2 p) rate of exploitation the increase in size limit increases the biomass 72% while the yield increases 2%.

In a sport fishery the numbers of fish as well as the weight should be considered. The yield (harvest) weights in Table 6 were converted to numbers by dividing yield for each age group by the mean weight for the June-December interval and then summing the results for all age groups. The yield in numbers was then tabulated for the size categories 8, 10, 12, 14, 16 and 18 inches and larger, for the rates of exploitation and minimum sizes considered previously (Table 8). A similar tabulation was made for the biomass in numbers in June of each year for bass 10, 12 and 16 inches and larger (Table 9). In this calculation the average weight in June of bass of each age group (starting with age III) was used to convert weight to numbers. The results for numbers differ from weight in that maximum yield decreases with an increase in minimum size for all rates of exploitation. An increase in the size limit from 10 to 12 inches at a rate of 0.35 (1 p) decreases the harvest by 33%, from 3,599 to 2,406; likewise at the rate of 0.55 (2 p) the harvest declines by 31%, from 4,784 to 3,290 (Table 8). For the biomass, an increase in the size limit from 10 to 12 inches at the 0.35 rate results in an increase in numbers of bass present in June from 9,750 to 12,594 or a 29% change; at the 0.55 rate the number of bass increases from 7,766 to 11,334, a 46% change (Table 9).

Commonly in discussions of size limits the question is asked: How many additional larger fish will be caught if the size limit is increased? The number varies with the fishing rate. For example, at the rate of 0.35 with a 10.0-inch size limit, the number of 12-inch and larger fish caught would be 1,345 (Table 8); however with an increase in the size limit to 12.0 inches the number of bass would increase to 2,406 (with the loss to harvest of 1,193 fish between 10 and 12 inches). But if there were a drop in the rate of exploitation (which commonly happens with more restrictive regulations) to 0.20 (1/2 p), the catch of bass 12 inches and larger would be only 1,608--only slightly greater than the original 1,345. In general there is an increase in the number of larger fish with an increase in the size limit. Saila (1958) also demonstrated this potential for increase in larger bass in the catch with an increase in size limits.

With the use of the yield equation the question of predictability or reliability always arises. How close to reality does the model come? The results from some past experiments with fishing regulations in Michigan permit an evaluation. In 1954-58 on Fife and Sugarloaf lakes the minimum size limit was 16 inches; for the previous 8 years the minimum size had been 10 inches (Table 5). On Sugarloaf Lake harvest decreased 61% under the higher size limit, from a mean of 6.4 pounds per acre to a mean of 2.5 pounds. According to the model, at a rate of exploitation of 0.35 (1 p), the yield per recruit should decrease from 3,137 at a 10-inch minimum size to 1,188 at a 16-inch minimum size or a 62% decrease (Table 6).

Although the predictability for Sugarloaf Lake is excellent, for Fife Lake it is nonexistent. On Fife Lake under a 16-inch size limit, the harvest stayed the same as under a 10-inch size limit. Only a few scale samples from the catch are available, but this lack of decrease in the yield is apparently the result of one or two strong year classes moving through the fishery.

In 1954-58 on Duck and Fine lakes the size limit was removed, and on both lakes the harvest increased slightly, 6% on Duck Lake and 12% on Fine (Table 5). According to the model a decrease in the size limit to 8 inches at a rate of exploitation of 0.35 should result in a decrease in yield of about 10% unless there was an increase in exploitation (Table 6). This certainly could have been the case with the liberalization of the regulation, and a slight gain in harvest is not surprising. Actually few bass as small as 8 inches long were kept, and interpolating at a higher rate of exploitation (2 p) at a 9-inch size limit would result in a value between 2,820 and 3,590, which would be slightly higher than the 3,137 yield expected under the standard 10-inch minimum and 0.35 (1 p) exploitation (Table 6). In this analysis the predictability of the model has been satisfactory in three out of four cases.

Recruitment

As stated earlier biomass affects recruitment, predation and catch-and-release fishing. Of these, recruitment is vital for population success. In the model I assume that recruitment is constant, although it is well known that many populations have variable recruitment. The relationship between spawning stock and size of the year class produced is unknown. Neither Bennett (1954) nor Johnson and McCrimmon (1967) found any relationship between numbers of adult bass and numbers of young produced. However Bennett suspected a negative relationship, i.e., a greater number of young when spawners were few in number.

It is well established that mortality is most compensatory during the first few weeks of life in fish populations (Ricker, 1954). It is assumed that largemouth bass would not be an exception and that when the number of young produced was small, mortality would be less, and when the number was great, the losses would be much more severe. However, since this relationship cannot as yet be quantified, it seems worthwhile to consider for the model an average, direct relationship between spawners and young.

Clady (1970) recorded a 0.1% survival in 1968 and 0.2% in 1969 of largemouth bass from estimated number of eggs carried by females, to fall fingerlings. I took the June biomass estimates in the model for each age group and converted them to numbers as described earlier. On the basis of Beckman's (1949) inspections of bass in Michigan, I assumed that half of the population were females. The number of eggs per female was calculated for each age group from the fecundity equation relating length of bass to number of eggs. The summation of the number of eggs for each age group was multiplied by the mean (0.15%) of Clady's survival values. The calculated number of fingerlings surviving to fall was then compared to number needed to equal the 1,000 pounds of age-0 bass in the model (Table 1). At an average weight of 0.03 pound, the number of age-0 December fingerling equals 33,333. Clady (1970) found female bass 10 inches and larger mature. In the model these would be age-III fish in June, but assuming a normal distribution of lengths, only half of them would be 10 inches or larger during the May-June spawning season; therefore only half of the age-III bass were considered mature for the calculations of egg potential. As I mentioned earlier there is a paucity of quantitative information on size at maturity for largemouth bass. Kelley (1962) in Maine, and Kramer and Smith (1962) in Minnesota, reported females maturing at about 12 inches (Table 4). Under the premise that an average growing population might mature at a larger size than the 10 inches observed by Clady (1970), I also calculated number of fall fingerlings for all biomass estimates of bass 12 inches and larger (Table 10).

With the bass maturing at 10 inches, a 10-inch minimum size limit and a rate of exploitation of 0.35, the spring biomass has the potential to produce 79,372 fall fingerlings or 2.4 times as many as the 33,333 fingerlings needed to replace the population. I would judge that a factor of 2 would be a reasonable protection. If the fishing rate is doubled (0.55), the factor reduces to 1.5, and a tripling of the fishing rate reduces the factor to 1.1. At this level the fall fingerlings are just barely replaced. Increasing the minimum size limit to 12 inches insures that there will be more than twice the number of fall fingerlings needed to replace the population.

If the bass do not mature until 12 inches, under the 10-inch minimum size limit with the rates of exploitation 0.35, 0.55, and 0.70, the numbers of fall fingerlings for 0.55 and 0.70 are only 0.6 and 0.3 times the number needed (Table 10). At a 12-inch minimum size, the extreme rate of 0.70 results in numbers slightly below the adopted 2 standard. Of course, all of the above may be a useless exercise, for compensation in mortality, which is greatest at this time in the life of fish, may be more than enough to adjust for any calculated decrease in spawning stock. A very small increase in the percentage survival results in a large increase in number of fall fingerlings.

Predation

In any discussion of higher size limits for largemouth bass it is usually suggested that any increase in numbers of larger bass should lead to increased predation upon the ubiquitous bluegill, with the result for the bluegill of better growth and a size more desirable for angling. However the evidence that this interaction takes place is sparse to non-existent. In fish the size of a year class is set in the first few weeks of life by either predation, competition or climatic factors. Further, it is a common observation that once year-class strength is established it maintains its relative strength through the life of the class. Predation does not seem to reduce the numbers of an abundant year class (Ricker, 1954; Schneider, 1971). Perhaps this explains why an effective predator-prey relationship is rarely achieved in farm ponds with the simple bass-bluegill species combination (Bennett, 1971). It would then seem presumptuous to expect the largemouth to be an effective predator on the bluegill where there are multiple prey species available such as minnows, perch and crayfish to act as buffers. Indeed, studies of food habits indicate that largemouth either do not have a preference for bluegills, or that the bluegill is less vulnerable than other food items to predation (Lewis and Helms, 1964; Lewis, 1967; Schneider, 1971; Snow, 1971). In Alabama, Elrod (1971) added adult largemouth bass at the rate of 10.1 per acre to a 25.5-acre pond to reduce the abundance of bluegill, but these additional bass had no effect on bluegill numbers.

From 1954 through 1958 there was a 16-inch minimum size limit on largemouth bass in Sugarloaf Lake, Michigan, and from 1959 through 1963, a 14-inch minimum size. Before the experimental changes (1946-53) the size limit was 10 inches. During all of the years, a creel census was conducted by counting and interviewing a sample of the anglers (Taube, 1965). K. E. Christensen, who was in charge of this project for most of the time period, wrote in 1962, "A 16-inch minimum size was in effect for five years (1954-1959). This was as drastic a regulation as might be imposed, short of complete protection. We could not, after seven years (two years additional under a 14-inch limit), detect an improvement in growth of pan fish; in other words, protecting bass did not make them significantly more effective predators . . ." The empirical data on age and growth that Christensen referred to are presented in Table 11. Certainly there is no increase in growth of the 1962 bluegills over those from 1952, and it appears at least for the early years of life that growth was less in 1962 than 1952.

Catchability and hooking mortality

The final consideration of benefits, to be derived from an increase in biomass, is increased recreation from a catch-and-release fishery. Presumably this would only be successful if losses from hooking are minimal and the bass are reasonably re-catchable.

I do not know of any studies of hooking losses for bass less than 10 inches long, but most bass of this size would be caught on bait by anglers fishing for panfish, and mortality probably would be greater than if the same fish were caught on lures (Shetter and Allison, 1958). Most of the information available on losses from catch-and-release fishing comes from studies of the professional bass fishing tournaments in which the fish are of relatively large size--usually a pound or two in weight--and are retained in a live well or on a stringer for several hours before release. There is a report by Elmer Guerri in Outdoor America for January 1974, of 88% survival of bass in a tournament on Watts Bar Lake, Tennessee, being studied by fisheries biologists, but most survival figures have been much lower. R. H. Stroud (1973 a,b; 1974), in reporting on various studies of catch-and-release mortalities in tournaments, notes direct plus delayed losses of from 51 to 98%. It appears that considerable refinement in catching and handling techniques is needed to reduce hooking losses.

Schneider (1973b) provides, in his discussion of angling for bass on Mill Lake, Michigan, an excellent review of the literature on catchability. In Mill Lake, which was opened to fishing after a 5-year closed season, 83% of those parties fishing for bass were successful in catching a bass the first day, but on the second and third days the percentage successful dropped to 57 and 46, respectively. In terms of total catch, 481 bass were caught opening day, 155 the second day and only 49 the third day. Using the known population size, Schneider was able to demonstrate that this decline was due to catchability and not to a decrease in number of bass in the population. This phenomenon has been demonstrated earlier in Michigan by Brown and Ball (1942) and Westers (1963), and by others nationwide. In Loch Alpine, Michigan, anglers considered the bass to be "fished out" when there were still 6 legal-size fish per acre (Lagler and DeRoth, 1953).

The combination of decreasing catchability and the potential for high hooking losses suggest any catch-and-release fishery needs evaluation.

Creel limits and closed seasons

Setting the creel limit at five largemouth bass apparently is a very ineffective means of limiting the harvest. In Wisconsin, on Escanaba Lake and Murphy Flowage, only 1.1% of the anglers caught more than five bass under a no-limit regulation (Mraz, 1964). Although it has not yet been documented for Michigan lakes, observations indicate the same is true here; anglers catching a limit of five bass is not a common occurrence.

Formerly, the fishing season for largemouth bass opened on "the third Saturday in June." In 1962, the opening day was advanced to June 1, and in 1972 to the "Saturday immediately preceding Memorial Day." Extension of the season was based on an analysis of K. E. Christensen's data (Table 5).

Pontiac, Whitmore and Bear lakes had no closed season on largemouth bass for 1954-58; the result was a substantial increase in catch per acre. For example, on Pontiac Lake the bass harvest was 5.4 pounds per acre in 1946-53 with a closed season, and 8.4 pounds per acre during 1954-58 with an open season, an increase of 56%. Likewise the harvest increased in Whitmore and Bear lakes 48% and 76%, respectively. The additional catch took place in the spring, without a decrease in summer and fall harvests and without any indication of depletion of the population (K. E. Christensen, unpublished manuscript, 1962).

In Minnesota, two experiments in extending the season on largemouth bass resulted in no increase in total harvest of bass; the peak period for harvest occurred in the spring extension or the following 2 weeks (Maloney et al., 1962). In Quabbin Reservoir, Massachusetts, with an open spring season for largemouth bass, 65% of the harvest took place during this normally closed period. From 1954 through 1958, the first 5 years of the open season, there was an increase in the number of bass harvested each year except 1955 (McCaig et al., 1960). Stroud (1973) recently noted the results of the first evaluation of an open season on bass. In 1944 and 1945, R. W. Eschmeyer in the TVA impoundments documented an increase of about 50% in the catch, without any measurable change in the composition of the population. Mraz (1964), in evaluating an earlier opening and a no-size limit combined, for bass on Browns Lake, Wisconsin, concluded that the increase in angling did not harm the fish population. Neither Mraz (1964) nor Murphy (1950) found reproduction and recruitment adversely affected by a fishing season open during the spawning period.

Discussion

At present, a 12-inch minimum size limit, combined with the existing 5-fish creel limit and season which is open from the Saturday immediately preceding Memorial Day to December 31, would be appropriate fishing regulations for largemouth bass in Michigan. The critical size, or size of greatest biomass, for the growth and mortality rates postulated for largemouth, is 12 inches (Fig. 3). For a 0.35 (1 p) rate of exploitation, the greatest harvest, in weight, occurs at a 10-inch minimum size, but with an increase in the rate of exploitation the greatest harvest occurs at the 12-inch minimum size (Table 6). Although the relationship between spawning stock and progeny is not known for largemouth bass and compensatory survival is great among newly hatched fry, it would seem prudent to protect the biomass of adults 12 inches and larger, particularly if exploitation is increasing. The difference in yield between 10 and 12 inches in minimum size is small, but the increase in biomass at the higher size limit is considerably greater (Tables 6 and 7).

The increase in biomass with the increased size limit is unlikely to have any measurable effect on associated populations of sunfishes. The potential of bass for a catch-and-release fishery has yet to be demonstrated.

In terms of numbers, an increase in the minimum size limit to 12 inches would reduce the catch considerably, at all projected rates of exploitation, but this is judged a reasonable sacrifice to insure a substantial biomass and to maintain or perhaps increase the yield in pounds. I am assuming there has been and will continue to be an increase in rate of exploitation.

The creel limit is apparently ineffective as a regulation to limit the catch or to insure a more even distribution among anglers, but in a recreational sense it does provide a goal to be attained.

The closed season has the potential for limiting the catch, as does the minimum size limit. Although bass are readily caught during the spring, apparently more easily than during the remainder of the year, there is no evidence of depletion of bass populations at the exploitation rates existing at the times of the experimental seasons. In the model which, with the June 1 opening, simulates essentially a spring season, the biomass did not appear marginal as spawning stock except at very high fishing rates. Perhaps a seasonal restriction might be desirable in conjunction with minimum size limits, if exploitation becomes extreme sometime in the future, or as an alternative to a size limit if losses from hooking prove substantial.

Table 1.--Computation of yield for a typical population of largemouth bass in Michigan

Age group	Month	Total length (inches)	Weight (pounds)	Growth rate g	Mortality rate Natural q	Mortality rate Fishing p	Weight of stock (pounds)	Yield (pounds)
0	Dec	4.2	0.03	0.285	0.103	0.0	1,000	.....
I	Jun	4.5	0.04	1.447	0.957	0.0	1,200	.....
	Dec	7.1	0.17	0.215	0.182	0.0	1,959	.....
II	Jun	7.6	0.21	0.668	0.321	0.0	2,024	.....
	Dec	9.4	0.41	0.215	0.125	0.0	2,863	.....
III	Jun	10.1	0.51	0.438	0.352	0.581	3,133	1,465
	Dec	11.6	0.79	0.049	0.048	0.0	1,909	.....
IV	Jun	11.8	0.83	0.351	0.352	0.581	1,911	865
	Dec	13.2	1.18	0.049	0.048	0.0	1,067	.....
V	Jun	13.4	1.24	0.285	0.372	0.581	1,068	469
	Dec	14.7	1.65	0.020	0.028	0.0	547	.....
VI	Jun	14.8	1.69	0.300	0.615	0.581	543	222
	Dec	16.3	2.28	0.020	0.039	0.0	222	.....
VII	Jun	16.4	2.33	0.174	0.759	0.581	217	83
	Dec	17.35	2.78	0.010	0.040	0.0	68	.....
VIII	Jun	17.4	2.80	0.166	0.824	0.581	66	24
	Dec	18.35	3.31	0.010	0.043	0.0	19	.....
IX	Jun	18.4	3.34	0.157	0.824	0.581	18	7
	Dec	19.35	3.91	0.010	0.043	0.0	5	.....
X	Jun	19.4	3.94	0.148	0.824	0.581	5	2
	Dec	20.35	4.57	.....	.....	.....	1	.....
Total		.....	....	.....	.....	.....	.....	3,137

Table 2.--Reported mortalities for largemouth bass

Water	Author	Mortality Total a	Natural v	Fishing u
Sugarloaf L., Mich.	Cooper & Latta, 1954	0.70	0.35	0.35
Whitmore L., Mich.	Cooper & Schafer, 1954	0.42	0.20	0.22
Jewett L., Mich	Patriarche, 1958-1961, 1963	....	....	0.08-0.47
L. Fort Smith, Ark.	Cole, 1966	0.38	0.06	0.32
Millerton L., Calif.	Fisher, 1953	....	....	0.20
Clear L., Calif.	Kimsey, 1957	0.56	0.36	0.20
Sutherland Res., Calif.	La Faunce et al., 1964	0.70	0.34	0.36
Folsom L., Calif.	Rawstron, 1967	0.89	0.49	0.40
Merle Collins Res., Calif.	Rawstron & Hashagen, 1972	0.71-0.92	0.11-0.56	0.36-0.65
L. Berryessa, Calif.	Rawstron & Reavis, 1974	....	....	0.58
Folsom L., Calif.	Rawstron & Reavis, 1974	....	....	0.47
Ridge L., Ill.	Bennett, 1954	0.35-0.40	0.05-0.11	0.25-0.30
Shoe L., Ind.	Ricker, 1942	....	....	0.20
Gordy L., Ind.	Gerking, 1952	0.60	0.24	0.36
Gladstone L., Minn.	Maloney et al., 1962	0.61	0.47	0.14
Dryden L., N.Y.	Green, 1973	0.40	0.26	0.14
Norris Res., Tenn.	Eschmeyer, 1942	....	....	0.18
Norris Res., Tenn.	Manges, 1950	....	....	0.18
South Holston Res., Tenn.	Chance, 1955	....	....	0.41
Watauga Res., Tenn.	Chance, 1955	....	....	0.42
Brown's L., Wisc.	Mraz & Threinen, 1957	0.24	0.12	0.12

Table 3.--Age-specific natural mortality rates for largemouth bass

Age group	Locality and author			
	Mill L. [1] J.C. Schneider 1971	Cub L. [2] M.D. Clady 1970	L. Carl Blackwell [3] P.L. Zweiaker 1972	Ridge L. [4] G.W. Bennett 1971
0	....	0.88	....	.....
I	....	0.68	0.75	.....
II	....	0.49	0.06	0.330
III	....	0.10	0.16	.....
IV	0.34	0.00	0.35	0.134
V	0.32	0.02	0.71	.....
VI	0.48	0.67	0.80	0.146
VII	0.55	0.57	....	.....
VIII	0.59	0.68	....	0.390
IX	0.56	....	....	.....
X	0.26	....	....	0.729

[1] Lake closed to fishing; rates are an average for 5 years of estimates.

[2] Lake closed to fishing; about 20% of older age groups cropped by netting; rates are an average for 3 years of estimates.

[3] Fishing mortality only 1.2%.

[4] Range of ages assigned by author to each rate as follows: 1-3, 0.330; 3-5, 0.134; 5-6, 0.146; 7-8, 0.390; older than 8, 0.729. Rates for 2- and 3-year periods; fishing concurrent.

Table 4.--Age and size of largemouth bass at maturity

Locality	Author		Age (years)		Length (inches)
Canada	W. B. Scott and E. J. Crossman, 1973	♂ ♀	3-4 4-5		....
Wisconsin	D. Mraz, S. Kmiotek and L. Frankenberger, 1961		3-4		10-12
Minnesota	R. H. Kramer and L. L. Smith, Jr., 1962		... ...	♂ ♀	11.5-20.1 12.2-20.5
Maine	J. W. Kelley, 1962	♀	3		11.6
Michigan	M. D. Clady, 1970	♀	4		10.0
Michigan [1]	R. C. Ball, 1952		2		....
California	D. A. LaFaunce, J. B. Kimsey and H. K. Chadwick, 1964		1		10-12
New York [1]	H. A. Regier, 1963		2		....
North Central States	G. W. Bennett, 1971		2		....
Alabama [1]	H. S. Swingle and E. V. Smith, 1950		1		....

[1] Farm ponds.

Table 5.--Annual harvest, standing crop, and hours of angling for largemouth bass under various fishing regulations

Lake and size (acres)	Years	Harvest (lb/acre)	Standing crop (lb/acre)	Hours of angling per acre	Fishing regulations
Fife (619) [1]	1946-53	0.9	3.7 [2]	86	Closed season 10-inch size limit
	1954-58	0.9	...	77	16-inch size limit
Sugarloaf (180) [1]	1946-53	6.4	6.6 [2]	110	Closed season 10-inch size limit
	1954-58	2.5	...	109	16-inch size limit
Duck (630) [1]	1946-53	4.7	...	111	Closed season 10-inch size limit
	1954-58	5.0	...	125	No size limit
Fine (320) [1]	1946-53	2.4	...	157	Closed season 10-inch size limit
	1954-58	2.7	...	111	No size limit
Pontiac (585) [1]	1946-53	5.4	...	209	Closed season 10-inch size limit
	1954-58	8.4	...	137	No closed season
Whitmore (680) [1]	1946-53	2.9	8.1 [2]	93	Closed season 10-inch size limit
	1954-58	4.3	...	96	No closed season
Bear (1,740) [1]	1946-53	1.4	...	33	Closed season 10-inch size limit
	1954-58	2.5	...	45	No closed season
Lower Loch Alpine (12.5) [3]	1950	6.5	30.2	19	Closed season 10-inch size limit
Upper Loch Alpine (10.9)	1951	0.2	12.2	7	Closed season 10-inch size limit

[1] Creel census data from unpublished manuscript of K.E. Christensen, 1962.

[2] Mark-and-recapture estimates of legal-size fish for Fife Lake, 1950; Sugarloaf, 1948-50; and Whitmore, 1953 (Cooper, 1952; Cooper and Schafer, 1954).

[3] Harvest and standing crop data from Lagler and DeRoth, 1953.

Table 6.--Yield per 1,000 pounds of recruits for largemouth bass at four rates of exploitation and various minimum sizes

Minimum size (inches)	Rate of exploitation			
	0.20 [1] (1/2 p)	0.35 (1 p)	0.55 (2 p)	0.70 (3 p)
8.0	2,446	2,808	2,820	2,898
10.0	2,461	3,137	3,590	3,987
12.0	2,187	2,990	3,675	4,207
14.0	1,243	1,933	2,781	3,458
16.0	731	1,188	1,815	2,343
18.0	166	287	468	621

[1] Instantaneous fishing mortality rate, p, equals 0.581.

Table 7.--Biomass per 1,000 pounds of recruits for largemouth bass 10 inches total length (age III) and longer in June of each year of life at four rates of exploitation and various minimum sizes

Minimum size (inches)	Rate of exploitation			
	0.20 [1] (1/2 p)	0.35 (1 p)	0.55 (2 p)	0.70 (3 p)
8.0	7,489	3,894	1,456	674
10.0	10,014	6,961	4,657	3,854
12.0	12,334	9,977	8,003	7,254
14.0	15,740	14,815	13,897	13,492
16.0	16,643	16,196	15,728	15,514
18.0	17,309	17,253	17,179	17,138

[1] Instantaneous fishing mortality rate, p, equals 0.581.

Table 8.--Number of largemouth bass per 1,000 pounds of recruits, 8 to 18 inches or longer, expected to be harvested at four rates of exploitation and various minimum sizes

Minimum size (inches)	Length category (inches)	Rate of exploitation			
		0.20[1] (1/2 p)	0.35 (1 p)	0.55 (2 p)	0.70 (3 p)
8.0	8 or longer	3,801	5,411	6,970	8,096
	10 "	1,849	2,014	1,496	996
	12 "	898	754	321	121
	16 "	61	24	2	0
10.0	10 or longer	2,473	3,599	4,784	5,697
	12 "	1,202	1,345	1,030	695
	16 "	83	42	7	1
12.0	12 or longer	1,608	2,406	3,290	3,968
	16 "	110	76	21	4
14.0	14 or longer	548	886	1,332	1,697
	16 "	196	245	214	157
16.0	16 or longer	263	436	687	900
18.0	18 or longer	44	77	127	170

[1] Instantaneous fishing mortality rate, p, equals 0.581.

Table 9.--Number of largemouth bass per 1,000 pounds of recruits, 10 to 16 inches or longer, estimated to be present in the June biomass at four rates of exploitation and various minimum sizes

Minimum size (inches)	Length category (inches)	Rate of exploitation			
		0.20 [1] (1/2 p)	0.35 (1 p)	0.55 (2 p)	0.70 (3 p)
8.0	10 or longer	8,950	5,453	2,429	1,219
	12 "	4,356	2,018	507	144
	16 "	329	69	3	0
10.0	10 or longer	11,967	9,750	7,766	6,958
	12 "	5,824	3,607	1,623	815
	16 "	439	123	10	1
12.0	10 or longer	13,932	12,594	11,334	10,801
	12 "	7,789	6,451	5,191	4,658
	16 "	588	221	34	5
14.0	10 or longer	15,899	15,552	15,193	15,028
	12 "	9,756	9,409	9,050	8,885
	16 "	1,052	705	346	181
16.0	10 or longer	16,254	16,109	15,954	15,881
	12 "	10,111	9,966	9,811	9,738
	16 "	1,407	1,262	1,107	1,034
18.0	10 or longer	16,466	16,451	16,433	16,422
	12 "	10,323	10,308	10,290	10,279
	16 "	1,619	1,604	1,586	1,575

[1] Instantaneous fishing mortality rate, p, equals 0.581.

Table 10.--Number of largemouth bass fall fingerlings estimated to survive from the June biomass for females maturing at 10 or 12 inches in length. The ratio of fall fingerlings produced to fingerlings per 1,000 pounds of recruits needed is in parentheses.

Minimum size (inches)	Rate of exploitation		
	0.35[1] (1 p)	0.55 (2 p)	0.70 (3 p)
	Mature at 10 inches		
10	79,372 (2.4)	49,647 (1.5)	38,530 (1.1)
12	......	96,987 (2.9)	87,885 (2.6)
	Mature at 12 inches		
10	51,332 (1.5)	21,607 (0.6)	10,490 (0.3)
12	......	68,947 (2.1)	59,845 (1.8)

[1] Instantaneous fishing mortality rate, p, equals 0.581.

Table 11.--Average total length in inches for some fishes of Sugarloaf Lake before (1952) and after (1962) higher minimum size limits on largemouth bass

(Number of fish is in parentheses)

Species and year	Age-group I	II	III	IV	V	VI	VII	VIII
Bluegill (*Lepomis macrochirus*)								
1952	....	4.4 (20)	5.4 (186)	6.7 (63)	7.4 (10)	8.1 (14)	8.2 (2)	8.3 (2)
1962	....	3.7 (50)	4.9 (125)	6.2 (18)	7.0 (90)	7.9 (35)	8.4 (21)	8.8 (1)
Rock bass (*Ambloplites rupestris*)								
1952	4.0 (1)	5.2 (377)	7.8 (52)	8.7 (7)	9.5 (4)	9.7 (1)	10.7 (1)	....
1962	3.6 (1)	4.7 (20)	6.0 (165)	8.0 (59)	8.8 (7)	9.3 (3)	....	....
Black crappie (*Pomoxis nigromaculatus*)								
1952	6.3 (34)	9.0 (62)	10.9 (7)	11.3 (5)	10.8 (3)	....	....	....
1962	6.1 (125)	8.3 (3)	10.4 (57)	11.8 (4)	13.3 (1)			
Pumpkinseed (*Lepomis gibbosus*)								
1952	3.7 (2)	4.7 (54)	6.4 (10)	7.3 (1)	....	....	....	....
1962	....	4.0 (20)	5.3 (126)	6.6 (42)	7.7 (21)	....	....	....
Warmouth (*Lepomis gulosus*)								
1952	....	5.5 (3)	6.6 (140)	7.6 (23)	7.7 (15)	7.9 (15)	....	....
1962	....	4.7 (21)	5.8 (32)	6.8 (12)	7.2 (24)	7.7 (1)	....	....

(continued, next page)

Table 11.--concluded

Species and year	Age-group							
	I	II	III	IV	V	VI	VII	VIII
Largemouth bass *Micropterus salmoides)*								
1952	7.0 (6)	8.8 (25)	10.1 (67)	11.7 (48)	13.0 (4)	16.6 (1)	16.2 (1)	....
1962	6.5 (9)	8.1 (11)	10.3 (18)	11.8 (24)	13.4 (15)	15.2 (10)	16.1 (1)	17.2 (2)
Northern pike *Esox lucius*								
1952	16.6 (6)	19.8 (42)	25.5 (1)	31.0 (1)	....	31.0 (2)	....	....
1962	....	23.7 (14)	26.0 (9)	29.4 (4)	33.3 (1)	36.5 (1)		

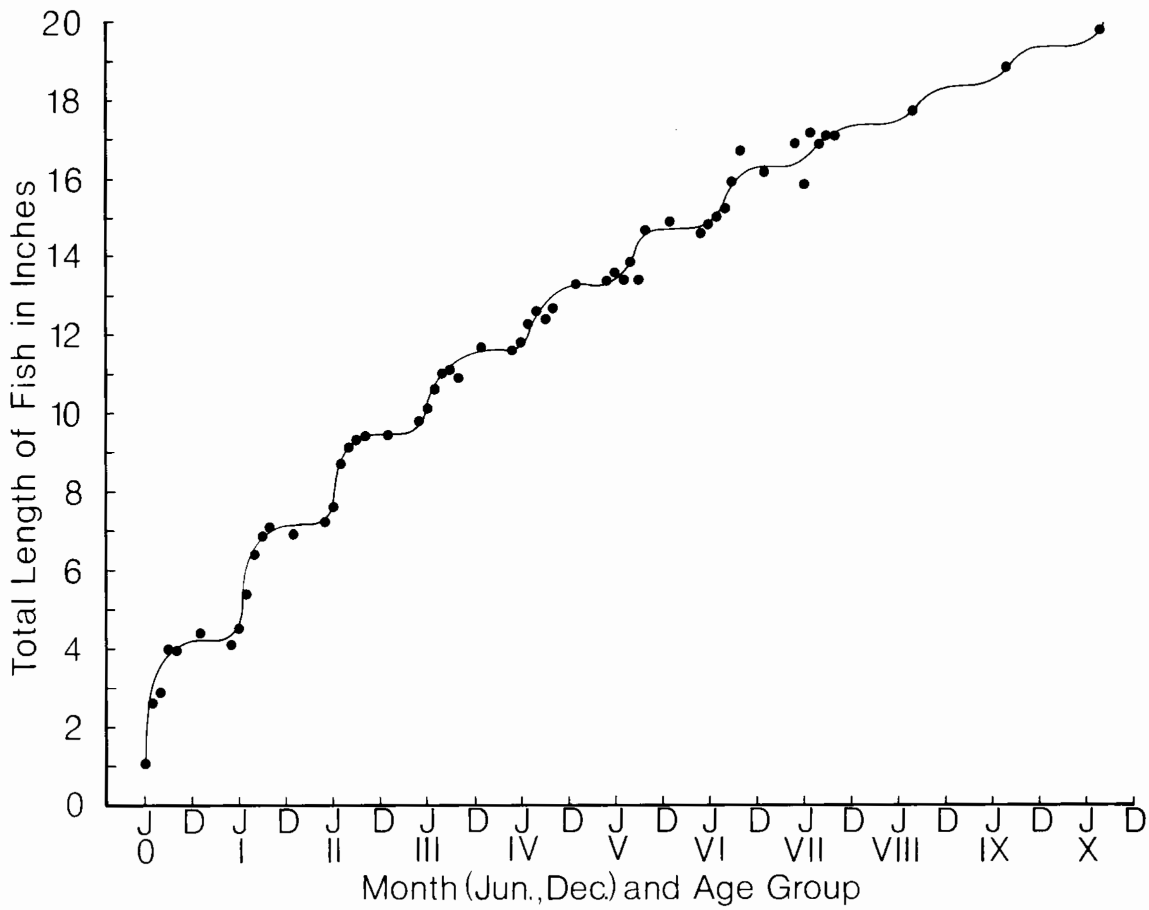

Figure 1. --Average seasonal growth in length of largemouth bass in Michigan.

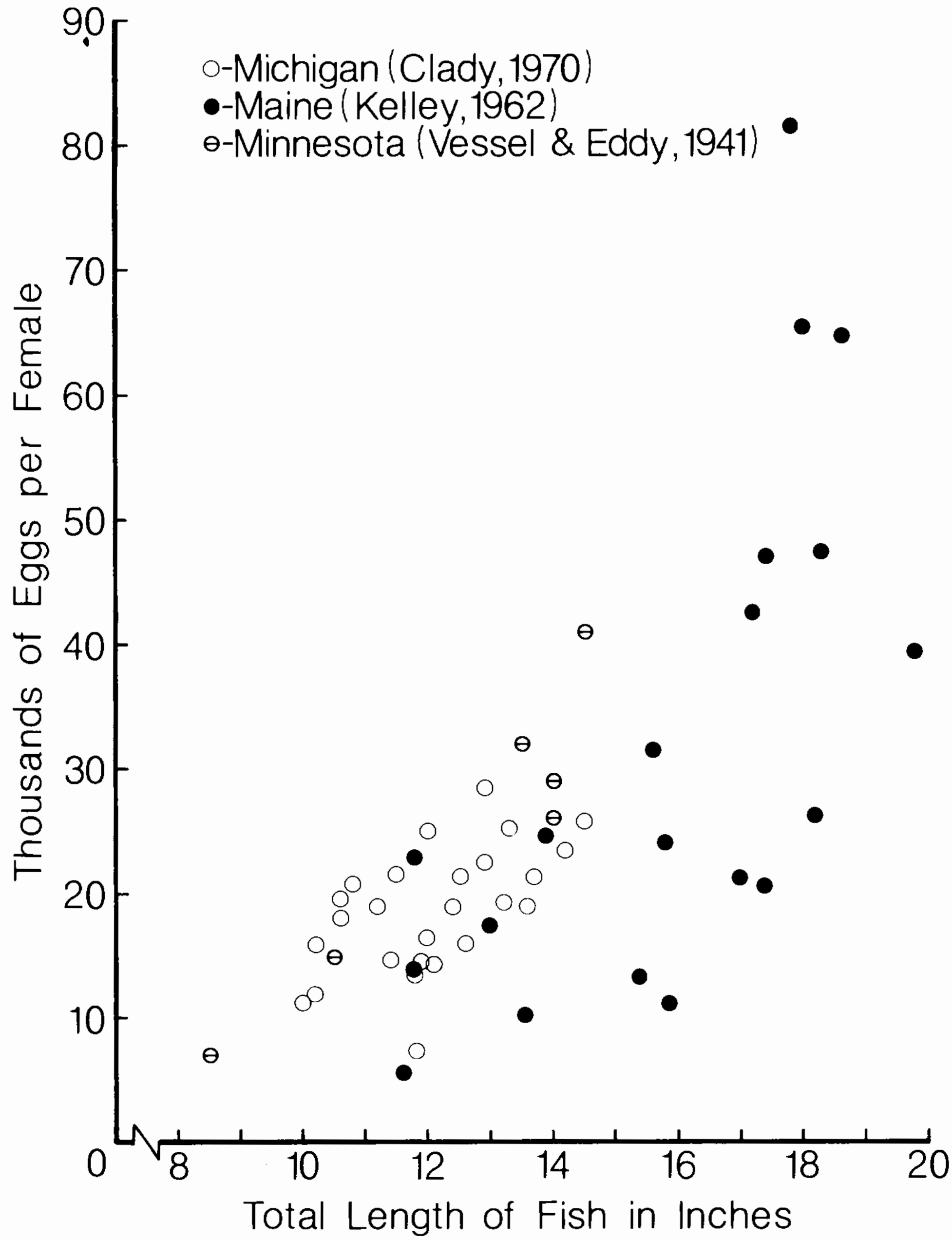

Figure 2. --Relationship between number of eggs and total length of female largemouth bass.

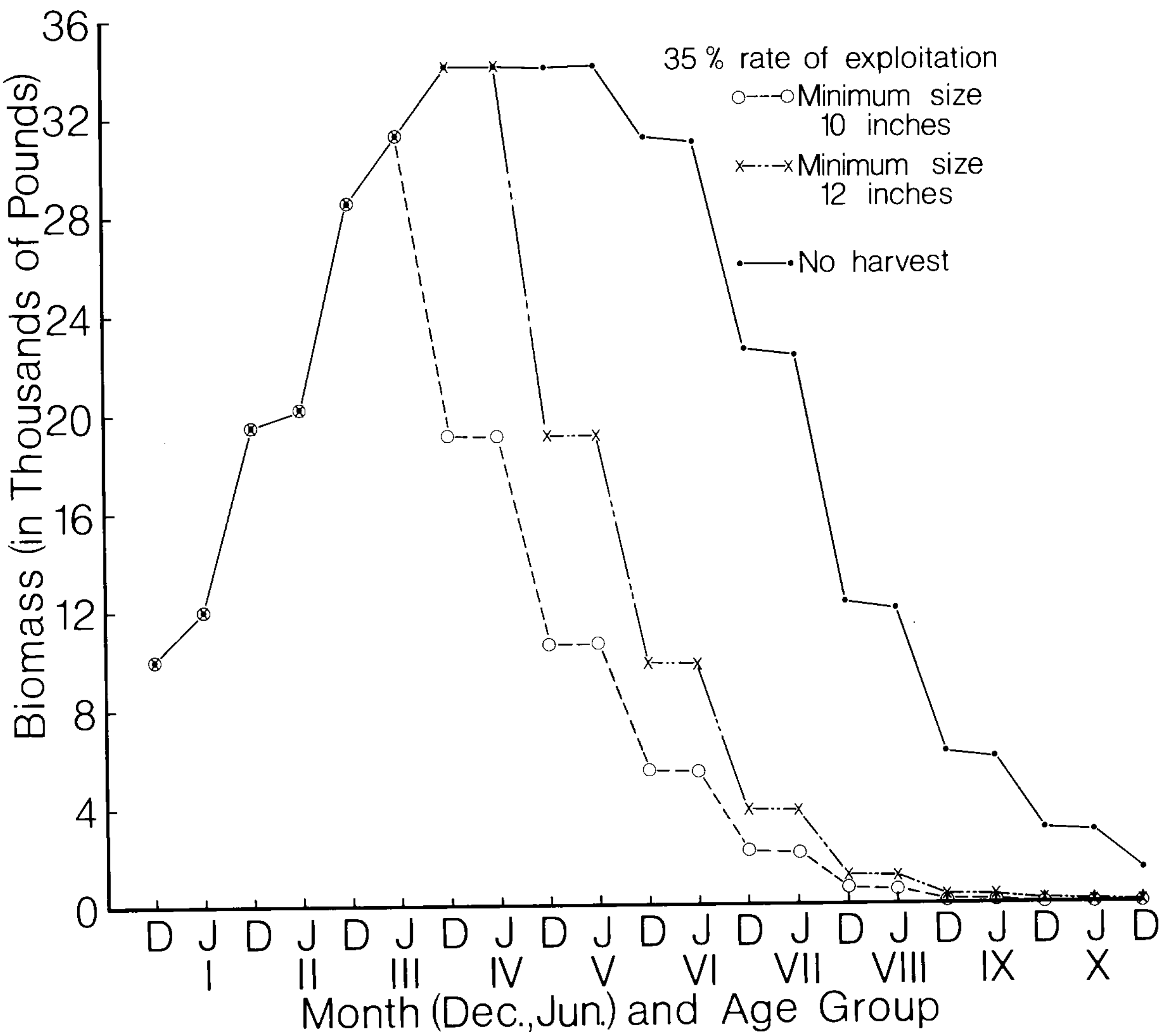

Figure 3.--Biomass of largemouth bass in a typical population in Michigan, without harvest, and with harvest at minimum sizes of 10 and 12 inches and a 35% rate of exploitation.

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Typed by M. S. McClure