MICHIGAN DEPARTMENT OF NATURAL RESOURCES
Research and Development Report No. 241*

July 6, 1971

THE NORTHERN PIKE IN MICHIGAN: A COMMENTARY ON REGULATIONS FOR FISHING [1]

By W. C. Latta

Abstract

The effects of various fishing regulations on northern pike in Michigan were evaluated with a model of a typical population. Typical conditions were created from average growth, mortality, spawning and angling figures from Michigan lakes. Under average conditions it appears that the spawning stock left at the end of a fishing season is more than twice what is needed to maintain a pike population. Prohibiting spearing or a complete ban on winter fishing decreases the yield, with a needless gain in number of spawners. However a ban on winter fishing does result in an increase in fish to be harvested during the summer, but it is necessary to have an increase in fishing pressure or the gain will be lost to natural mortality. An increase in the minimum size limit from the present 20 inches to 22 inches leads to a decrease in yield with a further gain in number of spawners. A decrease in the size limit to 16 inches results in the highest yield of northern pike but leaves a spawning stock considerably below what is judged necessary to maintain the population. Fishing regulations as now extant are not leading to a decrease in northern pike in Michigan. The apparent valid observation that pike are decreasing in abundance in Michigan is probably a result of destruction of their spawning marshes rather than overexploitation through lax regulations.

---

* Institute for Fisheries Research Report No. 1780.

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

MICHIGAN DEPARTMENT OF NATURAL RESOURCES
Research and Development Report No. 241*

July 6, 1971

THE NORTHERN PIKE IN MICHIGAN: A COMMENTARY ON REGULATIONS FOR FISHING [1]

By W. C. Latta

The northern pike (Esox lucius) is found in most of the larger lakes and rivers of Michigan. To some people it is an ugly, elongated, slimy fish with a large mouth, full of teeth; but to most fishermen it is a bold, slashing predator, a prize to possess. At a very small size, about 3 inches, pike begin to eat fish, and they continue to do so throughout life. The larger the size of the pike, the larger the fish that is eaten. However, before they reach 3 inches, they eat only microscopic crustacea and small insect larvae. The adults spawn in late March or early April just as the ice is leaving the lakes. The females broadcast their adhesive eggs through flooded, emergent vegetation; thus shallow, marshy shores or bays on lakes are essential for sizable pike populations.

The pike is sought by fishermen both summer and winter. Controversy over season of the year to fish, or method of catching, has been going on since the pike became an acceptable game fish. In the late 1800's the state Fish Commissioners in Michigan advocated a "policy of extermination" for pike, referring to them as the "fresh-water devil fish" (Williams, 1952). However by the early 1930's the pike was in

---

* Institute for Fisheries Research Report No. 1780.

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

better favor; for example, there existed "a local controversy of considerable proportions over the question of whether winter fishing on Otsego Lake is depleting the fish stock so as to interfere with the success of summer fishing." Professor Carl L. Hubbs, then of the University of Michigan and Director of the fledgling Institute for Fisheries Research, attempted to answer the question at Otsego Lake, with the help of Conservation Officer Thomas Marlatt and research staff members R. W. Eschmeyer and G. P. Cooper (Hubbs, 1934). Although the data available were too meager to provide a definitive answer, Hubbs and staff deduced that "winter fishing for pike in Otsego Lake definitely detracts from summer pike fishing in the lake" and "Prohibiting winter fishing, or at least winter spearing in this lake, would be expected to increase the summer catch of pike." And those statements reflect the gist of a fisheries conflict that has been almost continuous through the years. The following commentary will hopefully provide a rational method and general analysis to answer the questions:

(1) Does winter spearing result in overexploitation of the spawning stock?

(2) Does the winter harvest result in less fish for the summer angler? and finally

(3) What combination of regulations--season, size limit and methods--provides the optimum harvest?

Population parameters

In order to answer these questions I simulated a typical northern pike population in which individuals are continually growing and dying.

Growth rates were obtained from Laarman's 1963 compilation of the average growth in length of Michigan fishes. In 1969, Laarman calculated average weight for each age group, utilizing Beckman's (1948) length-weight relationships for pike in Michigan plus additional data from the files. In 1963-1965, Mercer Patriarche, in an intensive study of northern pike in Grebe Lake, established that 80% of the growth (and natural mortality) occurred between April and October, the open-water period. Accordingly I adjusted the average growth figures to conform to an 80%-20% growth pattern each year (Table 1).

Mortality estimates from the literature were summarized in Table 2. The most meaningful data were those of Schneider (1971) and Patriarche (unpublished data), in that their records were for several years (Schneider, 1965-1969, and Patriarche, 1966-1967), for several year classes, and for two lakes in Michigan. In addition, the estimates by Schneider and Patriarche were made in the absence of fishing. With the exception of the estimate from Lake Windermere, England, of 0.26 to 0.30 for natural mortality (Kipling and Frost, 1970), there is remarkably little variability in the remaining mortality estimates (0.37 to 0.56) (Table 2).

For the pike-population model, I used a weighted average (0.51) of the natural mortality data for Michigan lakes from Schneider and Patriarche. Then, as indicated earlier, I assumed 80% mortality during the April-October period as found by Patriarche. A further refinement, of course, would be to use age-specific mortality rates for the northern pike; but these are lacking for the early and late years of life, and for the middle years (age III-VI) mortality is consistently about 0.5 as used.

Although in the semi-popular fisheries articles (Threinen et al., 1966) and in conversations with fisheries managers, it is stated that exploitation of northern pike is 50% or greater, it is difficult to find quantitative information to verify these assertions. For the most part, fishing appears to account for something greater than one-fourth, but less than one-half, of the mortality observed in pike populations (Table 2). In Shaw Lake in Michigan, John E. Williams reported two anglers catching 28% of the pike population in 11 man-hours of fishing (less than 2 1/2 hours of angling per acre).[2] This is an impressive rate of exploitation, but it was in a lake closed to fishing and the pike had never been exposed to angling. Also we have no information on what the results might have been under continuous angling; a few days after the fishing took place, the lake was treated with rotenone, a fish toxicant, to recover the total pike population.

In many instances observations by field biologists are as valid as dated literature, so for the present model I used exploitation rates of 0.49 and 0.70 annually. The distribution of exploitation within the year was varied, to simulate various methods and patterns of fishing, but that will be discussed in greater detail later on.

To complete the parameters for the population model, requires information on age and size of northern pike at maturity, fecundity of females, ratios of males to females, and survival during the first year

---

[2] Unpublished report given at Midwest Fish and Wildlife Conference, December 1969.

of life. Males mature at about 2 years of age, or 16 to 18 inches in length, and females at 3 years, or 20 to 22 inches (Table 3). In northern waters the fish are older before they reach maturity, but they are about the same size (Frost and Kipling, 1967b).

Carbine (1944) provided excellent data on the relationship between weight of female pike and number of eggs per female. In Figure 1, I plotted Carbine's data, and then those of Vessel and Eddy (1941) for Minnesota waters. They were in very good agreement. For these data a pound of female northern pike is equal to about 10, 800 eggs. This may be compared with Lake George, Minnesota, where one pound equaled 13, 078 eggs (Franklin and Smith, 1963), and with Lake Windermere, Great Britain, where one pound equaled 12, 258 eggs (Frost and Kipling, 1967b).

After the first year or two of life, female northern pike grow faster than males. Because of the paucity of data if separated by sex, they are considered together in the model. The difference in growth probably leads to a greater harvest of the females. Males are not known to exceed 30 inches in length, whereas females will exceed 40 inches, according to Threinen et al. (1966). However to make my analysis complete, the sex ratio of a spawning population is needed. Carbine (1944) again provided the necessary data for Michigan waters. In Houghton Lake, 1939 and 1940, the ratio of males to females was 2.24:1 and 1.25:1, respectively. For comparison the ratio in Lake George, Minnesota, for the years 1957, 1958 and 1960 varied from 1.30:1 to 2.44:1 (Groebner, 1964). At Houghton Lake the average length of the females during the spawning run in 1939 was 23.5 inches, and for the males it was 21.2 inches (Carbine, 1942). At the state average length-weight relationship, these fish would weigh 45.5 and 33.0 ounces, respectively.

Survival of pike from the egg to young leaving the marsh is usually a fraction of a per cent (Table 4). The data presented in Table 4, with the exception of Forney's Oneida Lake figures, are for natural spawning runs and marshes. In Forney's case he controlled the number of spawners entering the marsh. The average survival from egg to emigration from the marsh for the other observations under natural conditions is 0.9%.

Estimates of survival from the time the pike leave the marsh at a size of about 3 inches until the first fall of life are not available in the literature. George B. Beyerle for the last 2 years has been attempting to measure the survival of pike fingerlings in Long Lake, Michigan. His preliminary figures indicate a mean survival of about 11.5% from the time of emergence from the marsh to the first fall of life.

Angling parameters

Before any judgments can be made as to the impact of winter fishing on northern pike populations, it is necessary to know how much winter fishing is going on. From the literature and files I have attempted to summarize some of the information available on percentage of harvest during winter and summer, by spearing and angling (Table 5). The data for Minnesota lakes, although dating back to the early 1950's, was voluminous and impressive. It included 32 lakes for a 6-year period. In those years, 86% of the northern pike were taken during the summer, and only 12% during the winter by spearing (Johnson et al., 1957). On the other hand, Threinen et al. (1966), in their semi-popular treatment of pike in Wisconsin lakes, venture that 50% of the harvest occurs during the summer, and 50% during the winter. They gave no breakdown for spearing. The remainder of the lakes cited in Table 5 are in Michigan. The lakes vary in size from Grebe Lake at 72.5 acres, to Houghton which is Michigan's largest lake at about 20,000 acres. Prior to 1958, the minimum size limit for pike in Michigan was 14 inches. It was increased to 20 inches in December 1957. On Fine Lake, in 1957, under a research experiment there was no size limit for northern pike. Since 1940 spearing has been prohibited on Houghton Lake. Fletcher Floodwater, with an obviously high density of pike in the catch, has been a problem lake in past years because of slow growth of pike. For all years presented, the minimum size for pike in the Floodwater was 14 inches. For all the lakes cited in Table 5, total hours fished applies to all fish, and not just to pike fishing, which explains why the catch per hundred hours is so low in many cases; people were catching other fish between catches of pike.

In Michigan lakes the percentage of pike harvested by summer angling varied from 36 to 86 with a mean of 58. The remaining catch was by winter spearing and winter angling. It appeared to me that, for the model, 50% for summer angling and 25% each for winter spearing and winter angling would be reasonable assumptions from the data in hand.

Yield equation

Yield for a typical population of northern pike in Michigan was calculated as illustrated in Table 1 (Ricker, 1958). The model starts with 1,000 pounds of 0-age pike in October of their first year of life. They become legal size at 20 inches in their fourth year of life (age group III). Growth and natural mortality rates, as given above, were used with the assumption (also discussed above) that half of the catch is taken during the summer and half during the winter. Under these assumed conditions, the recruitment of 1,000 pounds of young fish will yield 1,307 pounds of northern pike in the catch. This then I propose as the base line or standard to be used in judging the effects of proposed changes. I suggest that this is a typical population of northern pike in Michigan today.

Although yield is given the first consideration, of equal concern is the biomass or standing crop of fish left in each age group after the harvest has taken place. It is this biomass, of course, that provides the spawning fish. Without sufficient spawning stock the population would obviously collapse. The biomass for the typical population in Michigan is plotted in Figure 2. An annual rate of exploitation of 0.49 becomes 0.30 on a semiannual basis, which will explain the notation in the graph of 30% winter and 30% summer harvest. Also plotted on the graph is the biomass that would exist if no harvest during the winter was taking place, and also if there was no harvest either winter or summer. The spawning stock consists of the biomass of mature pike present in April. As discussed earlier, 20 inches is the approximate size at maturity for pike in Michigan, and under that premise there would be 2, 329 pounds of pike available to spawn under present harvest regimes. Under no harvest there would be 5, 187 pounds available. Conversions of biomass as pounds of spawners into numbers of female pike and numbers of eggs for recruitment will be attempted later.

Now with a base line of yield and biomass established for a typical northern pike population in Michigan, it is appropriate to consider what happens to these parameters when spearing is prohibited, or when all winter angling is prohibited, or when some other change in regulations is proposed. From the above discussion of harvest of pike in Michigan (Table 5) it appears that a ban on spearing would reduce the catch about 25%. Assuming that there would not be a compensatory increase in angling, i.e., anglers would give up spearing and not switch to hook-and-line, the yield equation was solved with an appropriate reduction in fishing rate for the winter months but no change for the summer. This meant that the rates of exploitation changed from 30 and 30 to 18 and 30, winter and summer, respectively (Table 6, Fig. 3). It appears from data for Houghton and Bear lakes that when spearing is prohibited, anglers will shift to the other form of fishing; however on the Fletcher Floodwater when spearing was banned, they did not shift. So the question is not answerable with the data in hand.

The second alternative considered was that all angling during the winter months would be prohibited, perhaps under the argument that really most of the fishing during the winter is by spearing; perhaps the data in Table 5 do not reflect the current situation, and exploitation by spearing should be something greater than a quarter of the winter harvest. Also it could be argued that restricting the winter catch will leave more pike for the summer anglers. Again it was assumed that there would not be an increase in fishing pressure during the remainder of the year because of the wintertime closure. Under this alternative, exploitation was 0 during the winter and stayed at 30% during the summer.

The third alternative considered was that, with a ban on fishing during the winter, harvest rate would increase two-fold during the summer to compensate. Under these conditions, exploitation during the winter would be 0, but during the summer it would increase to 49%. The results for the yield equation of the three alternatives may be compared graphically in Figure 3, and figuratively in Table 6.

According to the model, a ban on spearing (or a 25% reduction in harvest) would result in a 5% decrease in yield and a 10% increase in biomass. The second alternative--a complete ban on winter fishing--would result in a 14% decrease in yield and a 28% increase in biomass. The third alternative--a ban on winter fishing with a 100% compensatory increase during the summer--would result in an 18% increase in yield with no decrease in biomass.

Only in the third alternative was there an increase in yield with no decrease in biomass. This occurs because of the doubling of the fishing rate during the time of year that natural mortality is highest. Under the conditions of the model, 80% of natural mortality takes place during the summer. Any increase then in fishing rate results in a gain in yield with less natural loss, thus the biomass does not change.

Minimum recruitment

No judgment can be made on the sufficiency of the biomass left under various harvest conditions until it is related to number of spawners and resulting recruitment. For the model proposed to have a sustained yield, it is necessary to have an annual recruitment of 1,000 pounds of 0-age pike, each weighing 3.3 ounces, in October (Table 1). This amounts to 4,848 individuals. Using Beyerle's survival figure of 11.5% from marsh emigration to first fall, the number of pike needed to equal present recruitment is increased to 42,157 fingerlings. Survival from egg to marsh emigration was calculated as 0.9% which means that 4,684,111 eggs are needed. In Michigan a pound of female pike will produce about 10,800 eggs; thus it takes 434 pounds of female pike to produce the 4.7 million eggs.

The next step is to relate both a differential growth rate and the prevailing sex ratio to the pounds of pike required. Two simultaneous equations were solved:

$$33.0\,x + 45.5\,y = 1600$$

$$\frac{x}{y} = \frac{224}{100}$$

where x = number of males

y = number of females;

224:100 is the ratio of males to females; 33.3 and 45.5 are the mean weights in ounces of mature males and females, respectively. The first equation was made equal to 100 pounds, or 1,600 ounces, of pike. The result is that under the conditions proposed, every 100 pounds of pike will contain 38.1 pounds of females. This may now be related to the earlier 434 pounds needed to assure recruitment; thus 1,139 pounds of spawners (male and female) are necessary to guarantee an input of 1,000 pounds of young pike each October.

Small changes in the percentage survival at this stage of life of the pike result in large changes in the pounds of biomass necessary to assure constant recruitment. For example, if the lowest survival figures available are used--i.e., 7.9% survival rather than 11.5% from marsh emigration to first fall, and 0.07% survival rather than 0.9% from egg to marsh emigration--then 21,399 pounds of biomass are needed rather than the 1,139 pounds calculated earlier. Obviously this is impossible, and recruitment then would result in something less than 1,000 pounds.

However using the average conditions rather than the extremes, we can now look at the biomass figures calculated under the various alternatives and see if they are equal to or greater than the needed 1,139 pounds for recruitment (Fig. 3, Table 6).

The biomass figures considered thus far--the base line plus the alternatives--have ranged from 2,329 to 2,977 pounds. All of these are more than twice as great as the biomass calculated necessary to equal recruitment. A two-fold difference would appear to be a good safety factor, and I would judge that the alternative questions with regard to no spearing, no winter fishing, and an increase in summer fishing in the absence of winter fishing, can be answered in relation to factors such as harvest or recreational potential, rather than biomass of spawners left.

Many other alternatives may be explored with the model as outlined, but it appears appropriate in this analysis to look at two changes in minimum size limit. It might be suggested that an increase in the minimum size from 20 to 22 inches would assure a sufficient spawning stock, and there would certainly be no argument with that. In the model as proposed, under a 22-inch limit the biomass of spawners would be 2, 728 pounds, almost three times the 1, 139 pounds needed to produce 1, 000 pounds of recruits. Also the yield would decrease by about 17%.

On the other hand, it might be suggested that the size limit be lowered to the point where the biomass is the greatest during the life history of the pike. Ricker (1958) calls this the critical size, and cropping at this point should result in the greatest yield. For this typical population, 16 inches is the critical size and it occurs in April of the third year of life (age group II). The 16-inch size limit results in the largest yield calculated--1, 694 pounds, or a 30% increase above the standard population. However it also leaves a biomass of only 823 pounds, considerably below the 1, 139 pounds proposed as necessary for spawning stock.

For those who feel that a 49% rate of exploitation annually is not sufficient and that in reality northern pike are at present being cropped at a much higher rate, I made the same calculations at a 70% rate of exploitation (which on a semiannual basis equals 49% for winter and 49% for summer). This results in yields that are somewhat higher, but of more concern, the biomass still stays at a level (1,917 to 2,328 pounds, with one exception) considerably above the 1,139 pounds of spawners needed for basic recruitment (Table 6). The one exception is where the biomass dropped to 240 pounds under the 16-inch size limit, 79% below the biomass needed to assure sustained recruitment.

Discussion

At this point it seems appropriate to go back to our three questions and answer them with reference to the model. The first question was:

> (1) Does winter spearing result in overexploitation of the spawning stock?

In the analysis, I did not find that under present conditions of harvest and recruitment there was any indication of depletion of the spawning stock. There appears to be a safety factor of about two, i.e., the biomass left after harvest was about twice what was calculated as necessary to sustain recruitment. The only situation where biomass was less than what was needed occurred in the calculation for a 16-inch size limit. A ban on spearing or a total prohibition of winter spearing would increase the biomass only a moderate amount. Winter spearing does not result in overexploitation of the spawning stock.

The second question was:

(2) Does the winter harvest result in less fish for the summer angler?

Under the conditions of the model in which 80% of the natural mortality takes place during the summer and only 20% takes place during the winter, a reduction in winter angling results in an accumulation of biomass during the winter. (Here, I am referring to biomass of all pike, not just spawners.) In Figure 2, I have plotted the biomass under the conditions of no harvest during the winter and 30% harvest during the summer. This line may be compared with the standard population biomass plotted directly below (on the graph). Note that there is comparatively little decrease in biomass from April to October, in the simulation where there is no winter fishing. How much of this accumulation would show up in the catch is not known. In the line or case shown, very little of the gain shows up in the catch because it is assumed the rate of exploitation does not change. In the alternative where winter fishing was prohibited and summer fishing rate was doubled, there was a marked increase in catch; this was attributable to fishing taking some of the fish that would otherwise die of natural causes, and also utilizing more of the winter accumulation of biomass.

The final question posed was:

(3) What combination of regulations--season, size limit and methods--provides the optimum harvest?

I do not know if this question can be answered completely in the present analysis. The easiest part to answer is the one concerning size limits. It appears certain that under the conditions of growth and mortality as put forth here, a 20-inch size limit is most appropriate. A reduction of the size limit to 16 inches appears to endanger the spawning stock, and an increase to 22 inches leads to a needless reduction in harvest and increase in biomass.

With regard to methods cf harvest, it has already been demonstrated that spearing does not endanger the spawning stock. It has been hypothesized that because spearing tends to harvest the larger fish which are predominantly females (Johnson et al., 1957), spearing is detrimental to the population. In the model, this possibility was considered in the ratio of males to females in the biomass. The ratio of 224 males to 100 females, as used in the model, had the largest preponderance of males known for Michigan waters; presumably this abberant sex ratio reflects a disproportionate harvest. Spearing cannot be condemned from the data in hand.

The last part of the question to consider is season of harvest. Although a prohibition of winter angling will lead to an accumulation of biomass, and an increase in summer fishing should lead to an increase in yield, these are only gained by the loss of a season of recreation. I would venture that the gain is not worth the loss, but the final decision must be made by the people participating in the fishery. In either case the pike fishery is in no danger of depletion.

I believe that the model as presented here, a combination of Ricker's yield equation and related analysis of recruitment success, although unsophisticated mathematically, has the advantage of versatility. Any parameter--growth, mortality, sex ratio--may be easily substituted in the model if it seems more appropriate for the analysis being done. The state average growth rates, for example, probably cannot be improved upon very much. On the other hand certainly age-specific mortality rates would refine the model. The area of survival during the first summer of life is one in which much improvement in data could be made. The simplistic approach used in the present analysis, between eggs available and resulting fry, needs considerable refinement. An adjustment for compensatory survival of eggs and also for compensatory growth of fish would be highly desirable. Obviously an on-going creel census at representative lakes would provide up-to-date information on sex ratios, on amount of spearing, and on other parameters of the catch. Certainly improvement in input into the model will lead to improvement in predictability.

No discussion of fishing regulations for northern pike should be completed without at least a few brief comments on its role as predator in an aquatic system. Invariably it is suggested that protection of the pike stock will lead through predation to a reduction in some prey species that is overabundant, growing slowly and thus undesirable. Usually the species discussed as prey are the bluegill (<u>Lepomis macrochirus</u>) and the yellow perch (<u>Perca flavescens</u>). A few recent papers shed some light on this discussion. George B. Beyerle (1971a) published a study of two small lakes in Michigan, demonstrating that pike could not control numbers of bluegills. No other species of fish were present in the lakes to act as a buffer. In 1969, Leon D. Johnson concluded, after an analysis of the stomach contents of northern pike caught in Murphy Flowage, Wisconsin, that "Although bluegills were the predominant prey species, a more important fact for fish management is that pike took perch more frequently than bluegills in proportion to their abundance." In two other studies in which northern pike have been cropped extensively with nets as part of an experimental program (Lawler, 1965; Frost and Kipling, 1967a), these authors noted an increase in numbers of perch with a change in numbers and age structure of the pike populations. Lawler (1961), on 640-acre Heming Lake, Manitoba, has been cropping 2 to 4 pounds of pike per acre since 1945. The average size of the pike has decreased, and the number of larger perch has increased. A similar thing has happened on Lake Windermere, Great Britain. Here northern pike have been cropped since 1944 and the investigators (Frost and Kipling, 1967a) noted, as did Lawler, an increase in larger perch. From the evidence to date, it would appear that northern pike would be more likely to control yellow perch than bluegills. However there is a great deal yet to be learned about pike and their prey, in productive and non-productive waters and at various densities.

Fishing regulations as now extant are not leading to a decrease in northern pike in Michigan, yet it is commonly suggested that pike are decreasing in abundance. John E. Williams, at the 1969 Midwest Fish and Wildlife Conference in St. Paul, Minnesota, stated that the average lake in southern Michigan has only one pike per acre. Destruction of the spawning habitat has to have more impact than overfishing. Williams in 1952 wrote, "Filling in of marshy shorelines and cutting off of spawning marshes for purposes of cottage and resort development, or by highways, have probably depleted more pike populations than overfishing or spearing ever have done." Nineteen years later our fishing regulations are more protective, the pike stocks are still declining, and more people than ever are attempting to fill the marshes. Regulations are needed to protect the stocks of pike, but undoubtedly number one priority is still protection of the environment.

Literature cited

Beckman, William C. 1948. The length-weight relationship, factors for conversions between standard and total lengths, and coefficients of condition for seven Michigan fishes. Trans. Amer. Fish. Soc., 75: 237-256.

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

Beyerle, George B. 1971b. Management of an impoundment containing a population of slow growing northern pike. Mich. Dept. Nat. Res., D-J Annual Prog. Rept., 1969-1970 (F-29-R-4): 65-70.

Carbine, W. F. 1942. Observations on the life history of the northern pike, Esox lucius L., in Houghton Lake, Michigan. Trans. Amer. Fish. Soc., 71: 149-164.

Carbine, William F. 1944. Egg production of the northern pike, Esox lucius L., and the percentage survival of eggs and young on the spawning grounds. Pap. Mich. Acad. Sci., 29: 123-137.

Christensen, Kenneth E. 1958. A summary of fishing on Houghton Lake, Roscommon County, June 8-September 24, 1957. Mich. Dept. Cons., Inst. Fish. Res. Rept. No. 1540, 6 p.

Christensen, K. E., and J. E. Williams. 1959. Status of the northern pike population in Fletcher Floodwater, Alpena and Montmorency counties, 1948 and 1955-1956. Mich. Dept. Cons., Inst. Fish. Res. Rept. No. 1576, 13 p.

Forney, John L. 1968. Production of young northern pike in a regulated marsh. N. Y. Fish and Game J., 15(2): 143-154.

Franklin, Donald R., and Lloyd L. Smith, Jr. 1963. Early life history of the northern pike, Esox lucius L., with special reference to the factors influencing the numerical strength of year classes. Trans. Amer. Fish. Soc., 92(2): 91-110.

Frost, W. E., and C. Kipling. 1967a. Removal of pike (Esox lucius) from Windermere and some of its effect on the population dynamics of that fish. Proc. Third British Coarse Fish Conf., p. 53-56.

Frost, Winifred E., and Charlotte Kipling. 1967b. A study of reproduction, early life, weight-length relationship and growth of pike, Esox lucius L., in Windermere. J. Anim. Ecol., 36: 651-693.

Groebner, James F. 1964. Contributions to fishing harvest from known numbers of northern pike fingerlings. Minn. Dept. Cons. Invest. Rept. No. 280, 16 p.

Hubbs, Carl L. 1934. The problem of winter versus summer fishing in Otsego Lake, Otsego County. Mich. Dept. Cons., Inst. Fish. Res. Rept. 245, 5 p.

Johnson, Fritz H., and Arthur R. Peterson. 1955. Comparative harvest of northern pike by summer angling and winter darkhouse spearing from Ball Club Lake, Itasca County, Minnesota. Minn. Dept. Cons. Invest. Rept. No. 164, 11 p.

Johnson, Leon D. 1969. Food of angler-caught northern pike in Murphy Flowage. Wisc. Dept. Nat. Res. Tech. Bull. No. 42, 26 p.

Johnson, Merle W., Warren J. Scidmore, Jerome H. Kuehn, and Charles R. Burrows. 1957. Status of the northern pike fishery in Minnesota. Minn. Dept. Cons. Invest. Rept. No. 178, 10 p.

Kipling, Charlotte, and Winifred E. Frost. 1970. A study of the mortality, population numbers, year class strengths, production and food consumption of pike, Esox lucius L., in Windermere from 1944 to 1962. J. Anim. Ecol., 39(1): 115-157.

Laarman, Percy W. 1963. Average growth rates of fishes in Michigan. Mich. Dept. Cons., Inst. Fish. Res. Rept. No. 1675, 9 p.

Lawler, G. H. 1961. Heming Lake experiment. Fish. Res. Bd. Canada, Prog. Rept. Biol. Sta. and Tech. Unit, London, Ontario, No. 2: 48-50.

Lawler, G. H. 1965. The food of the pike, Esox lucius, in Heming Lake, Manitoba, J. Fish. Res. Bd. Canada, 22(6): 1357-1377.

Miller, R. B., and W. A. Kennedy. 1948. Pike (Esox lucius) from four northern Canadian lakes. J. Fish. Res. Bd. Canada, 7(4): 190-199.

Montén, E. 1950. Studier över yngelförlusternas orsaker i fria vatten och i dammer. (II). Skr. ut. av Södra Sver. Fiskeriför., 1949: 20-101.

Rawson, D. S. 1932. The pike of Waskesiu Lake, Saskatchewan. Trans. Amer. Fish. Soc., 62: 323-330.

Ricker, W. E. 1958. Handbook of computations for biological statistics of fish populations. Fish. Res. Bd. Canada, Bull. No. 119, 300 p.

Schneider, James C. 1971. Characteristics of a population of warm-water fish in a southern Michigan lake, 1964-1969. Mich. Dept. Nat. Res., Research and Development Rept. No. 236, 158 p.

Snow, Howard. 1958. Northern pike at Murphy Flowage. Wisc. Cons. Bull., 23(2): 15-18.

Threinen, C. W., Clarence Wistrom, Bert Apelgren, and Howard Snow. 1966. The northern pike, its life history, ecology and management. Wisc. Cons. Dept. Publ. No. 235, 16 p.

Vessel, Matt F., and Samuel Eddy. 1941. A preliminary study of the egg production of certain Minnesota fishes. Minn. Dept. Cons. Invest. Rept. No. 26, 20 p.

Wesloh, Merlyn L., and Donald E. Olson. 1962. The growth and harvest of stocked yearling northern pike, *Esox lucius* Linnaeus, in a Minnesota walleye lake. Minn. Dept. Cons. Invest. Rept. No. 242, 9 p.

Williams, John E. 1952. Northern pike management. Mich. Cons., 21(2): 5-7, 33.

INSTITUTE FOR FISHERIES RESEARCH

W. C. Latta

Report approved by G. P. Cooper

Typed by M. S. McClure

Table 1.--Computation of yield for a typical population of northern pike in Michigan

Age group	Month	Total length (inches)	Weight (ounces)	Growth rate g	Natural mortality rate q	Fishing mortality rate p	Weight of stock (pounds)	Yield (pounds)
0	Oct	10.2	3.3	0.457	0.143	0.0	1,000	-
I	Apr	11.3	5.2	0.884	0.570	0.0	1,369	-
I	Oct	15.6	12.6	0.182	0.143	0.0	1,874	-
II	Apr	16.4	15.1	0.507	0.570	0.0	1,948	-
II	Oct	19.4	25.0	0.095	0.143	0.0	1,829	-
III	Apr	20.0	26.6	0.322	0.570	0.520	1,744	664
III	Oct	22.2	38.1	0.077	0.143	0.520	809	328
IV	Apr	22.7	41.0	0.247	0.570	0.520	450	167
IV	Oct	24.6	52.6	0.049	0.143	0.520	194	78
V	Apr	25.0	55.4	0.182	0.570	0.520	105	38
V	Oct	26.5	66.5	0.058	0.143	0.520	42	17
VI	Apr	27.0	70.7	0.207	0.570	0.520	23	8
VI	Oct	28.9	87.3	0.095	0.143	0.520	10	4
VII	Apr	29.7	95.6	0.300	0.570	0.520	5	2
VII	Oct	32.7	129.0	0.010	0.143	0.520	2	1
VIII	Apr	32.8	130.6	0.049	0.570	0.520	1	0
VIII	Oct	33.4	137.0	0.113	0.143	0.520	0	0
IX	Apr	34.5	153.2	0.351	0.570	0.520	0	0
IX	Oct	38.7	218.0	0.020	0.143	0.520	0	0
X	Apr	38.9	221.4	0.058	0.570	0.520	0	0
X	Oct	39.6	235.0	-	-	-	0	-
							Total	1,307

Table 2.--Reported mortalities for northern pike

Water	Author	Mortality Total a	Natural v	Fishing u
Mill Lake Michigan	Schneider, J. C. 1971	-	0.56	-
Grebe Lake Michigan	Patriarche, M. H. 1971 (unpublished data)	-	0.43	0.12-0.23
Murphy Flowage Wisconsin	Snow, H. 1958	0.76	0.44	0.32
Wisconsin waters	Threinen, C. W. et al. 1966	-	-	0.50
Lake Windermere England	Kipling, C. and W. E. Frost 1970	-	0.26-0.30	-
Lake George Minnesota	Groebner, J. F. 1964	0.65	0.51	0.14
Nokay Lake Minnesota	Groebner, J. F. 1964	0.71	-	-
Grove Lake Minnesota	Groebner, J. F. 1964	0.73-0.88	-	0.32-0.49
Lake Francis Minnesota	Groebner, J. F. 1964	0.77	-	-
Ball Club Lake Minnesota	Johnson, F. H. and A. R. Peterson. 1955	0.60	0.37	0.23
Grace Lake Minnesota	Wesloh, M. L. and D. E. Olson. 1962	-	-	0.22-0.28
Fletcher Flood-water, Michigan	Christensen, K. E. and J. E. Williams. 1959	-	-	0.38

Table 3.--Age and size of northern pike at maturity

Locality Author and date	Males		Females	
	Age (years)	Length (inches)	Age (years)	Length (inches)
Wisconsin waters Threinen, C. W. et al., 1966	2	16.0-18.0	3	20.0-22.0
Houghton Lake, Michigan Carbine, W. F. 1942	-	12.3-26.6 [a] 21.2	-	19.1-37.5 23.5
	-	12.1-26.8 19.8	-	15.1-35.9 23.2
Great Bear Lake, Canada Miller, R. B. and W. A. Kennedy 1948	5	15.3	6	17.8
Waskesiu Lake, Canada Rawson, D. S. 1932	-	-	4	18.0
Lake Windermere, England Frost, W. E. and C. Kipling 1967b	2	14.9	2	16.3

[a] Range and mean size of pike in the spawning runs of 1939 and 1940.

Table 4.--Survival of northern pike from the egg to emigration from the marsh

Water	Author	Year	Per cent survival
Houghton Lake Michigan	Carbine, W. F. 1944	1939	0.18
		1940	0.07
		1942	0.44
Lake George Minnesota	Franklin, D. R. and L. L. Smith, Jr. 1963	1956	4.62
		1957	0.30
		1958	0.08
Swedish Lake	Montén, E. 1950	1948	0.63
Oneida Lake	Forney, J. L. 1968	1964	4.10
		1965	3.16
		1966	2.79

Table 5. --Percentage of northern pike harvested in winter and summer, by spearing and angling

Locality Author and date Years involved	Percentage harvest Summer angling	 Winter spearing	 Winter angling	Total hours of fishing	Pike caught Total	 Per 100 hours
Minnesota lakes Johnson et al. 1957 1951-1956	86	12	2	-	-	-
Wisconsin lakes Threinen et al. 1966	50	←50→		-	-	-
Devoe Lake, Michigan Patriarche (unpubl. 1971) 1963-1965	76	24	-	6, 148	34	0.6
Grebe Lake, Michigan Patriarche (unpubl. 1971) 1963-1965	45	55	-	1, 562	46	2.9
Fletcher Floodwater, Michigan Beyerle, 1971b 1948-1956	54	46	-	232, 840	41, 560	17.8
Fletcher Floodwater, Michigan Beyerle, 1971b 1963-1965	82	0	18	295, 177	71, 997	24.4
Houghton Lake, Michigan Christensen, 1958 1956-1957	36	0	64	786, 000	51, 140	6.5
Bear Lake, Michigan Inst. Fish. Res. files 1952-1953	75	12	13	69, 959	472	0.7
Bear Lake, Michigan Inst. Fish. Res. files 1964-1965	68	24	8	68, 875	2, 429	3.5

(continued, next page)

Table 5.--concluded

Locality Author and date Years involved	Percentage harvest			Total hours of fishing	Pike caught	
	Summer angling	Winter spearing	Winter angling		Total	Per 100 hours
Fife Lake, Michigan Inst. Fish. Res. files 1952-1953	57	22	21	61,797	1,466	2.4
Fife Lake, Michigan Inst. Fish. Res. files 1964-1965	38	41	22	28,646	976	3.4
Duck Lake, Michigan Inst. Fish. Res. files 1959	38	56	6	61,108	379	0.6
Fine Lake, Michigan Inst. Fish. Res. files 1957	64	5	31	29,651	50	0.2
Sugarloaf Lake, Michigan Inst. Fish. Res. files 1959	42	56	2	23,375	194	0.8

Table 6.--Yield and biomass of northern pike in Michigan under different size limits and exploitation rates

Minimum size limit	Percent exploitation Winter	Percent exploitation Summer	Biomass in spring (pounds)	Yield (pounds)
16 inches	30	30	823	1,694
	49	49	240	2,003
20 inches	0	30	2,977	1,119
	0	49	2,328	1,538
	18	30	2,553	1,237
	32	49	2,040	1,589
	30	30	2,329	1,307
	49	49	1,917	1,633
	0	49	2,329	1,538
	0	70	1,917	2,187
22 inches	30	30	2,728	1,083
	49	49	2,234	1,347
∞ inches[1]	0	0	5,187	0

[1] No fishing; thus no harvest.

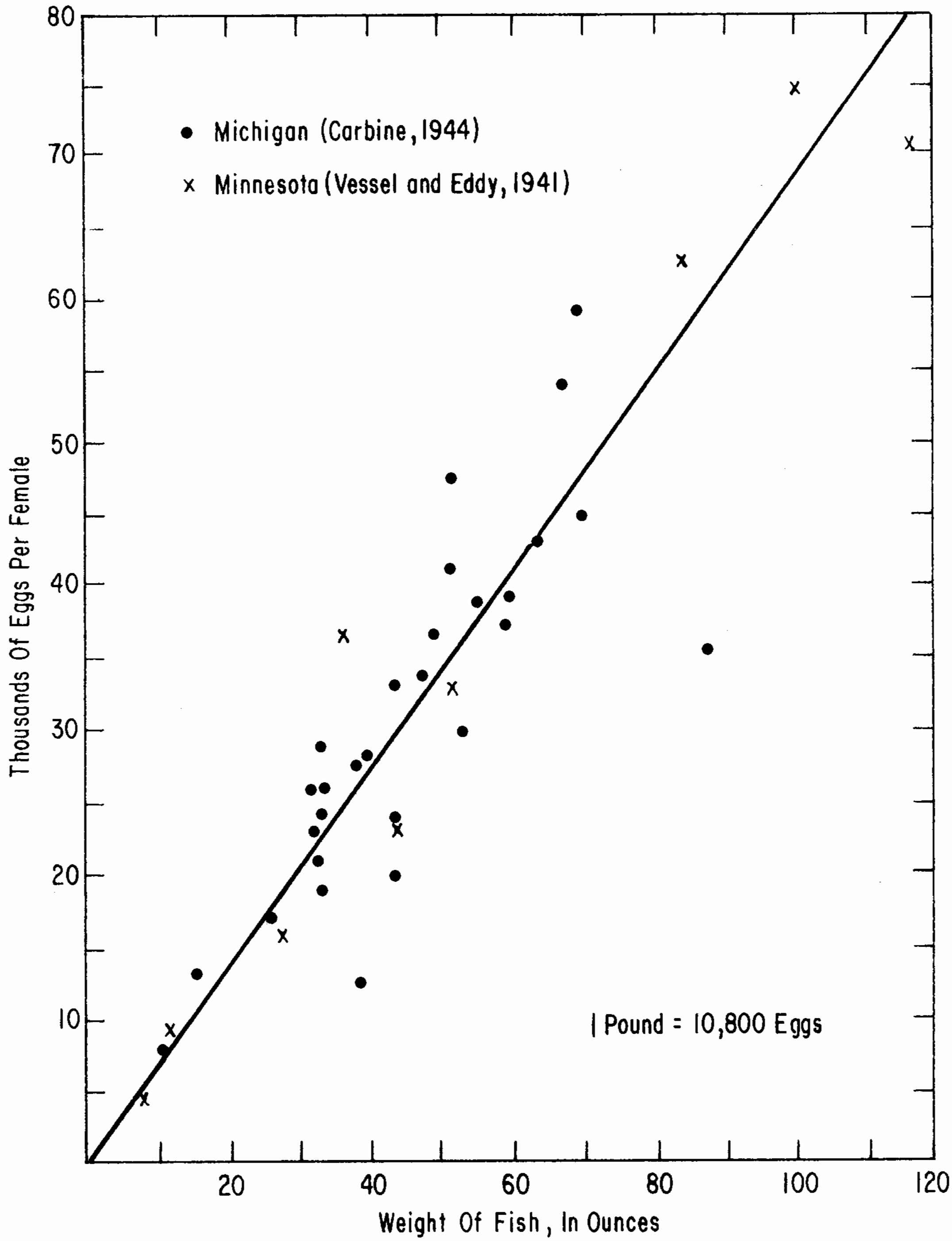

Figure 1. Relationship between number of eggs and weight of female northern pike.

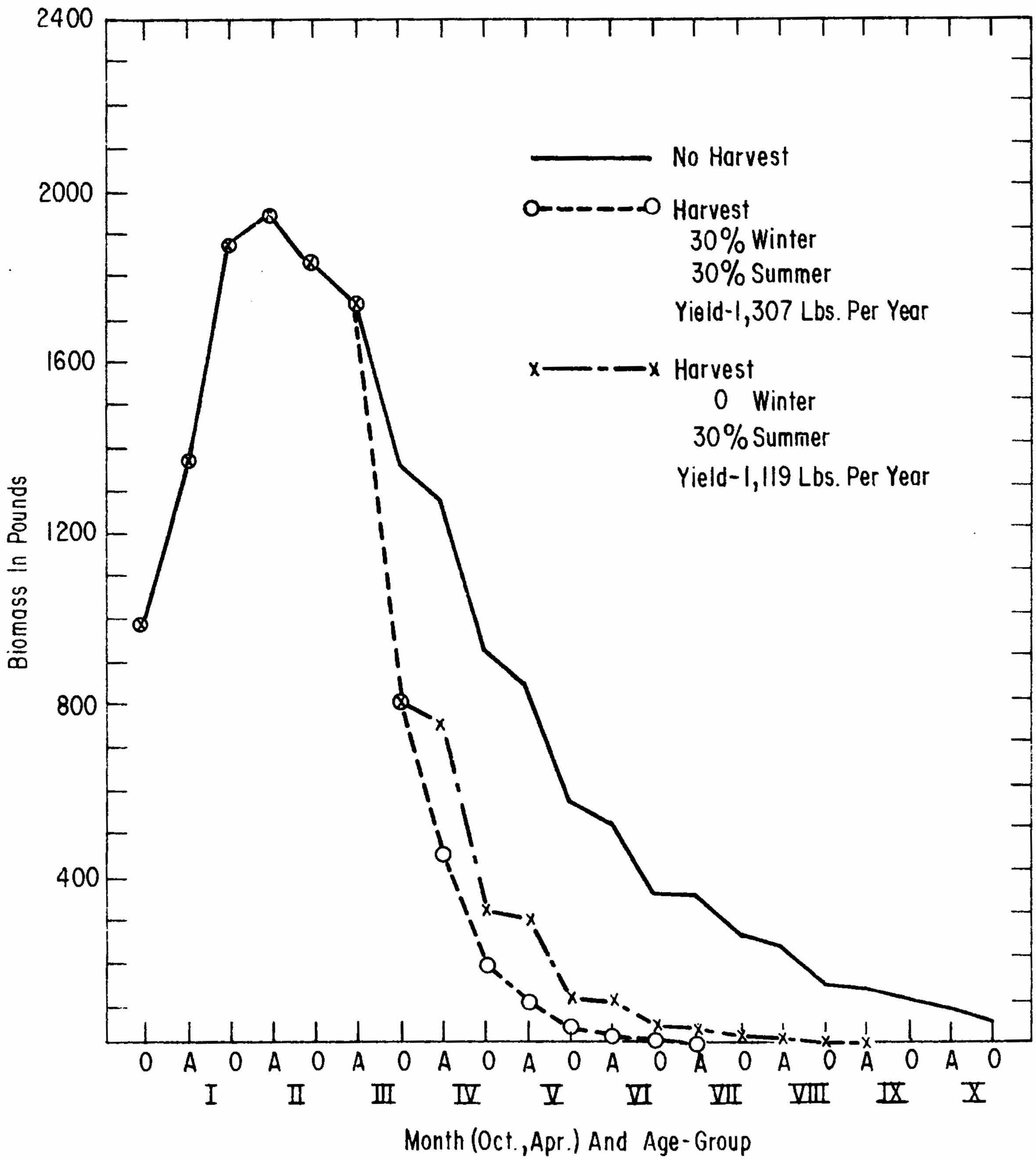

Figure 2. Biomass of northern pike in a typical population in Michigan without harvest, and with harvest at a legal length of 20 inches.

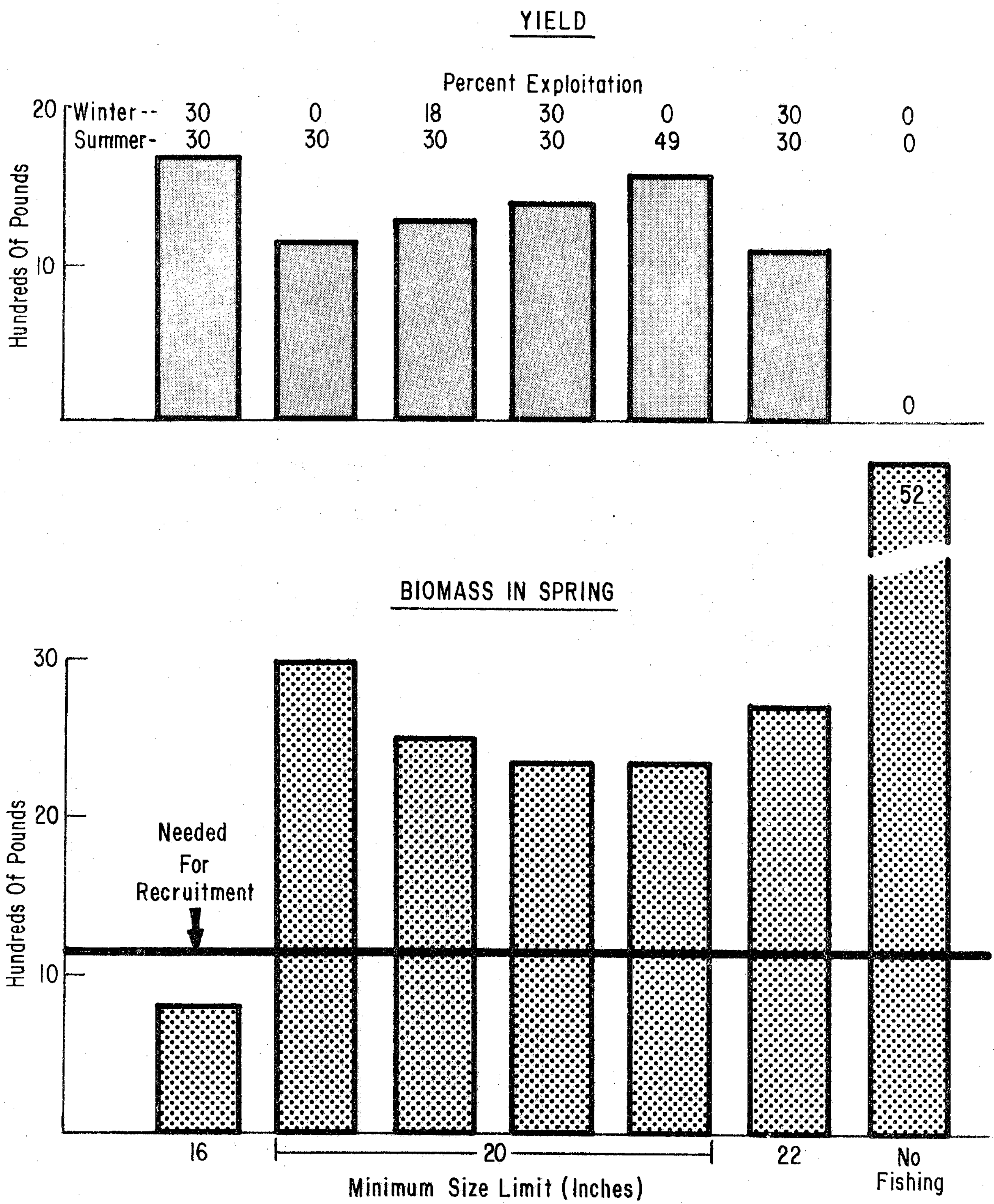

Figure 3. Yield and biomass for a typical population of northern pike in Michigan under different fishing regulations.