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# The Lake Trout Resource in Michigan Waters of Lake Michigan, 1970-1976

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Fisheries Research Report No. 1863
December 26, 1978

MICHIGAN DEPARTMENT OF NATURAL RESOURCES
FISHERIES DIVISION

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# THE LAKE TROUT RESOURCE IN MICHIGAN WATERS OF LAKE MICHIGAN, 1970-76[1]

By Ronald W. Rybicki and Myrl Keller

## Abstract

Reconstruction of the lake trout population in Michigan waters of Lake Michigan began with a planting of 1.07 million yearling lake trout in 1965. Since then 12.5 million lake trout have been stocked in Michigan waters alone. A part of the rehabilitation program has been evaluating the progress of the planted trout. This report presents the results of the evaluation projects during 1970-75, with some information for 1976.

The average annual natural mortality rate of age-V and older lake trout was estimated to be 25%. Annual fishing rates for these age groups in 1975 ranged from 19% in Statistical District MM5 to 47% in MM7 for a lake-wide mean of 30%. The standing crop of age-V and older lake trout in 1975 was estimated to be 254,000 fish.

No natural reproduction by the planted lake trout was found until 1977. This is believed to be due to the tendency of the hatchery-reared lake trout to home as adults to the inshore area of planting, where spawning occurs over unsuitable substrate and chances of egg survival are low. The hypothesis that reproductive failure is caused by environmental contaminants has been tested and rejected. Harvest of lake trout by the sport fishery is not an important factor in limiting natural reproduction because large aggregations of spawning lake trout have been observed for several years.

Movement by most adult lake trout, as determined from tag returns, appeared to be largely within a 20-mile radius of the tagging locality. The tagged fish showed a strong tendency to home to the tagging site during the spawning season.

Mean lengths of present-day lake trout are much greater than in 1947, ranging from 57% larger at age VII to 150% at age III. Because of reports of decreasing growth rates for Michigan salmon and Wisconsin lake trout, there was concern that a similar trend might exist for lake trout in Michigan waters of Lake Michigan. However, we found no consistent pattern to indicate that lake trout have decreased in average size since 1970. Four- and five-year-old lake trout from southern Lake Michigan were of larger average length than those in the middle and northern sectors of the lake; however, the mid-lake and northern stocks were equal to or greater than the southern population at age VI-IX. Southern and mid-lake stocks were slightly heavier than the northern population at the same length.

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[1] Partially supported by National Marine Fisheries Service, Commercial Fisheries Research and Development Act PL 88-309 Project 3-168-R.

The mail creel survey was believed to have overestimated the 1975 sport harvest of lake trout by a factor of 5. Thus the annual catches of lake trout, as determined from the mail survey over the years, may be in serious error. Nevertheless, the surveys were useful in following trends in the sport fishery. The number of sport-caught lake trout increased by nearly 5-fold from 1969 to 1975. The geographical distribution of salmonid catch and angling effort had shifted noticeably from northern to southern Lake Michigan. Since 1970, the percentage of lake trout in the sport catch has progressively increased in those sectors of the lake where the harvest was once dominated by salmon.

## Introduction

Following the extinction of Lake Michigan's lake trout population in the early 1950's and sea lamprey control in the early 1960's, lake trout were reintroduced into Michigan waters of Lake Michigan with a plant of 1.07 million yearling trout in 1965. Annual plants of lake trout have since ranged from 850,000 to 1.2 million and totaled 12.5 million fish through 1976 (Table 1).

Reconstruction of the lake trout population has been a spectacular success from several points of view. First, the technological breakthrough in sea lamprey control paved the way for all of the upper Great Lakes salmonid programs; second, a high degree of cooperation was established between state and federal agencies relative to program maintenance and problem solving; third, the anglers' catch increased 5-fold from 1969 to 1975; fourth, lakeside businesses and others have reaped economic benefits because of Lake Michigan's salmonid populations, of which lake trout are a very important part; fifth, because of the salmonids in Lake Michigan, attention has been focused on environmental contaminants, particularly chlorinated hydrocarbons; and sixth, predatory species like trout have utilized the overabundant prey populations of alewife and smelt.

Success was also accompanied by several problems, such as: (1) frequent disregard by sports fishermen for creel limit and snagging regulations, (2) a potential health hazard to the angler from eating contaminated fish, (3) dissatisfaction among the commercial fishermen over the exclusive allocation of the lake trout stocks to the sport fishery, and (4) failure of the lake trout to reproduce in Lake Michigan, though reproduction of unknown magnitude did occur in Grand Traverse Bay in 1977.

Included in the lake trout rehabilitation program in Michigan waters of Lake Michigan was the evaluation of progress of the planted stocks. This report is a melding of a series of evaluations conducted during 1970-75. Major topics discussed are mortality rates, natural reproduction, migratory patterns, food, growth, and the sport fishery.

## Methods

Information on lake trout mortality rates, food habits, and growth was provided by gill-net catches at index stations in 1970-75. Sampling of fish populations at index stations in Statistical Districts MM1, MM3, and MM4 was initiated in 1970, but was not begun until 1971 in MM5 and 1972 in MM6, MM7, and MM8 (Fig. 1).

During 1970-73, a standard gill-net gang consisted of two nets, each with eight 300-foot nylon panels, 6 feet deep, with mesh sizes from 2.5-6.0 inches (interval of 0.5 inch, extension measure); the mesh sizes were sequenced from small to large; and each half of the standard gang contained a full complement of mesh sizes. Two replicate sets of standard, gill-net gangs were made at approximately the same date and location at each index station each year. The set usually began at a depth of 15 feet, extended across the contour to whatever depth could be reached in 4800 feet of net, and was fished for 24 hours. This type of set did not allow for prevailing environmental conditions and resulted in highly erratic catch data between years at the same station. Thus, target fishing for a particular species according to its temperature preference was initiated in 1974. An additional refinement reduced the length of the standard gang from 4800 feet to 2400 feet, but increased the number of replications from two to four.

Since 1965, lake trout for each annual plant were marked with a fin clip to denote fish of hatchery origin and the year planted. Until recently, the clip was repeated about every third year. Eventually, an overlap in growth between year classes bearing the same clip made it difficult to separate them on the basis of length frequency. Thus, beginning in 1974, lake trout caught at index stations were scale sampled for age determination. Aging lake trout beyond the fifth or sixth year by scale analysis alone was difficult; however, aging the fish by both scale and fin clip allowed assignment to the proper year class.

The catch-per-unit-of-effort (CPE) data in Table 2 are the basis for survival rate estimates. CPE is defined as the number of lake trout caught per 1000 feet of graded-mesh gill net. These CPE's are the means of CPE's obtained in two consecutive years. Mean CPE's were not calculated for lake trout at the St. Joseph station. Two consecutive years were not available there because trout were not indexed in 1974. Means rather than CPE's for individual years were used because the former provided more consistent results. Adjusting each year-class CPE for the number planted caused erratic results, and therefore they were not used to estimate survival rates.

Weighted mean survival rates "s" for age-V and older lake trout in each Statistical District were calculated from the equation:

$$\hat{s} = \frac{N_{2+ \ldots} N_n}{N_{1+ \ldots} N_{n-1}}$$

"N" is the mean CPE for each age group. In most cases, the survival-rate calculation began with 5-year-old lake trout because that is the modal age at which the fish enter the sport catch; the exception was in the Grand Haven area where 3- and 4-year-old lake trout were dominant in the sport fishery. Since the survival rate pertains to the year previous to the time the CPE's were obtained, the rates given in Table 3 differ in time frame by t-1 from the year in which the CPE data were collected; the exception is the survival rate at the Frankfort station where the indexing was done at the close of the fishing season in the fall of 1975, so that the survival rate pertains to 1974-75.

An estimate of natural mortality was derived from the intercept of the relationship between instantaneous total mortality rates and sport fishing effort (Fig. 2). The instantaneous total mortality rates were computed from the survival rates given in Table 3. Effort is the mean number of angler days expended for salmonids in the open water in each of Statistical Districts MM3-MM7 in the years which match those years given for survival rates in Table 3. Statistical District MM1 was omitted from the analysis because the relatively small amount of angling effort (25,000 angler days) could not have resulted in a mortality rate of 92%. Though effort was not expended exclusively on lake trout, total salmonid angler days were used because of strong positive correlations (0.93-0.95) between effort and the number of lake trout caught in each statistical area for each year 1973-75; the catch-effort relationship in each of the years 1970-72 was weakly correlated. This is due to the progressive increase in importance of lake trout in Statistical Districts MM5-MM8, where a large proportion of the effort prior to 1973 had been directed primarily at salmon, and the lake trout catch was small compared to the effort. In contrast, MM3 and MM4 were, and still are, popular areas for lake trout angling.

To assess migratory and homing patterns, 4,081 adult lake trout of hatchery origin were tagged and released at Charlevoix in October-November 1973, and 2,892 in October 1974. These fish were captured in trap nets set near the Charlevoix pier heads for spawn-taking purposes. In 1973, the fish were marked with the Floy FT-2 (single-barbed dart) and the Floy FD-6P-B (anchor) tags; in 1974, only the latter type was used. All fish were anesthetized with MS-222 before tagging and treated with malachite green before release.

Annual catches in 1969-75 by sport fishermen were obtained through a questionnaire mailed to randomly selected holders of fishing licenses. Unlike other mail surveys conducted at the end of the fishing season during that period, the 1974 census was designed to sample the angler population on a quarterly basis. However, the quarterly census was suspected of overestimating effort and catch. Thus in 1975, both quarterly and annual sampling schemes were used, and the former was found to overestimate effort by 30% and the lake trout catch by 34%. The 1974 catch-effort data were adjusted accordingly and are used in this report.

Scientific and common names of all species of fish referred to in this report are presented in Appendix Table A, and taken from Special Publication No. 6 of the American Fisheries Society (Bailey et al. 1970).

## Results

### Survival/mortality rates

The weighted mean survival rates of lake trout shown in Table 3 ranged from a low of 8% at the St. Martin's Island index station in Green Bay (MM1) to a high of 71% in Grand Traverse Bay (MM4). There is an intensive gill-net fishery for whitefish in the vicinity of St. Martin's Island,

and it is believed that this fishery was largely responsible for the dismal survival of lake trout in the area. Survival of lake trout beyond age IX is slight, as suggested in Table 2. Furthermore, the 1964 and 1965 year classes were virtually extinct by 1974.

Natural mortality of lake trout vulnerable to the sport fishery was derived from the relationship of instantaneous total mortality rate and effort shown in Figure 2. The intercept value, 0.284, is also an estimate of the average instantaneous natural mortality rate, and corresponds to an annual natural mortality rate of 25%. Webster et al. (1959) estimated an average annual natural mortality rate of 39-47% for lake trout in Cayuga Lake, New York. Sakagawa and Pycha (1971) placed the natural mortality rate of Lake Superior lake trout at 10-20% during the pre-lamprey era. Fry (1952) estimated the natural mortality of lake trout in South Bay, Lake Huron, to be 25% in 1949, and 70% in 1950--the sharp increase being attributed to sea lamprey activity. Our estimate of 25% annual natural mortality is well within the range reported by these workers and appears to be realistic.

Natural mortality rates for unexploited lake trout in the I-IV age bracket for most areas of the lake were lacking. However, trawling CPEs obtained in Good Harbor Bay (Table 2) indicated an annual survival rate of 63% (Table 3), or a natural mortality rate of 37%, for age-II trout. CPEs for IV-year-old lake trout dropped sharply, but this was believed due to gear avoidance rather than a decrease in abundance.

Of special interest to the fisheries resource manager is the rate of fishing mortality. Given natural and total mortality rates, this statistic can be easily computed, as shown in Table 4. Estimated annual fishing mortality ranged from 19% in MM5 to 47% in MM7 (Table 4), and averaged 30% lake wide. Exploitation is expectedly greater in the southern half (MM6-MM8) of the lake because of the proximity to human population centers; nevertheless, the occurrence of such high fishing mortality on such a large body of water is surprising.

The potential impact of the several fishing rates estimated for 1975 on the trout population is shown in Figure 3. Under the various fishing rates, the expected percentage of fish surviving from age V to age X would be: 24% survival at a zero fishing mortality; 8% survival at a 20% fishing mortality;

and 1% at a 45% fishing mortality. Since we detected only a very low abundance of age-X fish, we concluded that the lake trout harvest was large enough to prevent appreciable survival beyond age IX. Although larger lake trout apparently are more vulnerable to lamprey attack than are smaller fish, lamprey wounding in recent years has been relatively light (Table 5) and is not believed to be a critical factor in lake trout survival.

Estimate of standing crop

The standing crop of age-V and older lake trout in Michigan waters of Lake Michigan was estimated by two methods: planting density × annual survival rates, and sport catch/fishing rate. The results obtained from these two techniques are presented in the following subsections:

Planting density × annual survival rate method.--If initial year-class recruitment and survival at successive ages are known, then the numerical size of that year class can be computed by multiplying successive annual recruitment by the survival rate. Summing the number of fish in each year class present in a particular year constitutes the population estimate. In our case, initial year-class recruitment was the number of yearling lake trout planted (usually in April and May) in a given year and Statistical District. The average annual survival rate for age groups I-IV was assumed to be 63% (computed for age II). Annual survival rate for age-V and older lake trout in each Statistical District was obtained from Table 4, column 3 by subtracting the adjusted total annual mortality rate (A) from 1.0. The computational mechanics for estimating the standing stock of age-V and older lake trout in MM3 in 1975 are illustrated in Appendix Table B.

The estimated standing crop of age-V and older lake trout in May 1975 ranged from 29,100 fish in MM5 to 60,700 in MM4, and totaled 254,000 for Statistical Districts MM3-MM8 (Table 6). Although age-X (1965 year class) trout were not found at every station in 1975, they did occur in small quantities in our 1976 index fishing, and therefore were included in the population estimates given in Table 6. None of the 1964 year class has been captured since 1973; hence survival was taken to be zero.

Sport catch/fishing rate method.--If estimates of both the catch (C) and fishing rate (F) are available, then the average standing crop ($\overline{N}$) can be estimated from the equation $\overline{N} = C/F$. The sport-catch data were from a mail creel survey conducted in Michigan in 1975 by Jamsen (1976). The average standing crop (number of age-V and older lake trout) in each Statistical District in 1975 is shown in column 3 of Table 7. Since the bulk of the sport fishing occurs during May through October, the average standing crop represents the average number of lake trout about mid-summer.

Given the average standing crop, the number of age-V and older lake trout at the beginning of the fishing season in May can be estimated from the equation $N = \overline{N}\,(F + M')/A'$. It is assumed that the instantaneous natural mortality rate (M = 0.284) is equally distributed over the year; thus the value of the natural mortality rate (M') for the 6-month period, May to October, is (0.284) (6/12) = 0.142. Total mortality rates (A') for May-October were computed from the equation: $A' = 1\text{-}\overline{e}^{\,(F + M')}$.

The estimated standing crop of age-V and older lake trout in each Statistical District at the beginning of the fishing season in May 1975, is given in column 7 of Table 7. These estimates range from 157,000 lake trout in MM7 to 277,000 in MM4, and totaled 1,402,000 fish.

Comparisons between the population estimates computed from the two methods revealed vast differences. The standing stock estimates based on the sport catch/fishing rate relationship were greater than those calculated from the planting density × survival method by factors ranging from 4.3 in MM3 to 9.8 in MM5, and was 5.5 for the lake as a unit (Table 8). These differences likely are due to a positive bias in the catch data. Questionnaire-type creel surveys tend to overestimate catch for a variety of reasons, several of which are: memory recall, misidentification of the fish, and failure of unsuccessful fishermen to respond. Eshenroder (pers. Comm.) found that the Michigan mail creel survey estimates for brown trout in Thunder Bay, Lake Huron, exceeded those obtained from field censuses by factors of 5.9 and 8.8 in 1975 and 1976, respectively.

Similar comparisons by Eshenroder for perch in Saginaw Bay, Lake Huron, also revealed that the mail surveys overestimated the field censuses by ratios of 5.0 and 20.0 in 1975-76. Carline (1972) reported that catch estimates obtained from a postcard survey were double those derived from a companion field census on two brook trout ponds in Wisconsin. That the standing stock estimates based on the C/F ratio were in serious error was also indicated by the unrealistically large survival rate (96% average) required from plant-out as yearlings until recruited to the fishery at age V to match the stock estimates.

Thus we concluded that the standing crop of age-V and older lake trout in Lake Michigan in 1975 was on the order of 254,000 fish, and that the mail creel survey in 1975 overestimated the lake-wide lake trout harvest by a factor 5.

## Reproduction

No known reproduction of lake trout in Lake Michigan occurred prior to 1976 (since their extinction in the early 1950's) although substantial numbers of mature lake trout have been present since 1970.[2] Extensive trawling and gill netting only produced trout of hatchery origin. A few live lake trout eggs were found on several inshore reefs, but efforts to collect fry have been fruitless (Wagner 1974; Stauffer and Wagner 1975, 1976). Various hypotheses have been advanced to account for this apparent reproductive failure. These include:

1. Eggs of Lake Michigan lake trout are not viable because of contaminants. This hypothesis was tested and rejected by researchers at various state and federal institutions. Considerable success was achieved in hatching the eggs under laboratory conditions. Michigan's hatcheries have successfully reared lake trout eggs from Lake Michigan brood stock to yearling size on a production basis. Eggs collected in 1972 from Lake Michigan trout showed survival rates of 72-85% from the green-egg stage to hatching. Stauffer and Wagner (1975, 1976) tested lake trout eggs from Lake Michigan (high in contaminants) against Marquette hatchery

[2] The first evidence of natural reproduction was found in 1977 in Grand Traverse Bay by biologists employed by WAPORA, Inc.

eggs (low in contaminants) for survival in both the hatchery and on artificial substrate in Grand Traverse Bay, Lake Michigan. They tentatively concluded that the contaminants DDT and PCB at the levels tested had no effect on early survival of lake trout.

2. Predation upon lake trout eggs and fry. In May and October, 1973-75, Wagner (1974), Stauffer and Wagner (1976), and Peck (1974, 1975, 1976) examined stomachs of potential predators captured in the areas where spawning concentrations of lake trout were observed. The species checked were alewives, lake chubs, ciscoes, rainbow smelt, suckers, lake trout, spottail shiners, round whitefish, sculpins, and yellow perch. In the three years of sampling, only three lake trout stomachs were found to contain lake trout eggs; no lake trout fry were found. Thus, predation does not appear to be an important source of mortality on either lake trout eggs or fry.

3. Lake trout are spawning in shallow-water inshore areas unsuitable for egg survival. Large concentrations of lake trout appear to be spawning in inshore areas where there is little chance of egg survival because of wave action, sedimentation, and ice build-up. This behavior is thought to be induced by releasing yearling lake trout in shallow waters to which the planted stocks "home" as adults. Attempts were made to assess survival of naturally deposited lake trout eggs by use of a suction pump on inshore reefs near Charlevoix. Each year during 1973-75, a few live eggs were pumped up in November and December, but efforts to collect sac fry and fry in the spring were unsuccessful (Wagner 1974; Stauffer and Wagner 1975, 1976).

All reefs are not necessarily suitable substrate for egg survival. Stauffer and Wagner (1975) described the fate of 12 containers, each filled with 120 pounds of rock and seeded with lake trout eggs, placed offshore in 36 feet of water on Irishmans Reef, 9 miles from Charlevoix: "The first and only lift of containers to determine survival of sac fry was made on 7 May 1975. Scuba divers were able to find only one container. This container was about 50 feet from where it had been placed in December 1974 and was laying on its side. ...The bottom at the planting site was scoured by severe wave action, as evidenced by the disappearance of 11 egg containers...while searching for the lost containers, Scuba divers found evidence of ice scouring of the bottom.... ."

A few mature lake trout were caught on traditional offshore reefs during the spawning seasons of 1973-75. However, evidence of egg deposition was scant. Stomachs from three lake trout captured on Traverse Shoal in Grand Traverse Bay contained lake trout eggs, suggesting that some spawning had occurred in 1973-74 (Peck 1974, 1975). Sampling with an egg pump on various offshore reefs failed to produce lake trout eggs. Stauffer concluded from these reef observations that few lake trout are finding the traditional, offshore spawning grounds.

4. Adult stocks have not yet reached a population density capable of producing detectable levels of natural recruitment. Peck (1974) reported that the abundance of lake trout on Traverse Shoal, Fisherman's Reef, and Dahlia Shoal in October and November 1973, was comparable to, or exceeded, the abundance of present-day, naturally reproducing populations in western Lake Superior. The lack of natural recruitment, then, is not the result of a shortage of spawning lake trout, but rather a dearth of spawners in the right places. Although the sport fishery removes substantial numbers of lake trout, its main effect seemingly has been to decrease the chance of a sufficient number of mature lake trout straying to hospitable spawning sites.

## Movement of tagged lake trout

To assess migratory and homing patterns, 4,081 spawning lake trout were tagged and released at Charlevoix in October and November 1973, and 2,892 in October 1974. These fish were captured in trap nets set near the Charlevoix pier heads for spawn-taking purposes. Tags were returned from four sources: anglers, commercial fisheries, Department survey crews, and miscellaneous. Of these, the sport fishery was by far the best source and accounted for 93-97% of the total returns (Table 9). The total return from the 1973 tagging project was 7%. Nine percent were made within 2 months after release, 66% in 1974, and 25% in 1975. Through December 1975, 3% of trout tagged in 1974 had been reported caught.

The tagged lake trout dispersed rapidly within 2 1/2 months after release in both tagging years. Thirty percent of the returns during October-December were 10 or more miles distant from the tagging site, and 24% were 20 or more miles away. One trout was recaptured 90 miles away from the release site, 45 days after tagging.

Our results indicate that most lake trout do not migrate long distances, although one was recovered 250 miles from the release site 8 months after tagging. Returns for each year at large showed that 72-90% of the recoveries were made within a 20-mile radius of the release locality (Table 10). The data in Table 10 exclude the recaptures reported during the 2 1/2 months immediately following tagging because the newly tagged fish needed time to disperse. In the majority of cases (where there were a reasonable number of recoveries), the greatest proportion of monthly returns came from a radius less than 10 miles from the tagging site. Buettner (1961) observed that more than half of the recoveries of hatchery-reared lake trout, after 2 years at liberty in Lake Superior, were within 25 miles of the planting site. Smith and Van Oosten (1939) reported that 77% of the tag returns of Lake Michigan lake trout came from within 50 miles of the tagging locality. Loftus (1957) noted that 96% of the recoveries of tagged Lake Superior lake trout (river-spawning strain) were made within 30 miles of the release point.

To provide directional perspective to the movement of tagged lake trout, percentage returns according to general area and time period are given in Table 11; combined returns from 1974-75 from the 1973 tagging project are illustrated in Figure 4. The largest annual percentage returns were from the Charlevoix area (0-9 mile zone) and ranged from 57-77%, Grand Traverse Bay ranked second with annual recapture rates ranging from 9-28%.

Monthly percentage recaptures in each year show a strong tendency for the tagged lake trout to return to the general tagging area during the spawning season. The percentage of recoveries (Table 10) progressively increased in the 0-4 mile zone from May-June (59%, 0%, 12%) to September-October (81%, 69%, 70%); concurrently, percentage returns decreased in the 5-mile and greater zones from May-June (40%, 100%, 88%) to September-October (19%, 31%, 30%). It was impossible to distinguish which tagged fish had been planted as yearlings in the immediate Charlevoix area. However, 95% of the adult lake trout tagged at Charlevoix in the fall of 1973 were released as yearlings in the Grand Traverse Bay-Charlevoix-Little Traverse Bay region. Circumstantially, at least, there is a strong possibility that a large proportion of the tagged fish had been planted in the vicinity of Charlevoix. Pycha (1973) reported that hatchery-reared lake trout planted in Lake Superior seemed to return to the areas where they were planted or to similar shore areas.

Food

Lake trout stomachs were sampled systematically in 1966-67 and 1973; cursory examination of stomachs in 1974-75 indicated that the diet was essentially the same as in 1973. Analysis of lake trout stomachs showed that the alewife, smelt, and sculpin were the dominant fish food items. There were some differences in frequency of occurrence of these items in 1973 as compared to 1966-67 (Table 12). Most notably, in northern Lake Michigan, alewife constituted 42% by frequency of the stomach contents of lake trout in the 14.0- to 16.9-inch group in 1966-67, but only 18% in 1973. Smelt and sculpins also comprised smaller proportions of the diet of sampled lake trout in the 17.0-inch and larger size grouping in 1973 than during 1966-67.

Sculpins outnumbered other prey of lake trout smaller than 16.0 inches (Table 13). Smelt and alewife were equally numerous in lake trout of the 16- to 18-inch groups. Alewife was the dominant food item for lake trout 19.0 inches and larger; in the 24- to 31-inch groups, 92% or more of the stomachs contained alewives.

Of the 663 lake trout stomachs examined in 1973, only one contained a chub. During the pre-lamprey era, bloater chubs (*C. hoyi*) were an important forage species for lake trout (Smith 1964). There is no evidence that Lake Michigan lake trout prey upon their own kind, as has occurred among Lake Superior lake trout (Schorfhaar, personal communication).

Growth

Lake Michigan has been stocked heavily with salmon and trout over the past 8 years. There has been some concern that the carrying capacity of the lake for salmonids may be saturated, and this concern was intensified when Michigan (Rybicki and Keller 1974) reported substantial decreases in growth of coho salmon in 1972-73. Wisconsin (Poff 1974) also presented creel census data showing a decrease in growth of lake trout during 1969-73. A summary of lake trout growth data is presented in Appendix Table C. Lengths were examined statistically to determine whether or not such a trend has occurred in our waters of Lake Michigan. The analysis was restricted to Statistical Districts MM1, MM3, MM4, and MM5, where sampling periods were comparable and spanned at least 3 years (Appendix Table D).

There were numerous significant differences in mean lengths of lake trout at a given age between years within a Statistical District. Those years in which mean lengths differed significantly from each other were determined by comparing the confidence limits placed on each mean (Appendix Table E); differences between means were significant if the confidence limits did not overlap. In the three Districts (MM1, MM3, and MM4) for which there were adequate data for age groups III and IV, there was a significant decline in growth from that of previous years in both 1973 and 1974. The trend was reversed by 1975. Growth of older fish in MM3 (age groups V-VII) fluctuated over the 5-year span but by 1975 equaled or exceeded that of 1969, 1971, and 1972--the earliest years in which prior data were available. In MM4, among age groups V-VII, only age-VII fish showed a growth rate superior to that of 1971; 5- and 6-year-old lake trout declined somewhat in mean total length. The reverse happened to these two age groups in MM5. Thus, we conclude there was no widespread decline in average size of lake trout.

The decreases in average length of 4- and 5-year-old lake trout in MM3 and MM4 are the only instances which could be considered a negative trend in growth. However, since no such trend is apparent in age-III or age-VI and older lake trout in MM3 and MM4, it remains to be seen whether the smaller average sizes are of a permanent or transitory nature. Back-calculated growth rates for lake trout showed a strong tendency toward Lee's phenomenon and, therefore, provided no insight about early growth patterns.

Growth comparisons between Districts must be limited to MM1, MM3, and MM4 when all sampling was done in May and June; the data shown in Appendix Table E for MM5 were obtained in the fall. By 1975, the mean lengths of age groups IV-VII were significantly greater in MM3 than MM4 and, likewise, 4-year-old fish in MM3 were significantly longer than age-IV trout in MM1. In prior years, too, lake trout in MM3 frequently exceeded the growth of those in MM4.

The average size of lake trout at a given age is much greater now than that during the pre-lamprey era. Van Oosten (1959) published growth data for lake trout captured in southern Lake Michigan in 1947, and these data were compared to growth statistics obtained in the same area in 1972 (Table 14). The percentage increases in average weight from 1947 to 1972 ranged from 57% at age VII to 150% at age III. The cause of the disparity between present and past growth rates is a matter of conjecture. Possibly there existed a greater population density of lake trout in the area in 1947 than in 1972. Differing genetic strains of past and present lake trout populations also have been suggested as appotential factor. Although the population density theory cannot be tested, differences due to genetic strains can be examined indirectly.

Lake trout planted in Lake Michigan originated essentially from Lake Superior and a Green Lake brood stock, although several experimental plants of lake trout obtained from Clear Lake, Manitoba, were made in recent years. The Green Lake brood stock originated from eggs collected from lake trout in Green Lake, Wisconsin, in the fall of 1959. The ancestry of these brood fish goes back to lake trout spawn obtained from southern Lake Michigan prior to 1944, were hatchery-reared, and planted in Green Lake. In 1966, progeny of the Green Lake strain were marked with a dorsal-right ventral fin clip and planted in the Ludington area. In 1967, the same strain of lake trout was planted in southern Lake Michigan at New Buffalo and Port Sheldon and marked with an adipose clip. Plants of the Green Lake strain have been made since then, but are indistinguishable from the Lake Superior strain as both bear the same clip.

The mean lengths and weights at capture of the Green Lake and Lake Superior strains of the 1965 and 1967 year classes are compared in Table 15. Although the plantings were not paired, in most cases there were enough stray fish of the Superior strain to compare average sizes. Only for age-VI trout (1967 year class) was the length and weight of the Superior strain significantly larger ($P < 0.05$). The Green Lake strain was significantly larger in length (but not weight) at age VIII. Thus, these data do not support the hypothesis that genetic strain is the cause of the difference between past and present average size of lake trout.

Mean lengths of lake trout from the southern, mid-lake, and northern sectors of Lake Michigan in June 1975 are compared in Table 16. New growth had not yet begun for the lake trout sampled in the mid-lake and northern areas in June. However, the southern sector was sampled in late July at which time new growth had started, requiring that length be back-calculated to June. Lengths back-calculated to the most recently formed annulus were not detectably influenced by Lee's phenomenon. At ages IV and V, southern Lake Michigan lake trout were significantly larger than the northern group. However, the length gap closed quickly. Differences in mean lengths within age groups VI-VII were not significant at the 95% level; northern and mid-lake 8-year-old trout were of similar size but both were significantly larger than the southern stock. There were no significant differences in the average length of 9-year-old lake trout. Length-weight relationships for the three geographically separated populations are shown in Figure 5. The southern and mid-lake stocks tend to be slightly heavier than the northern population at the same length. Mean length and weight curves at several ages for all areas combined are shown in Figure 6, and represent average size at approximately mid-summer.

## Sport fishery

The lake trout presently are the bread-and-butter fish of the Lake Michigan sport fishery, despite the fact that their fighting qualities at the end of a line are less spectacular than those offered by other members of the salmonid family. The popularity of the lake trout is attributable largely to their consistent availability during the entire fishing season, whereas the availability of the other salmonids fluctuates widely over the fishing season.

Trolling for lake trout in the Great Lakes began as a commercial venture on Lake Superior at Munising in 1926 (Van Oosten 1959). Sport trolling for the species originated on Grand Traverse Bay in 1928 and ceased in the early 1950's with the extinction of the lake trout stocks. Appropriately, the lake trout sport fishery on Lake Michigan was resurrected in 1968 on Grand Traverse Bay. Trolling still remains the primary method of catching lake trout on the Great Lakes, although spin-casting from shore, piers, and breakwaters produces trout during the spring and autumn when the fish are in shallow water. The modern-day lake trout fishery uses highly sophisticated gear. Many boats are equipped with sensitive fish finders, electronic thermometers, ship-to-shore radios, downriggers, and a vast assortment of tackle. Fishing with wire line is still done to some extent but is rapidly giving way to the downrigger--an ingenious creation by Michigan anglers for efficiently getting a lure down to the precise fishing depth. There is a release mechanism attached to a 7- to 10-pound lead ball lowered by the downrigger which allows the angler to land the fish free of weights.

At some locations on Lake Michigan, lake trout fishing opportunities exist almost every month of the year, either for open-water trolling or ice fishing. The fishery expanded rapidly, and has become established at nearly every port or locality where suitable harbor facilities are available within a reasonable distance of the lake trout grounds.

Catch and effort

Earlier in this report (p. 10) we concluded that the mail creel survey overestimated the total lake trout catch by a factor of 5 in 1975. That conclusion naturally casts doubt on the validity of the other mail surveys conducted prior to 1975. However, we were uncertain as to whether or not the error factor calculated for the 1975 lake trout catch in each Statistical District (Table 8) was constant over the years; consequently we elected not to revise the mail creel survey estimates. Although the previous estimates probably were in serious error, the value of those surveys was that it allowed us to follow trends in the sport fishery. The following presentation should be viewed accordingly.

The lake-wide trend in the lake trout catch in Michigan's waters of Lake Michigan during 1969-1975 generally was one of increasing harvest--89,000 in 1969 to 426,000 in 1975 (Table 17), almost a 5-fold increase. The trend line shown in Figure 7 suggested that the lake trout fishery may have entered a period of stability beginning in 1975, at perhaps a total harvest of 400,000-450,000 fish annually. However, major shifts in lake trout population density (e.g., due to natural recruitment, stocking policy, regulations, or economic conditions) could affect that projected level of stability. Also apparent are the small numbers of lake trout caught in MM1, MM2, and along the north shore (Mackinac County) of MM3. There are several factors which may account in large measure for the low catch of lake trout in these Districts.

In MM1, the lake trout population is at a very low density and this condition alone would preclude the development of a lake trout sport fishery. However, there is yet another factor which dampens the prospect of ever establishing an attractive lake trout fishery in MM1. This District simply is not suitable lake trout habitat because of its shallow depth, with the exception of small areas around Minneapolis Shoal and St. Martin's Island. Historically, Michigan waters of outer Green Bay contained populations of lake whitefish, ciscoes, and some lake trout, while the Bays de Noc were noted for walleye, yellow perch, northern pike, and smallmouth bass.

Planting density has been minimal in MM2 with a total planting of only 175,000 lake trout consisting of two year classes--certainly not enough to generate a fishery under the best of circumstances. However, given the facts that the nearest summer trout grounds are a minimum distance of 10-12 miles offshore and the low human population density of the area, it is improbable that an extensive sport fishery ever will develop. A large proportion of the angling effort in MM2 is for coho salmon during the early fall. Table 19 shows that coho comprised 51-56% of the catch during 1973-75.

In the northern half of MM3, substantial plantings of lake trout have been made along the north shore (Seul Choix Pt., Naubinway, and Epoufette): 1965 (553,000); 1966 (167,000); 1968 (103,000); and 1970 (100,000). However, the maximum catch and effort were estimated to be only 1,400 lake trout in 1971 (Table 17), and 4,200 angler days in 1974 (Table 18). We believe that the planted lake trout stocks suffered a high mortality rate caused by being taken incidentally in the commercial gill-net fishery for lake whitefish. Although this problem will be largely eliminated by conversion from a gill-net to a trap-net whitefish fishery, a low angler density in this area and limited access facilities preclude development of an extensive sport fishery.

The remaining Statistical Districts (southern half of MM3 through MM8) possess a well developed and highly successful sport fishery for lake trout (Table 17). However, there was a notable shift in the geographical distribution of the lake trout catch during 1969-75. Statistical District MM4 (Grand Traverse Bay), a traditional location for the lake trout sport fishery, declined in dominance from 64% of the annual, lake-wide lake trout harvest in 1969, to 12% in 1975 (Table 17). Although the 1975 catch was still a highly respectable 53,000 fish, it was well below the peak catches of 137,000 lake trout in 1970 and 1971. In contrast, the annual harvest of lake trout in Districts MM6-MM8 since 1973, has equaled or surpassed by a wide margin that in MM4. Also since 1973, the annual catch of lake trout in MM7 has been in excess of 100,000 fish, and this catch comprised 25-32% of the annual harvest.

Angling effort in several of the Statistical Districts also has shown a geographical shift--MM4 has slipped from 20% of the total number of angler days in 1970, to 9% in 1975 (Table 18); MM7 increased from 19% in 1970, to 27% in 1975; and MM8 rose from 12% in 1970, to

21% in 1975. The remaining statistical areas indicated only rather minor fluctuations in the percentage of the total annual fishing effort.

The importance of lake trout to the sport fishery, expressed as percentage species composition of the catch in each Statistical District is shown in Table 19. Lake trout have dominated the species composition in MM3 and MM4, constituting 50-80% of the annual catch. In Districts MM5 and MM6, lake trout have held a slight edge over coho salmon since 1972; prior to 1972, coho clearly were the mainstay of the fishery in these areas. Lake trout displaced coho as the dominant species in the 1972 catch in MM7, and it has held the "post position" since then. Only in MM8 do salmon remain unchallenged. However the lake trout catch increased from less than 8% in 1970-71 to 25-31% during 1973-75. Lake trout have made strong showings in the central and southern sectors of the lake in recent years because trout population densities reached levels attractive to the angler, the fishermen learned how to catch them, and the species was present throughout most of the open-water angling season. In contrast, coho are available for relatively short periods, primarily during the spring (in MM8 only), late summer, and autumn.

## Economic value

There is little information available on the economic value of the lake trout as a sport fish in Lake Michigan. Kapetsky and Ryckman (1973) estimated that $419,000 was spent by anglers in the Grand Traverse Bay (MM4) area from May 1971 through May 1972, because of the Bay's sport fishery. They also estimated that 21.5 full-time equivalent jobs were attributable to the fishery. Since lake trout comprised 67% and 80% of the salmonid catch in the Bay in 1971 and 1972, respectively, it follows that a major share of the economic value generated by the fishery resource was attributable to the lake trout.

Prior to the build-up of the salmonid populations, a Lake Michigan charter boat fishery did not exist. In 1976, the Michigan charter boat directory listed 135 operators, many of whom are largely dependent on the lake trout stocks to sustain their business.

## Discussion and recommendations

The initial objective of the lake trout restoration program was to establish a self-sustaining trout population. The apparent failure of the planted lake trout to perpetuate themselves is the most puzzling aspect of the rehabilitation project. If a put-and-take fishery is an acceptable resource management technique, then natural recruitment is of little concern. However, dependence solely upon the hatchery product is, economically, an expensive method of sustaining the lake trout fishery in Lake Michigan. Therefore, efforts should be continued to achieve the above-mentioned objective.

Fishing mortality is not believed to be an important factor inhibiting natural reproduction because sizable aggregations of spawning lake trout have been observed since 1970. Also, neither contaminant-laden eggs nor predation upon deposited spawn or fry appear to be significant forces limiting natural recruitment. The most probable cause of reproductive failure is the tendency of planted lake trout to spawn over unsuitable substrate because the yearling lake trout were planted in unsuitable spawning habitat to which they home as adults. The obvious solution to the homing problem is to stock the young fish over grounds which will provide the greatest chance of spawning success.

The problem and its solution were recognized several years ago and resulted in lake trout plants being made on two offshore reefs, beginning in 1973, in the Charlevoix and Leland areas. Offshore reef plantings were increased to 11 in 1974 (Table 20), and accounted for 59% of the total number of lake trout planted in MM1-MM5. Of these, South Fox Island Shoal, Trout Island Reef, Millicoquin Reef, Simmons Reef, and Gray's Reef are beyond the sport fishery (Fig. 8). If natural recruitment is to contribute to the sport fishery, either more reefs accessible to the fishery need to be planted with trout or the number of fish planted on those reefs presently stocked should be increased. Both approaches should be used. This could be accomplished easily by reallocating a portion of future inshore plants to the offshore sites. The strategy is not expected to significantly reduce the sport catch during the summer months. However, pier fishermen exploiting inshore spawning lake trout will experience a lower catch rate.

Review of the Charlevoix Federal Hatchery records for the period 1903-44 revealed numerous locations in northern Lake Michigan where lake trout fry were planted, and presumably most of the planting sites were also lake trout spawning grounds. Several additional reefs have been selected for trout plantings from that review. As a matter of reference, a brief narrative of the hatchery records is given in Appendix F.

It is recommended that future lake trout plants be allocated as follows:

1. Lake trout plants in MM1 should be terminated, except for the continuation of an annual planting of 25,000 on Minneapolis Shoal. Surplus fish resulting from the termination of plants in Little Bay de Noc (100,000 in 1976) could be planted in equal numbers on Boulder and Gull Island reefs (Fig. 8). Although inaccessible to the sport fishery, these reefs offer excellent spawning grounds. Alternatively, the surplus could be planted in the southern half of Lake Michigan where there is an intensive sport fishery.

Since 1969, 600,000 lake trout have been planted in Little Bay de Noc with little return to the angler (Table 17). The question, then, is whether efforts should be continued to superimpose a cold-water population on what is essentially warm-water habitat in Little Bay de Noc. Although the possibility exists of establishing a modest fall-winter-spring lake trout fishery, we are of the considered opinion that management efforts in the Bays de Noc would be far more rewarding if they were expended on warm-water species. Lake trout scheduled for Little Bay de Noc could be used more profitably elsewhere.

2. Maintain present planting densities at Seul Choix Pt., Trout Island Shoal, Millicoquin Reef, and Simmons Reef. Divert planting from Gray's Reef to Dahlia Shoal because the former is largely whitefish habitat.

3. Redistribute plant in Little Traverse Bay to two-thirds on Seven Mile Point and one-third on existing inshore sites.

4. Divide equally among Fishermans Island Reef, Cathead Reef, and inshore sites the planting normally scheduled for the inshore Charlevoix area. Continue the Fox Island plant at present density.

5. Allocate Grand Traverse Bay plants equally between the east and west arms, and Old Mission Point Reef. Discontinue planting on Grand Traverse Shoal because historically it has been whitefish territory.

6. Maintain the present stocking schedule in MM5.

7. Maintain the present stocking schedule in MM6-MM8. When traditional spawning grounds are identified in the southern two-thirds of the lake, planting sites should be adjusted accordingly.

8. The present 10.0-inch minimum size limit for creeled lake trout has no biological basis. No female lake trout less than 22.0 inches have been found to be mature, but 77% are mature in the 24.0-inch group (Table 21). The majority of creeled lake trout are at least 23.0 inches or longer in most areas of Lake Michigan. The exception was in MM7 where 40% of 328 sport-caught lake trout in June 1975, were less than 24.0 inches (Trimberger, personal communication). Nearly identical results were obtained in 1976. Although not presently a lake-wide problem, it would be prudent to consider increasing the size limit of creeled lake trout to 24.0 inches <u>before it becomes a widespread problem and opposition to change stiffens.</u> We have no data on the hooking mortality of released fish. However, we do not believe hooking mortality is, or would be, severe.

9. Future mail creel surveys must be designed to obtain specific effort data, and the catch must be monitored systematically to obtain biological data. The planning of management strategies--species mix, planting locations, densities, and regulations--is hindered by a lack of information on the amount of angling effort expended on each of the major salmonid species, and by limited knowledge on the biological aspects of the catch. The Lake Michigan Lake Trout Technical Committee has recommended that all charter boat captains be required to submit catch reports and we support that recommendation.

10. Planting densities of lake trout should not be reduced just to stimulate an increase in growth rate. The present growth rate is good and far greater than that of historical populations.

11. There appears to be little prospect for a commercial harvest of lake trout in Michigan waters of Lake Michigan in the foreseeable future by anyone other than the Indian fishery. The sport fishery is already cutting heavily into the stocks, and it is neither biologically nor economically advisable to add a competing commercial fishery. Levels of PCB in large lake trout continue to remain above the 5 ppm action level established by the Federal Food and Drug Administration, and therefore cannot be sold on interstate markets. If natural reproduction occurs in areas inaccessible to the sport fishery (primarily Simmons Reef, Millicoquin Reef, and Trout Island Shoal), the population reaches exploitable levels, and contaminant levels decrease, then a commercial fishery may be allowed to harvest the surplus production.

## Acknowledgments

M. H. Patriarche, J. R. Ryckman, and T. M. Stauffer gave helpful advice on this manuscript.

Table 1.--Number of lake trout planted in Michigan's waters of Lake Michigan, 1965-1976.

| Year planted | Statistical District and number planted (x $10^3$) | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|
| | MM1 | MM2 | MM3[a] | MM4 | MM5 | MM6 | MM7 | MM8 | |
| 1965 | - | - | 553<br>416 | 101 | - | - | - | - | 1,070 |
| 1966 | - | - | 167<br>261 | 163 | 100 | 165 | 100 | - | 956 |
| 1967 | - | - | 200 | 162 | 102 | 386 | 165 | 102 | 1,117 |
| 1968 | - | - | 103<br>150 | 177 | 117 | 62 | 141 | 100 | 850 |
| 1969 | 100 | 90 | 184 | 69 | 100 | 100 | 133 | 100 | 876 |
| 1970 | 90 | - | 100<br>150 | 150 | 50 | 200 | 135 | - | 875 |
| 1971 | 85 | 85 | 172 | 200 | 70 | 75 | 254 | 150 | 1,091 |
| 1972 | - | - | 200 | 328 | 125 | 150 | 285 | 99 | 1,187 |
| 1973[b] | 85 | - | 283 | 150 | 126 | 155 | 150 | 180 | 1,129 |
| 1974 | 92 | - | 250 | 175 | 100 | 100 | 100 | 100 | 917 |
| 1975 | 127 | 25 | 328 | 175 | 85 | 90 | 245 | 148 | 1,223 |
| 1976 | 125 | - | 341 | 153 | 111 | 150 | 225 | 150 | 1,255 |
| Total | 704 | 200 | 3,858 | 2,003 | 1,086 | 1,633 | 1,933 | 1,129 | 12,546 |

[a] Upper figure is number planted in Mackinac County; lower figure is number planted in Charlevoix and Emmet counties.

[b] See Table 18 for distribution of inshore and offshore plants in 1973-76.

Table 2.--Mean catch per unit of effort (CPE) for lake trout in the Michigan waters of Lake Michigan, according to station and combination of years.

| Index station and years | CPE at age | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | VII | VIII | IX | X |
| Green Bay (MM1) | | | | | | | | | | |
| 1974-75 | -- | 0.54 | 0.04 | 0.01 | -- | -- | -- | -- | -- | -- |
| Little Traverse Bay (MM3) | | | | | | | | | | |
| 1973-74 | -- | -- | -- | -- | 3.44 | 2.40 | 0.89 | 1.77 | <0.01 | 0.00 |
| 1974-75 | -- | -- | -- | -- | 8.59 | 2.34 | 0.89 | 0.99 | 0.16 | 0.00 |
| Grand Traverse Bay (MM4) | | | | | | | | | | |
| 1973-74 | -- | -- | -- | -- | 1.52 | 0.62 | 1.23 | 1.14 | 0.21 | 0.00 |
| 1974-75 | -- | -- | -- | -- | 2.25 | 0.99 | 0.48 | 0.89 | 0.40 | 0.40 |
| Frankfort (MM5) | | | | | | | | | | |
| 1974-75 | -- | -- | -- | -- | 10.57 | 9.58 | 5.43 | 2.34 | 0.00 | 0.10 |
| Good Harbor Bay[a] (MM5) | | | | | | | | | | |
| 1973-76 | 0.55 | 1.14 | 0.72 | 0.12 | -- | -- | -- | -- | -- | -- |
| Manistee (MM6) | | | | | | | | | | |
| 1974-75 | -- | -- | -- | -- | 5.16 | 2.08 | 3.96 | 1.67 | 0.10 | 0.00 |
| Grand Haven (MM7) | | | | | | | | | | |
| 1974-75 | -- | -- | 4.90 | 0.99 | 0.21 | 0.21 | 1.25 | 0.52 | 0.09 | -- |

[a] Geometric mean CPE of four year classes. CPE is number per 10-minute trawl tow.

Table 3.--Estimated mean survival rates for Lake Michigan lake trout, by station, age groups, and index years.

| Station | Index years | Age groups | Weighted mean survival (S) |
|---|---|---|---|
| Green Bay (MM1) | 1973-74 | IV-VI | 0.078 |
| Little Traverse Bay (MM3) | 1972-73 | V-IX | 0.595 |
| | 1973-74 | V-IX | 0.560 |
| Grand Traverse Bay (MM4) | 1972-73 | V-IX | 0.712 |
| | 1973-74 | V-X | 0.559 |
| Frankfort (MM5) | 1974-75 | V-X | 0.625 |
| Good Harbor Bay (MM5) | 1973-76 | II | 0.630 |
| Manistee (MM6) | 1973-74 | V-IX | 0.607 |
| Grand Haven (MM7) | 1973-74 | III-IX | 0.404 |

Table 4.--Adjusted mortality rates of Lake Michigan lake trout in 1975, by Statistical District.

| Statistical District | Number angler days ($x10^3$) | Instantaneous total rate (Z)[a] | Annual total rate (A)[b] | Instantaneous fishing rate (F)[c] | Annual fishing rate (m)[d] |
|---|---|---|---|---|---|
| MM3 | 144.490 | 0.595 | 0.448 | 0.311 | 0.267 |
| MM4 | 106.760 | 0.514 | 0.402 | 0.230 | 0.205 |
| MM5 | 98.430 | 0.496 | 0.391 | 0.212 | 0.191 |
| MM6 | 209.100 | 0.734 | 0.520 | 0.450 | 0.362 |
| MM7 | 296.140 | 0.921 | 0.602 | 0.637 | 0.471 |
| MM8 | 231.880 | 0.783 | 0.543 | 0.499 | 0.393 |

[a] $Z = 0.284 + 0.00215X$; X is number of angler days.

[b] $A = 1-e^{-Z}$

[c] $F = Z-0.284$

[d] $m = 1-e^{-F}$

Table 5.--Incidence of lamprey wounding on lake trout, expressed as a percentage, in Michigan waters of Lake Michigan, 1972-75.[a] Number of fish examined in parentheses.

| Size group (inches) | MM3 to MM5 | | | | MM6 to Indiana | | | |
|---|---|---|---|---|---|---|---|---|
| | 1972 | 1973 | 1974 | 1975 | 1972 | 1973 | 1974 | 1975 |
| 21.0-24.9 | 2.0 (246) | 1.4 (336) | 0.7 (301) | 0.0 (118) | 1.8 (547) | 3.0 (235) | 0.0 (78) | 2.8 (114) |
| 25.0-28.9 | 3.3 (489) | 1.1 (2295) | 1.3 (1995) | 1.6 (123) | 3.6 (1020) | 2.6 (1342) | 0.6 (355) | 1.6 (568) |
| 29.0-32.9 | - | 1.0 - | 2.8 (1154) | 9.7 (31) | - | 3.9 (355) | 0.0 (149) | 3.7 (271) |

[a] Data from Wells (1974, 1975).

Table 6.--Estimated standing crop of age-V and older lake trout in May 1975 in Michigan, by year class and Statistical District. Estimate is based on planting density × survival rates.

| Year class | Age in 1975 | Standing crop (number) | | | | | | Total |
|---|---|---|---|---|---|---|---|---|
| | | MM3[a] | MM4 | MM5 | MM6 | MM7 | MM8 | |
| 1964 | XI | 0 | 0 | NP | NP | NP | NP | 0 |
| 1965 | X | 2,107 | 1,964 | 1,320 | 869 | 249 | NP | 6,509 |
| 1966 | IX | 2,925 | 3,263 | 2,210 | 845 | 652 | 701 | 10,596 |
| 1967 | VIII | 3,974 | 5,963 | 4,163 | 5,070 | 1,400 | 1,504 | 22,074 |
| 1968 | VII | 8,832 | 3,887 | 5,842 | 3,629 | 3,319 | 3,290 | 28,799 |
| 1969 | VI | 13,043 | 14,130 | 4,797 | 15,123 | 8,464 | NP | 55,557 |
| 1970 | V | 27,095 | 31,506 | 11,027 | 11,815 | 25,278 | 23,629 | 130,350 |
| Total | | 57,976 | 60,713 | 29,359 | 37,351 | 39,362 | 29,124 | 253,885 |

[a] Charlevoix and Emmet counties only.

NP = None planted.

Table 7.--Estimated catch, mortality rates, average standing crops ($\bar{N}$) of age-V and older lake trout in Lake Michigan in 1975, and estimated standing crop (N) at the beginning of the fishing season in May 1975. See text for details.

| Statistical District | Number caught by anglers | Average standing crop | Instantaneous fishing rate[a] | F + M' | Total mortality rate (A') | Pre-fishing standing crop |
|---|---|---|---|---|---|---|
| MM3 | 62,400 | 201,000 | 0.311 | 0.453 | 0.364 | 250,000 |
| MM4 | 53,400 | 232,000 | 0.230 | 0.372 | 0.311 | 277,000 |
| MM5 | 40,500 | 191,000 | 0.212 | 0.354 | 0.298 | 288,000 |
| MM6 | 79,600 | 177,000 | 0.450 | 0.592 | 0.447 | 235,000 |
| MM7 | 69,600[b] | 109,000 | 0.637 | 0.779 | 0.541 | 157,000 |
| MM8 | 71,100 | 143,000 | 0.499 | 0.641 | 0.473 | 195,000 |
| Total | 376,600 | 1,053,000 | | | | 1,402,000 |

[a] Shown in Table 2.

[b] The estimated catch was 107,000 but only 65% were age V and older.

Table 8.--Comparison of numerical population estimates derived from the mail survey catch estimates (M) and from planting densities × survival method (S).

| Statistical District | Population estimates (M) | (S) | M/S ratio |
|---|---|---|---|
| MM3[a] | 250,000 | 58,000 | 4.3 |
| MM4 | 277,000 | 60,700 | 4.6 |
| MM5 | 288,800 | 29,400 | 9.8 |
| MM6 | 235,000 | 37,400 | 6.3 |
| MM7 | 157,000 | 39,400 | 4.0 |
| MM8 | 195,000 | 29,100 | 6.7 |
| Total | 1,402,000 | 254,000 | 5.5 |

[a] Charlevoix and Emmet counties only.

Table 9.--Number of recaptures of adult lake trout tagged at Charlevoix in the fall of 1973-74, and percent of returns recaptured by year.

| Year tagged and year recaptured | Anglers | | Department surveys | | Commercial fisheries | | Miscel-laneous | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Num-ber | Per-cent | Num-ber | Per cent | Num-ber | Per-cent | Num-ber | Per-cent | Num-ber | Per-cent |
| 1973 | | | | | | | | | | |
| 1973 (Nov-Dec) | 17 | 7 | 5 | 63 | 2 | 25 | 0 | 0 | 24 | 9 |
| 1974 (Jan-Dec) | 169 | 66 | 3 | 37 | 6 | 75 | 2 | 100 | 180 | 66 |
| 1975 (Jan-Dec) | 68 | 27 | 0 | 0 | 0 | 0 | 0 | 0 | 68 | 25 |
| Total | 254 | | 8 | | 8 | | 2 | | 272 | |
| 1974 | | | | | | | | | | |
| 1974 (Oct-Dec) | 8 | 9 | 0 | 0 | 1 | 100 | 0 | 0 | 9 | 10 |
| 1975 (Jan-Dec) | 80 | 91 | 1 | 100 | 0 | 0 | 0 | 0 | 81 | 90 |
| Total | 88 | | 1 | | 1 | | 0 | | 90 | |

Table 10.--Percentage recoveries of lake trout tagged at Charlevoix according to distance from tagging site, by year and bimonthly periods.

| Year tagged and year and month recovered | Miles traveled from tagging site | | | | | | | | Total number recovered |
|---|---|---|---|---|---|---|---|---|---|
| | 0-4 | 5-9 | 10-19 | 20-29 | 30-39 | 40-49 | 50-59 | 100+ | |
| 1973 | | | | | | | | | |
| 1974 | | | | | | | | | |
| Jan-Feb | 100 | - | - | - | - | - | - | - | 2 |
| Mar-Apr | 50 | - | - | - | - | - | - | 50 | 2 |
| May-Jun | 59 | 8 | 18 | 8 | 2 | - | 2 | 2 | 39 |
| Jul-Aug | 74 | 8 | 9 | 8 | 1 | - | - | - | 100 |
| Sep-Oct | 81 | 3 | 16 | - | - | - | - | - | 32 |
| Nov-Dec | 20 | - | - | 20 | 60 | - | - | - | 5 |
| Total annual percent | 71 | 7 | 12 | 7 | 3 | - | 1 | 1 | 180 |
| 1975 | | | | | | | | | |
| Jan-Feb | - | - | - | - | - | - | - | - | 0 |
| Mar-Apr | 100 | - | - | - | - | - | - | - | 1 |
| May-Jun | - | 33 | 30 | 24 | 12 | - | - | - | 33 |
| Jul-Aug | 72 | 17 | - | 11 | - | - | - | - | 18 |
| Sep-Oct | 69 | - | - | 23 | 8 | - | - | - | 13 |
| Nov-Dec | 50 | - | - | 50 | - | - | - | - | 2 |
| Total annual percent | 36 | 21 | 15 | 21 | 7 | - | - | - | 67 |
| 1974 | | | | | | | | | |
| 1975 | | | | | | | | | |
| Jan-Feb | - | - | - | - | - | - | - | - | 0 |
| Mar-Apr | - | - | - | 50 | - | - | 50 | - | 2 |
| May-Jun | 12 | 24 | 28 | 28 | 4 | - | - | 4 | 25 |
| Jul-Aug | 46 | 32 | 11 | 11 | - | - | - | - | 28 |
| Sep-Oct | 70 | 10 | 10 | 10 | - | - | - | - | 20 |
| Nov-Dec | 66 | - | - | 17 | - | 17 | - | - | 6 |
| Total annual percent | 42 | 22 | 15 | 17 | 1 | 1 | 1 | - | 81 |

Table 11--Percentages of annual recoveries of lake trout tagged at Charlevoix according to location during bimonthly periods. [a]

| Year tagged, year recovered, and area | Months of recovery Jan-Feb | Mar-Apr | May-Jun | Jul-Aug | Sep-Oct | Nov-Dec | Total annual percent |
|---|---|---|---|---|---|---|---|
| 1973 | | | | | | | |
| 1974 | | | | | | | |
| Charlevoix | 100 | 50 | 67 | 82 | 84 | 20 | 77 |
| Grand Traverse Bay | - | - | 13 | 9 | 3 | 20 | 9 |
| Little Traverse Bay | - | - | 13 | 8 | 9 | - | 9 |
| Leland | - | - | 2 | 1 | - | 40 | 2 |
| Other [b] | - | 50 | 5 | - | 3 | 20 | 3 |
| Total number recovered | 2 | 2 | 39 | 100 | 32 | 5 | 180 |
| 1975 | | | | | | | |
| Charlevoix | - | 100 | 36 | 89 | 62 | 50 | 57 |
| Grand Traverse Bay | - | - | 46 | 11 | 15 | - | 28 |
| Little Traverse Bay | - | - | 6 | - | 23 | 50 | 9 |
| Leland | - | - | 12 | - | - | - | 6 |
| Other | - | - | - | - | - | - | |
| Total number recovered | - | 1 | 33 | 18 | 13 | 2 | 67 |
| 1974 | | | | | | | |
| 1975 | | | | | | | |
| Charlevoix | - | - | 40 | 75 | 80 | 66 | 63 |
| Grand Traverse Bay | - | 50 | 40 | 14 | 10 | 17 | 22 |
| Little Traverse Bay | - | - | 8 | 11 | 10 | 17 | 10 |
| Leland | - | - | 8 | - | - | - | 3 |
| Other | - | 50 | 4 | - | - | - | 2 |
| Total number recovered | - | 2 | 25 | 28 | 20 | 6 | 81 |

[a] 4,081 lake trout were tagged in 1973 and 2,892 in 1974.

[b] Garden Island, Irishman's Reef, Arcadia, St. Joseph, Wisconsin.

Table 12.--Percent frequency of occurrence of fish food items in stomachs of lake trout of two size groups from northern and southern Lake Michigan.

| Lake area | Length range (inches) | Years | Percent frequency | | | | Number of trout stomachs |
|---|---|---|---|---|---|---|---|
| | | | Alewife | Smelt | Sculpin | Unidentified | |
| Southern (MM6 and MM8) | 14.0-16.9 | 1966-67 | 37 | 9 | 38 | - | 71 |
| | | 1973 | 30 | 9 | 10 | 12 | 20 |
| | ≥17.0+ | 1966-67 | 60 | - | - | - | 5 |
| | | 1973 | 68 | 4 | 4 | 24 | 229 |
| Northern (MM4) | 14.0-16.9 | 1966-67 | 42 | 14 | 26 | - | 407 |
| | | 1973 | 18 | 27 | 9 | 5 | 24 |
| | ≥17.0+ | 1966-67 | 53 | 27 | 15 | - | 120 |
| | | 1973 | 60 | 3 | 1 | 38 | 200 |

Table 13.--Percentage composition by fish species in the diet of lake trout of various lengths (inches) in Lake Michigan, May-September, 1973.

| Lake trout size group | Number of stomachs examined | Species | | | |
|---|---|---|---|---|---|
| | | Alewife | Smelt | Sculpin | Other[a] |
| 11 | 3 | - | 33 | 67 | - |
| 12 | 2 | 50 | - | 50 | - |
| 13 | 2 | - | - | 100 | - |
| 14 | 10 | 30 | 10 | 60 | - |
| 15 | 20 | 20 | 30 | 50 | - |
| 16 | 14 | 43 | 21 | 36 | - |
| 17 | 18 | 33 | 39 | 28 | - |
| 18 | 17 | 29 | 47 | 24 | - |
| 19 | 9 | 56 | 44 | - | - |
| 20 | 13 | 77 | 15 | 8 | - |
| 21 | 9 | 78 | 22 | - | - |
| 22 | 14 | 57 | 29 | 14 | - |
| 23 | 23 | 70 | 22 | 8 | - |
| 24 | 28 | 93 | 7 | - | - |
| 25 | 72 | 97 | 3 | - | - |
| 26 | 117 | 96 | 4 | - | - |
| 27 | 111 | 96 | 4 | - | - |
| 28 | 90 | 96 | 3 | - | 1 |
| 29 | 52 | 92 | 6 | - | 2 |
| 30 | 35 | 94 | 3 | - | 3 |
| 31 | 4 | - | - | - | - |

[a] Rainbow trout, round whitefish, chubs.

Table 14.--Mean size of lake trout by age group sampled at Montague in October 1947, and August 1972. Total length is in inches; weight in pounds.

| Age group | Year sampled | | | | | | Percentage increase | |
|---|---|---|---|---|---|---|---|---|
| | 1947 | | | 1972 | | | | |
| | Length | Weight | Sample size | Length | Weight | Sample size | Length | Weight |
| III | 12.5 | 0.6 | 12 | 17.1 | 1.5 | 63 | 36.8 | 150.0 |
| IV | 16.6 | 1.5 | 4 | 20.5 | 3.2 | 70 | 23.5 | 113.3 |
| V | 20.7 | 3.0 | 17 | 25.0 | 6.2 | 91 | 20.8 | 107.0 |
| VI | 23.1 | 4.3 | 30 | 26.1 | 7.7 | 44 | 13.0 | 79.1 |
| VII | 24.6 | 4.9 | 25 | 26.4 | 7.7 | 27 | 7.3 | 57.1 |
| VIII | 25.2 | 5.7 | 6 | 28.4 | 9.6 | 3 | 12.7 | 68.4 |

Table 15.--Mean total length (inches) and weight (pounds) at capture of Green Lake, Wisconsin, and Lake Superior strains of lake trout.

| Age group | Green Lake | | | Lake Superior | | |
|---|---|---|---|---|---|---|
| | Length | Weight | Sample size | Length | Weight | Sample size |
| | | | 1965 year class | | | |
| V | - | - | - | - | - | - |
| VI | 25.4 | 6.1 | 22 | 26.8 | 7.2 | 3 |
| VII | 26.8 | 7.6 | 21 | 27.1 | 8.2 | 25 |
| VIII | 28.3 | 10.4 | 7 | 28.9 | 10.7 | 17 |
| | | | 1967 year class [a] | | | |
| V | 25.2 | 6.4 | 140 | 25.8 | 6.6 | 72 |
| VI | 26.5* | 7.6* | 219 | 27.5* | 8.3* | 35 |
| VII | 26.3 | 7.2 | 14 | 29.4 | 9.5 | 3 |
| VIII | 27.8* | 8.9 | 24 | 26.6* | 7.4 | 19 |

[a] Ages V-VI sampled in August-September; ages VII-VIII sampled in July.

* Significant difference between strains at 95% level.

Table 16.--Mean total length (inches) of lake trout of different ages from southern, middle, and northern Lake Michigan in June 1975.

| Age group | Area of lake | | | | | |
|---|---|---|---|---|---|---|
| | Northern (MM4) | | Mid-lake (MM6) | | Southern (MM8) | |
| | Length | Sample size | Length | Sample size | Length | Sample size |
| III | 16.5 | 35 | 16.1 | 75 | 15.9 | 21 |
| IV | 18.4 | 39 | 19.1 | 67 | 20.9 | 19 |
| V | 20.5 | 44 | 21.6 | 44 | 24.0 | 17 |
| VI | 25.6 | 35 | 26.1 | 75 | 26.2 | 21 |
| VII | 28.2 | 19 | 27.8 | 47 | 27.8 | 25 |
| VIII | 29.3 | 7 | 28.7 | 63 | 26.7 | 16 |
| IX | 29.8 | 12 | 29.2 | 20 | 28.2 | 5 |

Table 17.--Estimated number of lake trout harvested annually from Michigan waters of Lake Michigan by the sport fishery, according to Statistical District and year.[a] Percentage (in parentheses) is portion of the total annual catch taken in each District.

| Statistical District | Year 1969 | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 |
|---|---|---|---|---|---|---|---|
| MM1 | 86 (1) | 700 (1) | 3,220 (1) | 1,020 (1) | 4,680 (1) | 715 (1) | 5,610 (1) |
| MM2 | 760 (1) | 160 (1) | 160 (1) | 1,530 (1) | 630 (1) | 477 (1) | 6,630 (1) |
| MM3[b] | 664 (1) | 0 | 1,400 (1) | 0 | 540 (1) | 596 (1) | 0 |
| MM3[c] | 17,380 (19) | 40,410 (17) | 47,280 (16) | 65,450 (19) | 46,260 (15) | 70,145 (14) | 62,390 (15) |
| MM4 | 57,652 (64) | 137,560 (58) | 137,680 (45) | 74,290 (21) | 33,390 (11) | 70,781 (14) | 53,380 (12) |
| MM5 | 4,054 (5) | 37,200 (16) | 32,120 (11) | 51,680 (15) | 26,550 (9) | 23,355 (5) | 40,460 (9) |
| MM6 | 3,717 (4) | 8,000 (3) | 46,000 (15) | 60,690 (18) | 63,660 (20) | 79,956 (16) | 79,560 (19) |
| MM7 | 3,717 (4) | 9,320 (4) | 22,700 (8) | 58,480 (17) | 101,430 (32) | 143,945 (29) | 106,930 (25) |
| MM8 | 1,605 (2) | 4,260 (2) | 12,680 (4) | 34,510 (10) | 34,730 (11) | 100,928 (21) | 71,060 (17) |
| Total number | 89,635 | 237,610 | 303,440 | 347,650 | 312,840 | 490,898 | 426,020 |

[a] Data from Jamsen, Ryckman, and Jamsen (1970), and Jamsen (1970, 1972, 1973, 1974, 1976).

[b] Mackinac County.

[c] Charlevoix and Emmet counties.

Table 18.--Estimated number of angler days expended on Lake Michigan by salmon-trout fishermen, according to Statistical District and year.[a] Percentage (in parentheses) is portion of annual effort expended in each District.

| Statistical District | 1969 | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 |
|---|---|---|---|---|---|---|---|
| MM1 | - | 8,919 (1) | 16,339 (2) | 14,110 (2) | 5,670 (1) | 27,461 (2) | 23,290 (2) |
| MM2 | - | 15,069 (2) | 28,234 (3) | 24,990 (4) | 11,250 (2) | 29,304 (2) | 26,690 (2) |
| MM3[b] | - | 2,027 (<1) | 3,388 (<1) | 0 | 270 (<1) | 4,195 (<1) | 680 (<1) |
| MM3[c] | - | 82,220 (13) | 107,590 (13) | 103,700 (15) | 62,370 (11) | 136,288 (11) | 117,130 (11) |
| MM4 | 103,163 (17) | 126,015 (20) | 142,300 (17) | 73,780 (11) | 65,070 (11) | 141,754 (11) | 106,760 (9) |
| MM5 | - | 62,853 (10) | 85,285 (10) | 66,300 (9) | 48,960 (8) | 94,206 (7) | 98,430 (9) |
| MM6 | - | 137,684 (22) | 157,043 (18) | 130,390 (19) | 118,800 (20) | 228,460 (18) | 209,100 (19) |
| MM7 | - | 114,974 (19) | 140,661 (16) | 140,760 (20) | 187,650 (32) | 336,524 (26) | 296,140 (27) |
| MM8 | - | 72,518 (12) | 176,119 (21) | 135,320 (20) | 90,810 (15) | 287,577 (22) | 233,180 (21) |
| Total number | 596,000 | 622,279 | 856,959 | 679,350 | 590,850 | 1,285,769 | 1,110,100 |

[a] Data from Jamsen, Ryckman, and Jamsen (1970), and Jamsen (1970, 1972, 1973, 1974, 1976).

[b] Mackinac County.

[c] Charlevoix and Emmet counties.

Table 19.--Percentage species composition and estimated total number of salmonids caught in the open-water of Lake Michigan, by Statistical District and year.

| Statistical District, and species | Year 1970 | 1971 | 1972 | 1973 | 1974 | 1975 |
|---|---|---|---|---|---|---|
| MM1 | | | | | | |
| Lake trout | 11 | 17 | 55 | 89 | 8 | 38 |
| Rainbow trout | 33 | 22 | 36 | 2 | 34 | 7 |
| Brown trout | 7 | 2 | 0 | - | 21 | 14 |
| Coho salmon | 49 | 59 | 0 | 7 | 5 | 19 |
| Chinook salmon | 0 | 1 | 9 | 2 | 32 | 22 |
| Total number | 6,320 | 18,680 | 1,870 | 5,220 | 9,258 | 14,790 |
| MM2 | | | | | | |
| Lake trout | 1 | 1 | 4 | 2 | 1 | 21 |
| Rainbow trout | 4 | 19 | 50 | 38 | 40 | 12 |
| Brown trout | 7 | 2 | 0 | 1 | 4 | 7 |
| Coho salmon | 88 | 77 | 42 | 56 | 51 | 52 |
| Chinook salmon | 0 | 1 | 4 | 4 | 4 | 8 |
| Total number | 11,160 | 28,160 | 37,230 | 24,300 | 33,875 | 32,130 |
| MM3 | | | | | | |
| Lake trout | 50 | 50 | 63 | 60 | 57 | 58 |
| Rainbow trout | 36 | 20 | 21 | 7 | 23 | 11 |
| Brown trout | <1 | <1 | 1 | - | 6 | 10 |
| Coho salmon | 14 | 26 | 5 | 8 | 4 | 6 |
| Chinook salmon | <1 | 4 | 9 | 25 | 10 | 15 |
| Total number | 80,570 | 97,720 | 103,530 | 78,600 | 124,894 | 107,950 |
| MM4 | | | | | | |
| Lake trout | 62 | 67 | 80 | 65 | 66 | 56 |
| Rainbow trout | 12 | 10 | 6 | 9 | 15 | 16 |
| Brown trout | 5 | 2 | 1 | - | 6 | 9 |
| Coho salmon | 20 | 20 | 10 | 22 | 10 | 14 |
| Chinook salmon | 1 | 1 | 4 | 4 | 3 | 5 |
| Total number | 223,650 | 204,220 | 92,650 | 51,480 | 107,047 | 95,880 |
| MM5 | | | | | | |
| Lake trout | 40 | 37 | 57 | 47 | 21 | 38 |
| Rainbow trout | 8 | 11 | 7 | 15 | 21 | 15 |
| Brown trout | 3 | 1 | 1 | - | 3 | 8 |
| Coho salmon | 49 | 44 | 32 | 35 | 45 | 31 |
| Chinook salmon | <1 | 7 | 3 | 3 | 10 | 8 |
| Total number | 93,850 | 86,300 | 90,780 | 56,700 | 109,895 | 107,270 |

(continued, next page)

Table 19. --continued.

| Statistical District, and species | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 |
|---|---|---|---|---|---|---|
| MM6 | | | | | | |
| Lake trout | 15 | 21 | 41 | 47 | 33 | 34 |
| Rainbow trout | 30 | 6 | 13 | 13 | 16 | 13 |
| Brown trout | 3 | 5 | 2 | - | 6 | 7 |
| Coho salmon | 25 | 62 | 36 | 29 | 21 | 28 |
| Chinook salmon | 27 | 6 | 8 | 11 | 24 | 18 |
| Total number | 53,447 | 224,720 | 149,260 | 135,090 | 243,531 | 234,430 |
| MM7 | | | | | | |
| Lake trout | 10 | 22 | 52 | 52 | 45 | 42 |
| Rainbow trout | 9 | 9 | 12 | 11 | 11 | 11 |
| Brown trout | 2 | 1 | <1 | - | 3 | 3 |
| Coho salmon | 62 | 50 | 19 | 22 | 20 | 27 |
| Chinook salmon | 17 | 17 | 16 | 15 | 21 | 17 |
| Total number | 90,230 | 101,340 | 116,900 | 194,400 | 32,052 | 256,870 |
| MM8 | | | | | | |
| Lake trout | 6 | 8 | 20 | 29 | 31 | 25 |
| Rainbow trout | 4 | 10 | 5 | 8 | 8 | 5 |
| Brown trout | 2 | 2 | 1 | - | 2 | 1 |
| Coho salmon | 86 | 78 | 72 | 56 | 49 | 58 |
| Chinook salmon | 1 | 2 | 2 | 7 | 10 | 11 |
| Total number | 68,180 | 169,520 | 170,000 | 125,550 | 322,697 | 283,050 |

Table 20. --Number of yearling lake trout planted on offshore reefs and inshore areas in Michigan waters of Lake Michigan.

| Statistical District and planting site | Year 1973 | 1974 | 1975 | 1976 |
|---|---|---|---|---|
| MM1 | | | | |
| Deepwater Point | | 14,000 | | |
| Minneapolis Shoal | | 24,000 | 51,000 | 25,000 |
| Escanaba Reef | | 20,000 | 50,000 | 50,000 |
| Inshore | 85,000 | 34,000 | 26,000 | 50,000 |
| Totals | 85,000 | 92,000 | 127,000 | 125,000 |
| Northern MM3 | | | | |
| Seul Choix Point | | 25,000 | 25,000 | 25,000 |
| Trout Island Shoal | | 25,000 | 25,000 | 25,000 |
| Millecoquin Reef | | 34,000 | 25,000 | 25,000 |
| Simmons Reef | | 30,000 | 25,000 | 25,000 |
| Gray's Reef | | 25,000 | 25,000 | 25,000 |
| Totals | | 139,000 | 125,000 | 125,000 |
| Southern MM3 | | | | |
| South Fox Island Reef | 75,000 | 25,000 | 35,000 | 36,000 |
| Fishermans Island Reef | | 50,000 | 50,000 | 25,000 |
| Inshore | 208,000 | 36,000 | 118,000 | 155,000 |
| Totals | 283,000 | 111,000 | 203,000 | 216,000 |
| MM4 | | | | |
| Grand Traverse Shoal | | 60,000 | | 51,000 |
| Inshore | 150,000 | 150,000 | 175,000 | 102,000 |
| Totals | 150,000 | 210,000 | 175,000 | 153,000 |
| MM5 | | | | |
| Good Harbor Reef | 76,000 | 57,000 | 35,000 | 36,000 |
| Inshore | 50,000 | 50,000 | 50,000 | 75,000 |
| Totals | 126,000 | 107,000 | 85,000 | 111,000 |

Table 21.--Percentage of mature lake trout, according to age and length, captured in June and July, 1974-75. Sample sizes are in parentheses. Age and inch-group columns are not related.

| Age | Percentage mature | | Inch group | Percentage mature | |
|---|---|---|---|---|---|
| | Male | Female | | Male | Female |
| III | 4 (48) | 0 (27) | <18.9 | 0 (75) | 0 (52) |
| IV | 22 (65) | 6 (48) | 19.0-19.9 | 14 (22) | 0 (15) |
| V | 48 (58) | 17 (41) | 20.0-20.9 | 6 (16) | 0 (18) |
| VI | 89 (76) | 90 (100) | 21.0-21.9 | 35 (39) | 0 (33) |
| VII | 90 (59) | 92 (67) | 22.0-22.9 | 73 (40) | 21 (24) |
| VIII | 100 (39) | 97 (31) | 23.0-23.9 | 84 (32) | 55 (33) |
| IX | 100 (12) | 100 (25) | 24.0-24.9 | 90 (55) | 77 (34) |
| X | 100 (3) | 100 (7) | 25.0-25.9 | 96 (45) | 84 (31) |
| | | | 26.0-26.9 | 96 (28) | 94 (36) |
| | | | 27.0-27.9 | 100 (31) | 97 (32) |
| | | | ≥28.0 | 100 (52) | 100 (87) |

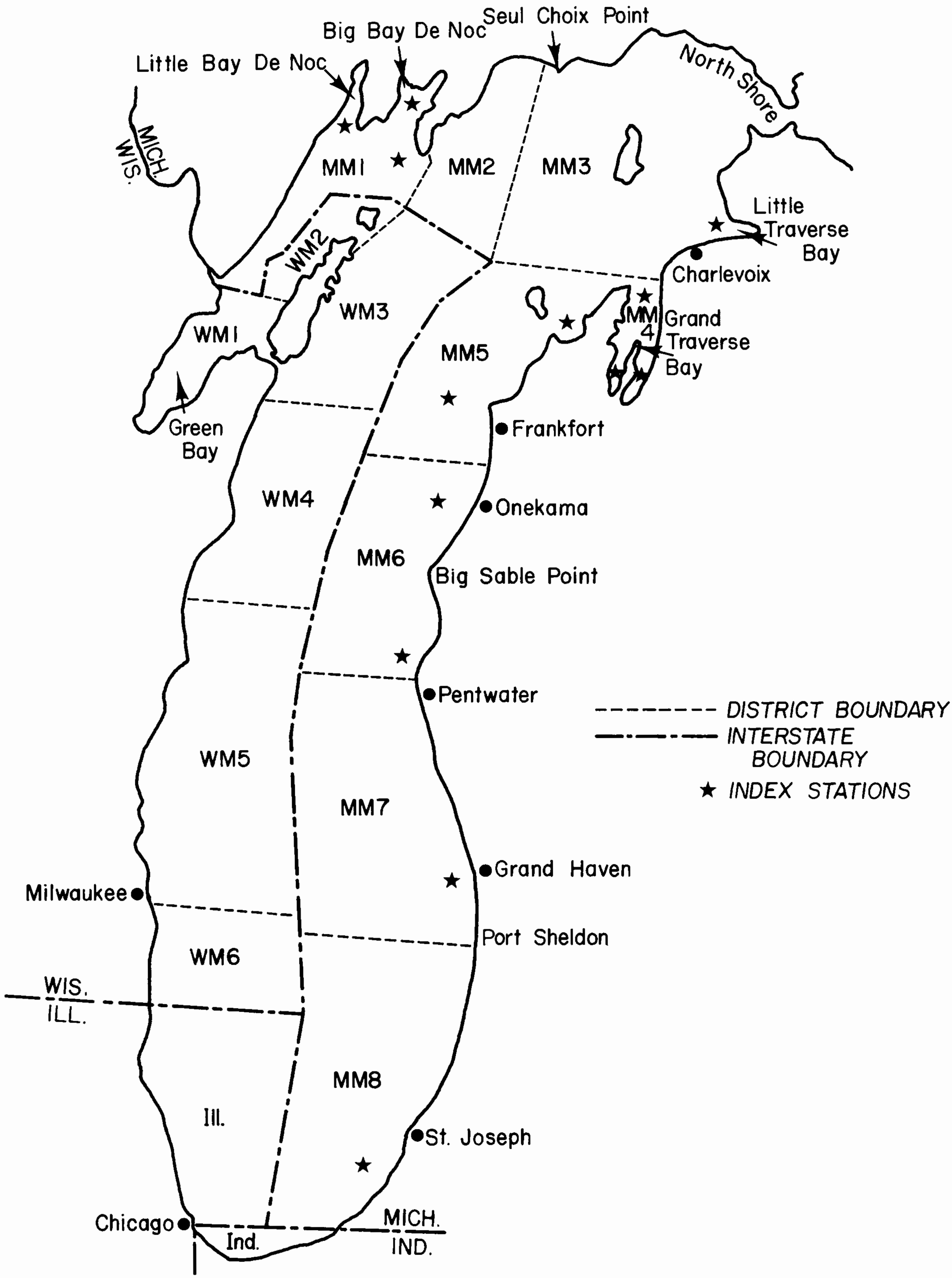



Figure 1.--Statistical Districts and locations of index fishing stations on Lake Michigan in 1970-75.

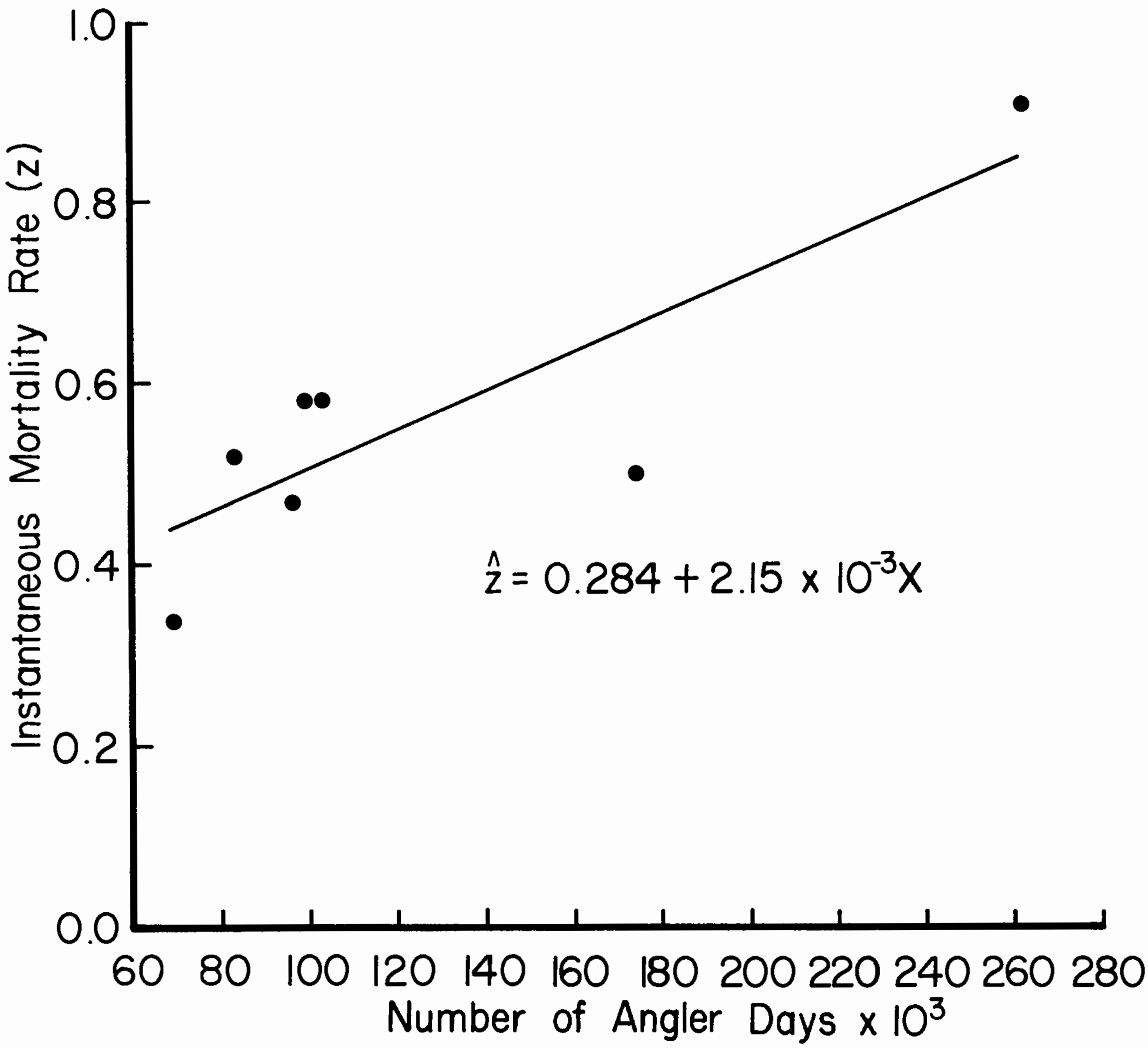



Figure 2.--Relation between instantaneous total mortality rate of lake trout and number of angler days on Lake Michigan.

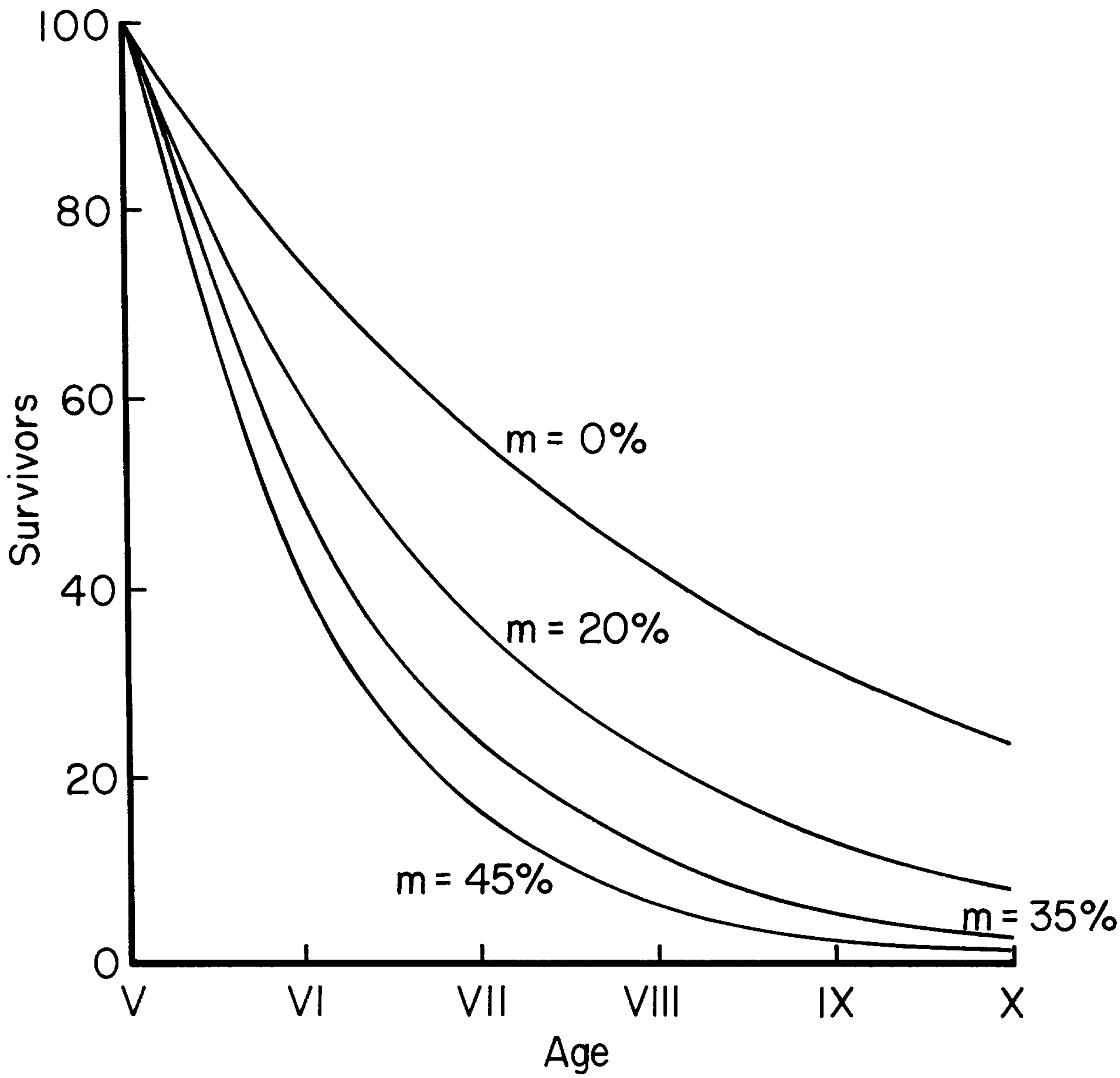



Figure 3.--Expected number of survivors per 100 age-V recruits, at annual fishing rates (m) of 0, 20, 35 and 45%. Annual natural mortality rate is estimated to be 25%.

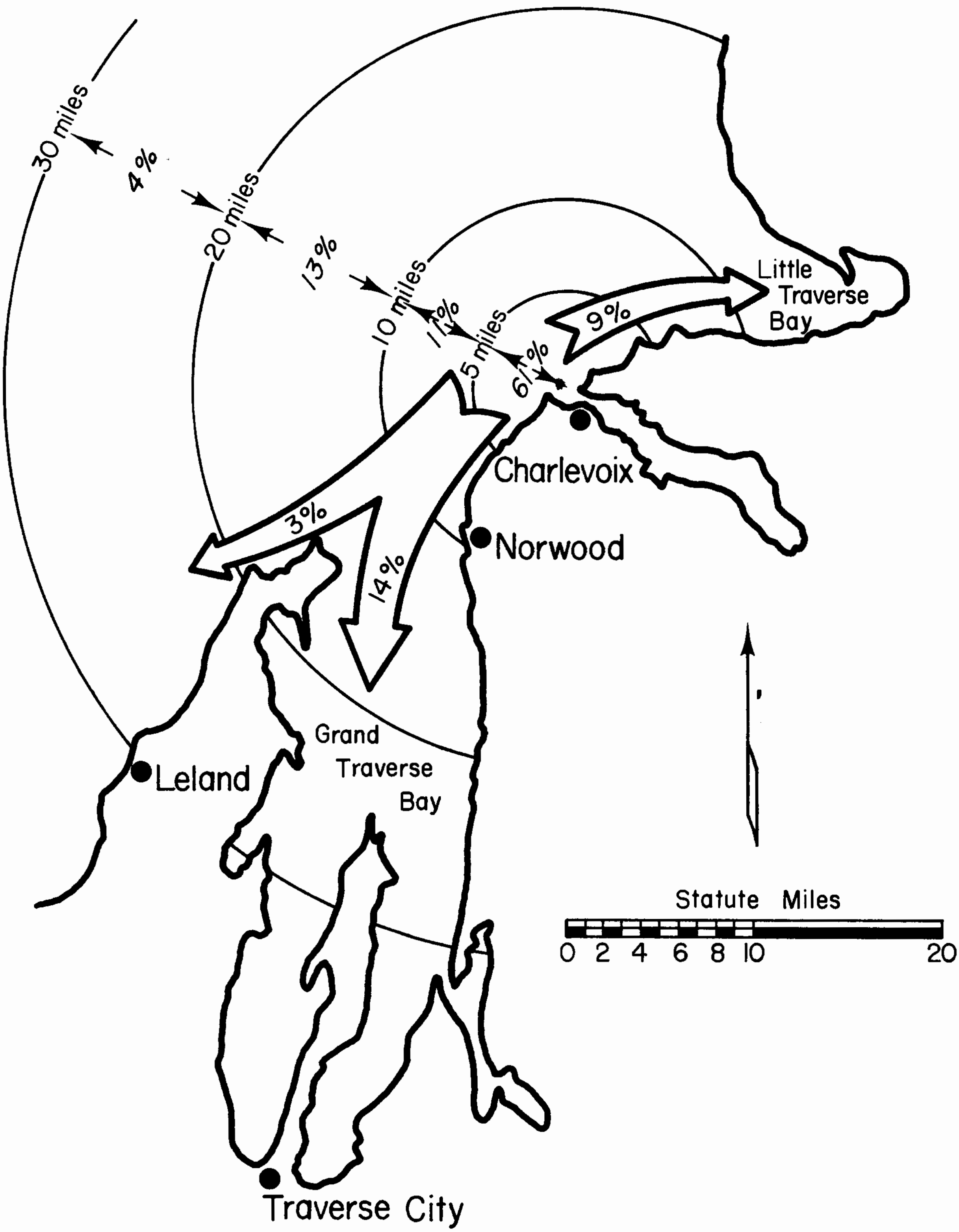



Figure 4.--General migratory pattern of tagged lake trout in 1974-75 (tagged in 1973 at Charlevoix). Percent in rings is proportion of total returns from within the zone; percent in arrows is proportion of total returns from outside the 10-mile zone and in the direction indicated by the arrow.

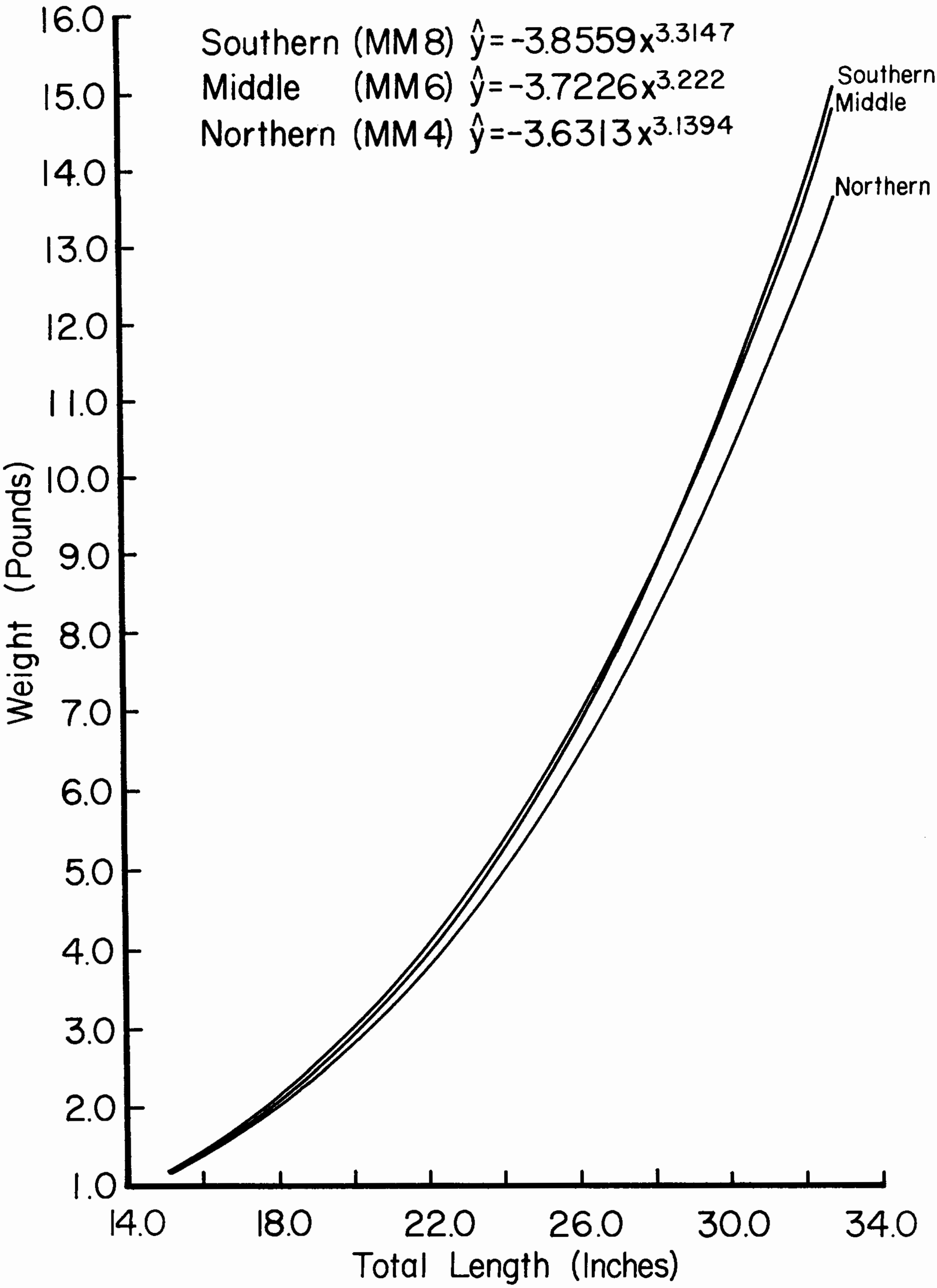



Figure 5.--Length-weight relationships for lake trout in southern, middle, and northern Lake Michigan, 1975.

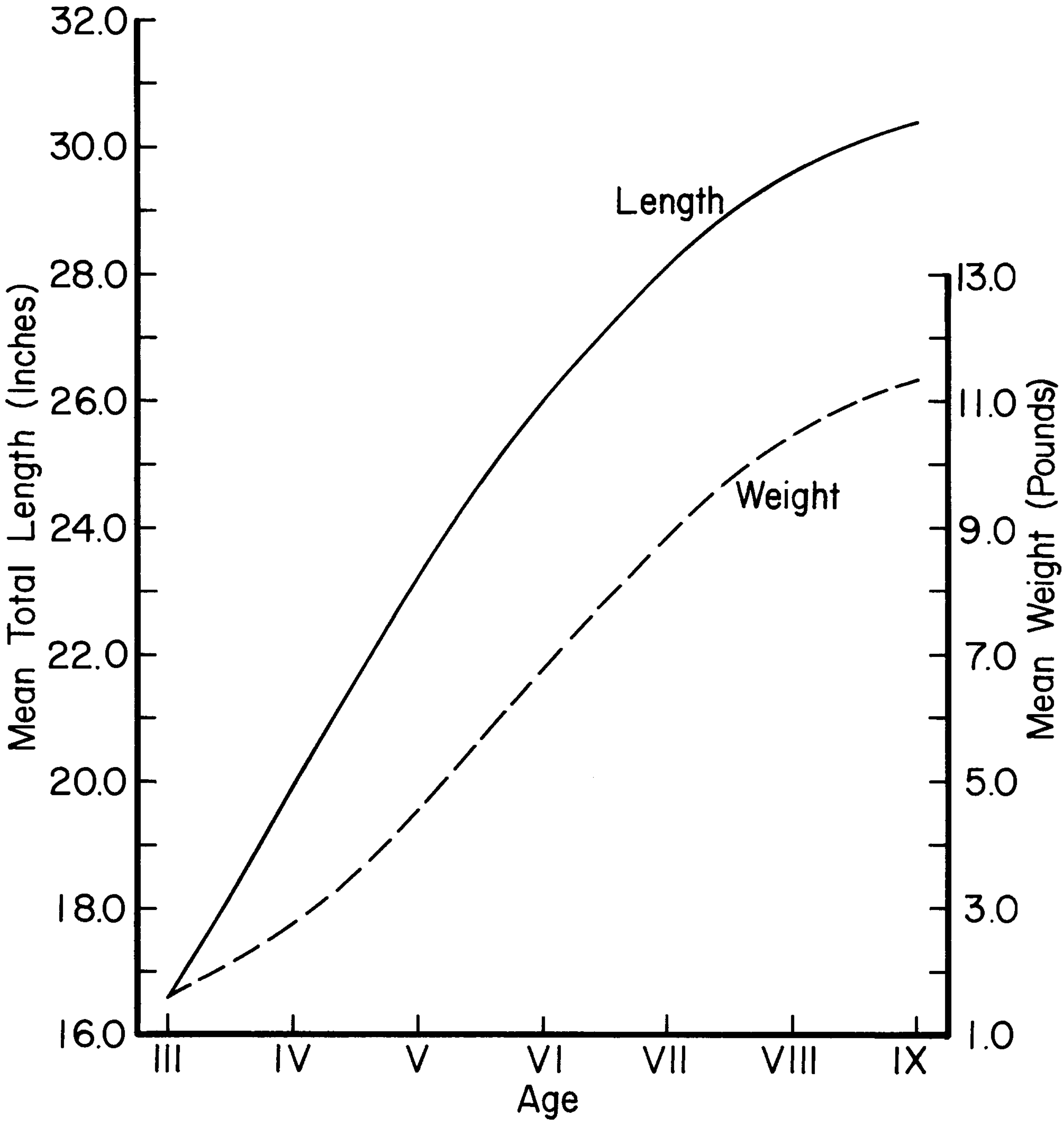



Figure 6.--Mean length and weight at various ages for lake trout in Lake Michigan in mid-summer, 1975.

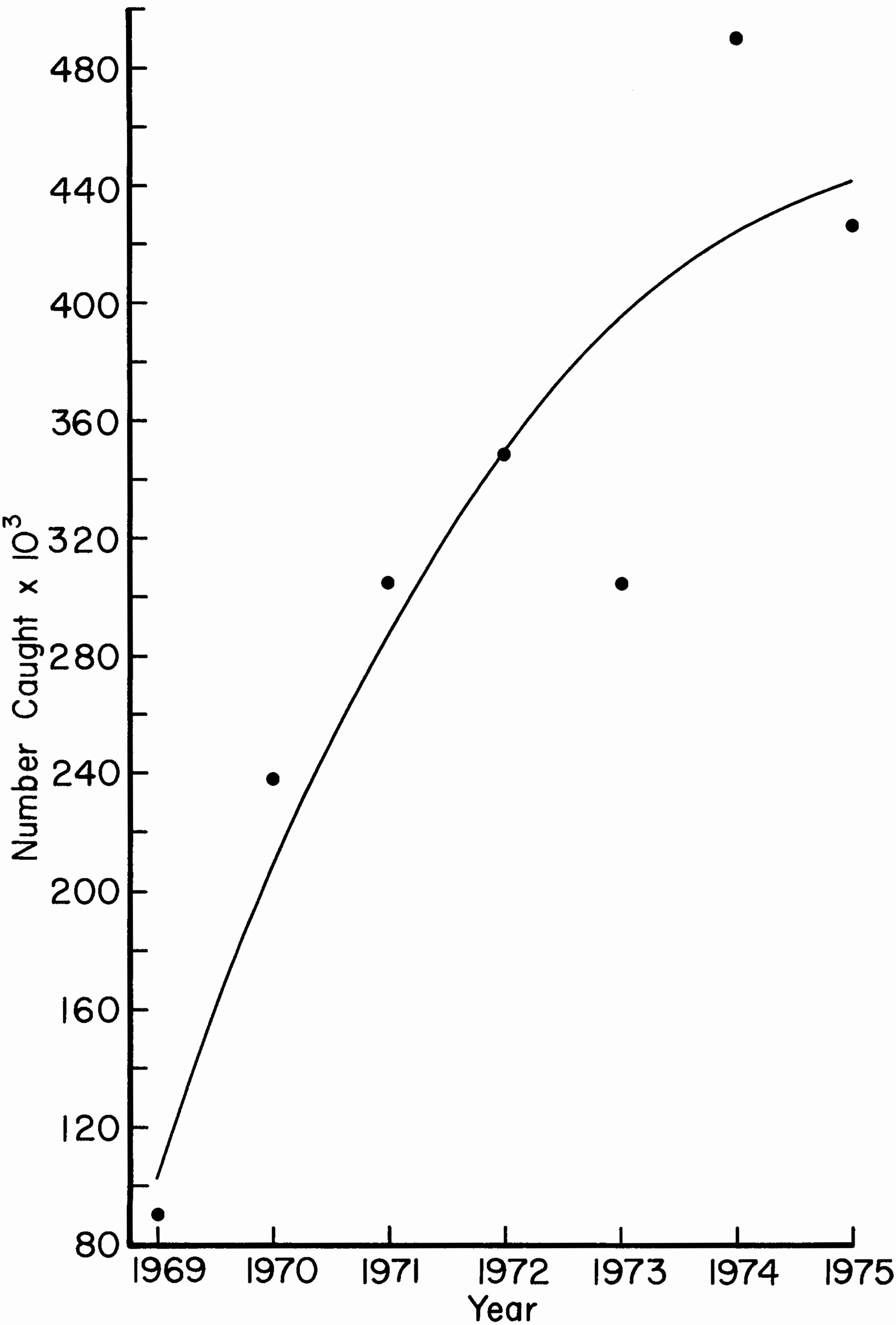
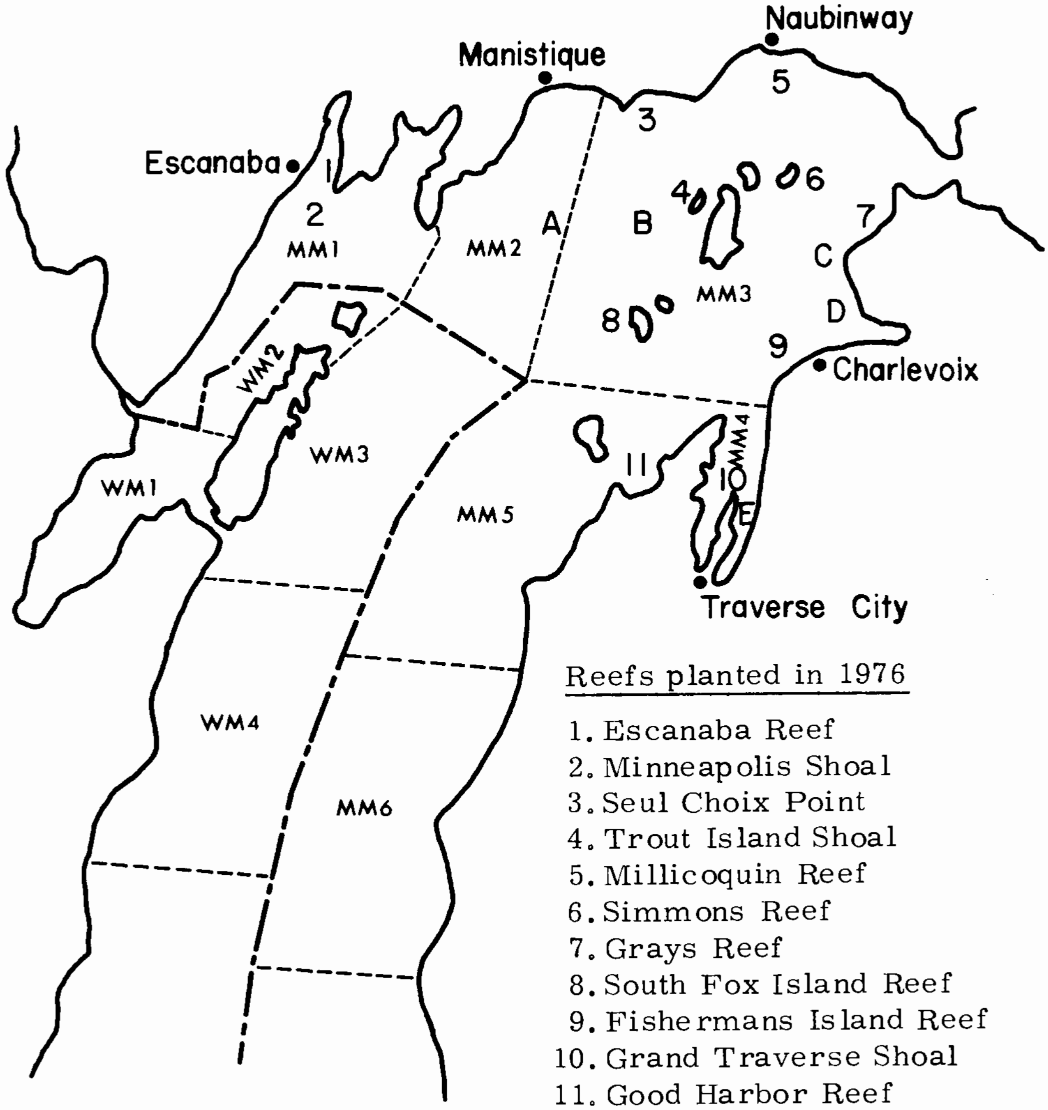



Figure 7.--Trend in annual lake trout sport catch for Lake Michigan, 1969-1975.




Reefs planted in 1976

1. Escanaba Reef
2. Minneapolis Shoal
3. Seul Choix Point
4. Trout Island Shoal
5. Millicoquin Reef
6. Simmons Reef
7. Grays Reef
8. South Fox Island Reef
9. Fishermans Island Reef
10. Grand Traverse Shoal
11. Good Harbor Reef

Proposed additional reefs

A. Boulder Island Reef
B. Gull Island Shoal
C. Dahlia Shoal
D. Seven Mile Point
E. Old Mission Point

Figure 8.--Approximate locations of Lake Michigan reefs planted with lake trout in 1976, and new reefs proposed for trout plantings.

Literature cited

Bailey, Reeve M., John E. Fitch, Earl S. Herald, Ernest A. Lachner, C. C. Lindsey, C. Richard Robins, and W. B. Scott (eds.). 1970. A list of common and scientific names of fishes from the United States and Canada (3rd ed.). Am. Fish. Soc. Spec. Publ. 6. 150 pp.

Buettner, Howard J. 1961. Recoveries of tagged, hatchery-reared lake trout from Lake Superior. Trans. Am. Fish. Soc. 90(4): 404-412.

Carline, Robert F. 1972. Biased harvest estimates from a postal survey of a sport fishery. Trans. Am. Fish. Soc. 101(2): 262-266.

Fry, F. E. J. 1952. The 1944 year class of lake trout in South Bay, Lake Huron. Trans. Am. Fish. Soc. 82: 178-192.

Jamsen, G. C. 1970. 1970 Michigan sport fishing survey results. Mich. Dep. Nat. Resour. Res. Develop. Rep. 268, Append. A, B.

Jamsen, G. C. 1972. Michigan's 1971 sport fishery. Mich. Dep. Nat. Resour. Res. Develop. Rep. 268, Append. A, B.

Jamsen, G. C. 1973. Michigan's 1972 sport fishery. Mich. Dep. Nat. Resour. Surv. Stat. Serv. Rep. 122, Append. A.

Jamsen, G. C. 1974. Michigan's 1973 sport fishery. Mich. Dep. Nat. Resour. Surv. Stat. Serv. Rep. 133, Append. A.

Jamsen, G. C. 1976. Michigan's 1975 sport fishery. Mich. Dep. Nat. Resour. Surv. Stat. Serv. Rep. 156, Append. A.

Jamsen, G. C., J. R. Ryckman, and F. W. Jamsen. 1970. Michigan's 1969 salmon and trout sport fishery. Mich. Dep. Nat. Resour. Res. Develop. Rep. 203.

Kapetsky, James M., and James R. Ryckman. 1973. Economic implications from the Grand Traverse Bay sport fishery. Mich. Dep. Nat. Resour. Fish. Manage. Rep. 5: 83-91.

Koelz, Walter. 1926. Fishing industry of the Great Lakes. U.S. Bur. Fish. Doc. 1001.

Loftus, K. H. 1957. Studies of populations of river-spawning lake trout in eastern Lake Superior. Trans. Am. Fish. Soc. 87: 259-277.

Peck, James W. 1974. Location of lake trout spawning in lakes Michigan and Superior. Mich. Dep. Nat. Resour. Fish. Div., D-J Prog. Rep. F-31-R-8: 255-262.

Peck, James W. 1975. Location of lake trout spawning in lakes Michigan and Superior. Mich. Dep. Nat. Resour. Fish. Div., D-J Prog. Rep. F-35-R-1: 137-150.

Peck, James W. 1976. Location of lake trout spawning in lakes Michigan and Superior. Mich. Dep. Nat. Resour. Fish. Div., D-J Prog. Rep. F-35-R-2: 139-157.

Poff, R. J. 1974. Lake Michigan committee report to the Management and Research Committee. Great Lakes Fish. Comm. Lake Mich. Committee Meeting, March 26-27.

Pycha, Richard L. 1973. Rehabilitation of spawning runs of lake trout in Lake Superior. Great Lakes Fish. Comm. Rep., March 14, 1973.

Rybicki, R. W., and Myrl Keller. 1974. 1973 progress report on certain Lake Michigan fish stocks, harvest and regulations. Great Lakes Fish. Comm. Lake Mich. Committee Meeting, March 26-27.

Sakagawa, Gary T., and Richard L. Pycha. 1971. Population biology of lake trout (Salvelinus namaycush) of Lake Superior before 1950. J. Fish. Res. Board Can. 28: 65-71.

Smith, Oliver H., and John Van Oosten. 1939. Tagging experiments with lake trout, whitefish, and other species of fish from Lake Michigan. Trans. Am. Fish. Soc. 69: 63-84.

Smith, Stanford H. 1964. Status of the deepwater cisco population of Lake Michigan. Trans. Am. Fish. Soc. 93(2): 155-163.

Stauffer, T. M., and W. C. Wagner. 1975. Survival of lake trout from egg to swim-up fry in Lake Michigan (fall 1974). Mich. Dep. Nat. Resour. Fish. Div., D-J Ann. Prog. Rep. F-35-R-1.

Stauffer, T. M., and W. C. Wagner. 1976. Survival of lake trout from egg to swim-up fry in Lake Michigan (fall 1975). Mich. Dep. Nat. Resour. Fish Div., D-J Ann. Prog. Rep. F-35-R-2.

Van Oosten, John. 1944. Lake trout. U.S. Dep. Int., Fish Wildl. Serv. Fish. Leafl. 15, 8 pp.

Van Oosten, John. 1959. Progress report on the study of Great Lakes trout. The Fisherman, summer issue, 1950.

Wagner, Wilbert C. 1974. Survival of eggs and young lake trout in lakes Michigan and Superior (fall 1973). Mich. Dep. Nat. Resour. Fish. Div., D-J Ann. Prog. Rep. F-31-R-8.

Webster, Dwight, William G. Bentley, and James P. Galligan. 1959. Management of the lake trout fishery of Cayuga Lake, New York, with special reference to the role of hatchery fish. Cornell Univ. Agr. Exp. Sta. Mem. 357.

Wells, LaRue. 1974. Sea lamprey wounding rates on lake trout, Lake Michigan, September-October 1973. Great Lakes Fish. Comm. Lake Mich. Committee Meeting, March 27, 1974.

Wells, LaRue. 1975. Sea lamprey wounding rates on lake trout, Lake Michigan, September-October 1975. Great Lakes Fish. Comm. Lake Michigan Committee Meeting, February 24-25, 1976.

Report approved by W. C. Latta

Typed by M. S. McClure

Appendix Table A.--Common and scientific names of fishes used in the text.

| Common name | Scientific name |
|---|---|
| Alewife | *Alosa pseudoharengus* |
| Bloater | *Coregonus hoyi* |
| Brown trout | *Salmo trutta* |
| Chinook salmon | *Oncorhynchus kisutch* |
| Cisco | *Coregonus artedii* |
| Coho salmon | *Oncorhynchus tshawytscha* |
| Lake trout | *Salvelinus namaycush* |
| Lake whitefish | *Coregonus clupeaformis* |
| Northern pike | *Esox lucius* |
| Rainbow smelt | *Osmerus mordax* |
| Rainbow trout | *Salmo gairdneri* |
| Round whitefish | *Prosopium cylindraceum* |
| Sculpin sp. | Cottidae |
| Sea lamprey | *Petromyzon marinus* |
| Smallmouth bass | *Micropterus dolomieui* |
| Spottail shiner | *Notropis hudsonius* |
| Sucker spp. | Catostomidae |
| Walleye | *Stizostedion vitreum* |
| Yellow perch | *Perca flavescens* |

Appendix Table B.--Computation of the standing stock of lake trout in May 1975 in MM3 (Charlevoix and Emmet counties) based on planting densities × annual survival rates.

| Age group | Annual survival rates [a] | Number of survivors | | | | | | | Standing stock in May 1975 |
|---|---|---|---|---|---|---|---|---|---|
| | | Year class | | | | | | | |
| | | 1964 | 1965 | 1966 | 1967 | 1968 | 1969 | 1970 | |
| I[b] | | 416,000 | 261,000 | 200,000 | 150,000 | 184,000 | 150,000 | 172,000 | |
| | 0.630 | | | | | | | | |
| II | | 262,080 | 164,430 | 126,000 | 94,500 | 115,920 | 94,500 | 108,360 | |
| | 0.630 | | | | | | | | |
| III | | 165,110 | 103,591 | 79,380 | 59,535 | 73,030 | 59,535 | 68,267 | |
| | 0.630 | | | | | | | | |
| IV | | 104,020 | 65,262 | 50,009 | 37,507 | 46,009 | 37,507 | 43,008 | |
| | 0.630 | | | | | | | | |
| V | | 65,532 | 41,115 | 31,506 | 23,629 | 28,985 | 23,629 | 27,095 | 27,095 |
| | 0.552 | | | | | | | | |
| VI | | 36,174 | 22,696 | 17,391 | 13,043 | 16,000 | 13,043 | | 13,043 |
| | 0.552 | | | | | | | | |
| VII | | 19,968 | 12,528 | 9,600 | 7,200 | 8,832 | | | 8,832 |
| | 0.552 | | | | | | | | |
| VIII | | 11,022 | 6,915 | 5,299 | 3,974 | | | | 3,974 |
| | 0.552 | | | | | | | | |
| IX | | 6,084 | 3,817 | 2,925 | | | | | 2,925 |
| | 0.552 | | | | | | | | |
| X | | 3,359 | 2,107 | | | | | | 2,107 |
| | 0.000 | | | | | | | | |
| XI | | | | | | | | | 0 |
| Total | | | | | | | | | 57,976 |

[a] 0.630 calculated for age II and assumed to be representative average for groups I-IV. 0.552 is from Table 4, column 4 (0.552 = 1 -0.448).

[b] Number of yearling lake trout planted in April-May. Number of survivors as age II in following April/May = number planted × survival.

Appendix Table C.--Mean total length and weight at capture of Lake Michigan lake trout sampled in experimental gill nets by Statistical District, date, and age group.

| Statistical District, month and year sampled | Age group | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | II | III | IV | V | VI | VII | VIII | IX |
| MM1 | | | | | | | | |
| June-July 1970 | | | | | | | | |
| Length | 12.7 | 15.6 | 21.6 | 25.4 | 27.7 | - | - | - |
| Weight | 0.8 | 1.5 | 4.7 | 6.9 | 8.5 | - | - | - |
| Number | 51 | 96 | 17 | 104 | 22 | - | - | - |
| May-June 1971 | | | | | | | | |
| Length | 11.4 | 15.5 | 18.5 | 24.1 | 26.7 | 28.5 | - | - |
| Weight | 0.5 | 1.4 | 2.4 | 5.4 | 7.6 | 8.5 | - | - |
| Number | 1 | 85 | 85 | 5 | 28 | 5 | - | - |
| May 1972 | | | | | | | | |
| Length | 16.6 | 15.3 | 19.5 | 22.8 | 23.0 | - | 27.0 | - |
| Weight | 1.6 | 1.3 | 2.8 | 4.5 | 3.9 | - | 6.1 | - |
| Number | 3 | 32 | 24 | 7 | 1 | - | 1 | - |
| May 1973 | | | | | | | | |
| Length | - | 13.6 | 17.5 | 23.0 | 21.4 | - | 28.9 | 28.1 |
| Weight | - | 0.7 | 1.8 | 4.8 | 3.6 | - | 7.6 | 8.1 |
| Number | - | 6 | 17 | 5 | 2 | - | 1 | 1 |
| May 1974 | | | | | | | | |
| Length | - | 14.0 | 16.0 | 20.8 | 26.2 | - | - | - |
| Weight | - | 0.9 | 1.5 | 3.4 | 6.0 | - | - | - |
| Number | - | 3 | 8 | 1 | 1 | - | - | - |
| May 1975 | | | | | | | | |
| Length | - | 15.0 | 18.4 | 18.1 | 26.1 | - | - | - |
| Weight | - | 1.2 | 2.0 | 2.0 | 6.8 | - | - | - |
| Number | - | 5 | 5 | 1 | 1 | - | - | - |
| MM3 | | | | | | | | |
| May 1969 | | | | | | | | |
| Length | - | - | 20.4 | 22.2 | - | - | - | - |
| Weight | - | - | 3.5 | 4.6 | - | - | - | - |
| Number | - | - | 96 | 2 | - | - | - | - |
| May 1971 | | | | | | | | |
| Length | 12.1 | 14.2 | 20.7 | 23.8 | 26.7 | 25.6 | - | - |
| Weight | 0.7 | 1.1 | 3.6 | 5.4 | 7.6 | 5.6 | - | - |
| Number | 2 | 28 | 31 | 45 | 33 | 2 | - | - |
| May 1972 | | | | | | | | |
| Length | - | 14.7 | 21.2 | 24.8 | 26.0 | 28.4 | - | - |
| Weight | - | 1.1 | 3.5 | 6.3 | 6.7 | 8.8 | - | - |
| Number | - | 21 | 2 | 1 | 10 | 14 | - | - |

(continued next page)

Appendix Table C. --continued

| Statistical District, month and year sampled | Age group | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | II | III | IV | V | VI | VII | VIII | IX |
| MM3, cont. | | | | | | | | |
| May 1973 | | | | | | | | |
| Length | - | 14.4 | 18.1 | 21.2 | 27.7 | 27.6 | 28.5 | - |
| Weight | - | 1.1 | 2.2 | 3.7 | 7.9 | 8.0 | 9.2 | - |
| Number | - | 11 | 35 | 5 | 9 | 7 | 19 | - |
| May 1974 | | | | | | | | |
| Length | - | 14.5 | 17.9 | 22.1 | 28.1 | 28.8 | 28.6 | 33.0 |
| Weight | - | 1.1 | 2.2 | 4.3 | 9.0 | 9.1 | 10.1 | 17.0 |
| Number | - | 22 | 87 | 61 | 37 | 10 | 15 | 1 |
| May 1975 | | | | | | | | |
| Length | - | 15.5 | 19.5 | 23.0 | 27.0 | 30.5 | 28.3 | 29.8 |
| Weight | - | 1.4 | 3.0 | 4.4 | 8.5 | 11.0 | 9.1 | 10.0 |
| Number | - | 3 | 7 | 8 | 8 | 7 | 4 | 3 |
| MM4 | | | | | | | | |
| May 1971 | | | | | | | | |
| Length | - | - | 17.5 | 24.2 | 26.4 | 26.8 | - | - |
| Weight | - | - | - | 5.7 | 7.2 | 7.1 | - | - |
| Number | - | - | 1 | 46 | 65 | 12 | - | - |
| May-June 1972 | | | | | | | | |
| Length | - | 16.3 | 21.0 | 24.1 | 25.4 | 27.4 | 28.1 | - |
| Weight | - | 1.6 | 3.5 | 5.5 | 6.5 | 7.9 | 8.1 | - |
| Number | - | 6 | 7 | 48 | 180 | 120 | 8 | - |
| June 1973 | | | | | | | | |
| Length | 12.9 | 12.4 | 17.9 | 23.4 | 26.0 | 26.2 | 28.2 | 30.6 |
| Weight | 0.7 | 0.7 | 2.0 | 4.8 | 6.6 | 6.5 | 8.5 | 9.1 |
| Number | 6 | 7 | 28 | 9 | 10 | 26 | 14 | 1 |
| May-June 1974 | | | | | | | | |
| Length | - | 14.5 | 18.2 | 23.3 | 25.3 | 26.8 | 28.2 | 30.3 |
| Weight | - | 1.1 | 2.2 | 5.0 | 5.9 | 7.6 | 8.7 | 10.9 |
| Number | - | 3 | 44 | 77 | 9 | 24 | 51 | 10 |
| June 1975 | | | | | | | | |
| Length | - | 16.5 | 18.2 | 20.5 | 25.6 | 28.2 | 29.0 | 29.8 |
| Weight | - | 1.6 | 2.2 | 3.2 | 6.2 | 8.5 | 9.5 | 10.1 |
| Number | - | 35 | 38 | 44 | 39 | 18 | 8 | 12 |

(continued next page)

Appendix Table C. --continued

| Statistical District, month and year sampled | Age group | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | II | III | IV | V | VI | VII | VIII | IX |
| MM5 | | | | | | | | |
| April-May 1971 | | | | | | | | |
| Length | - | - | 16.0 | 19.8 | 25.6 | 25.7 | - | - |
| Weight | - | - | 1.4 | 2.9 | 5.9 | 6.2 | - | - |
| Number | - | - | 3 | 14 | 5 | 1 | - | - |
| Sep-Oct 1971 | | | | | | | | |
| Length | 14.0 | 18.5 | 23.1 | 24.4 | 26.5 | 27.0 | - | - |
| Weight | 0.9 | 2.1 | 4.3 | 5.6 | 7.2 | 6.9 | - | - |
| Number | 24 | 41 | 68 | 18 | 10 | 1 | - | - |
| June 1972 | | | | | | | | |
| Length | - | 18.0 | 21.6 | 25.2 | 27.1 | 28.1 | 28.6 | - |
| Weight | - | 2.2 | 3.8 | 6.2 | 7.6 | 8.4 | 8.2 | - |
| Number | - | 54 | 83 | 178 | 176 | 98 | 3 | - |
| May 1973 | | | | | | | | |
| Length | - | - | 21.2 | 25.0 | 27.3 | 28.2 | 29.3 | 30.0 |
| Weight | - | - | 3.5 | 5.9 | 8.1 | 9.1 | 10.1 | 10.2 |
| Number | - | - | 19 | 29 | 446 | 315 | 74 | 7 |
| September 1974 | | | | | | | | |
| Length | - | 18.8 | 22.7 | 25.8 | 28.0 | 28.2 | 27.5 | - |
| Weight | - | 2.3 | 4.2 | 6.4 | 8.2 | 8.4 | 8.0 | - |
| Number | - | 1 | 23 | 167 | 58 | 75 | 13 | - |
| October 1975 | | | | | | | | |
| Length | - | 21.0 | 23.3 | 25.0 | 27.2 | 28.2 | 29.1 | - |
| Weight | - | 3.3 | 4.5 | - | 7.4 | 8.4 | 10.8 | - |
| Number | - | 4 | 26 | 19 | 33 | 14 | 17 | - |
| MM6 | | | | | | | | |
| August 1972 | | | | | | | | |
| Length | 12.9 | 15.2 | 18.7 | 24.6 | 27.1 | 26.9 | 28.6 | - |
| Weight | 0.7 | 1.2 | 2.5 | 6.0 | 7.2 | 7.8 | 8.4 | - |
| Number | 16 | 177 | 59 | 33 | 3 | 3 | 2 | - |
| August 1973 | | | | | | | | |
| Length | 13.4 | 15.1 | 17.9 | 24.6 | 26.6 | 28.1 | 28.3 | 29.7 |
| Weight | 0.6 | 1.1 | 2.1 | 6.6 | 7.8 | 9.5 | 10.3 | 10.6 |
| Number | 11 | 54 | 28 | 29 | 95 | 52 | 18 | 6 |
| June 1974 | | | | | | | | |
| Length | 12.5 | 15.8 | 17.8 | 21.0 | 25.7 | 27.6 | 28.4 | - |
| Weight | 0.7 | 1.4 | 2.0 | 3.5 | 6.6 | 8.1 | 9.0 | - |
| Number | 29 | 43 | 117 | 80 | 35 | 5 | 18 | - |

(continued next page)

Appendix Table C.--concluded

| Statistical District, month and year sampled | Age group II | III | IV | V | VI | VII | VIII | IX |
|---|---|---|---|---|---|---|---|---|
| MM6, cont. | | | | | | | | |
| June 1975 | | | | | | | | |
| Length | 10.8 | 16.1 | 19.4 | 21.2 | 26.1 | 27.9 | 28.2 | 29.1 |
| Weight | - | 1.4 | 2.7 | 4.1 | 7.2 | 8.7 | 9.1 | 10.3 |
| Number | 21 | 80 | 66 | 70 | 91 | 74 | 86 | 31 |
| MM7 | | | | | | | | |
| August 1972 | | | | | | | | |
| Length | 11.3 | 17.1 | 20.5 | 25.0 | 26.1 | 26.4 | 28.4 | - |
| Weight | 0.5 | 1.5 | 3.2 | 6.2 | 7.7 | 7.7 | 9.6 | - |
| Number | 5 | 63 | 70 | 91 | 44 | 27 | 3 | - |
| September 1973 | | | | | | | | |
| Length | 13.1 | 17.4 | 21.7 | 26.4 | 26.5 | 28.6 | 29.9 | 30.0 |
| Weight | 0.7 | 2.0 | 4.0 | 7.6 | 7.7 | 10.0 | 11.7 | 9.9 |
| Number | 1 | 14 | 14 | 75 | 173 | 164 | 8 | 1 |
| July 1974 | | | | | | | | |
| Length | 12.6 | 15.4 | 17.0 | 24.0 | 25.8 | 26.8 | 28.0 | - |
| Weight | 0.7 | 1.3 | 1.7 | 5.3 | 7.0 | 7.6 | 8.4 | - |
| Number | 57 | 81 | 17 | 3 | 3 | 17 | 8 | - |
| July 1975 | | | | | | | | |
| Length | 10.8 | 15.5 | 18.2 | 20.4 | 28.8 | 28.7 | 30.4 | 32.8 |
| Weight | 0.4 | 1.2 | 2.0 | 3.3 | 9.3 | 9.4 | 10.6 | 14.8 |
| Number | 3 | 25 | 1 | 2 | 3 | 7 | 1 | 1 |
| MM8 | | | | | | | | |
| September 1972 | | | | | | | | |
| Length | 13.6 | 17.1 | 22.9 | 25.0 | 27.6 | 28.5 | - | - |
| Weight | 0.9 | 2.0 | 4.8 | 6.3 | 8.8 | 9.0 | - | - |
| Number | 6 | 4 | 24 | 93 | 51 | 6 | - | - |
| September 1973 | | | | | | | | |
| Length | 14.9 | 17.0 | 23.8 | 26.7 | 26.8 | 28.4 | 29.6 | - |
| Weight | 1.3 | 1.5 | 5.3 | 7.3 | 7.8 | 9.2 | 10.8 | - |
| Number | 21 | 14 | 6 | 28 | 81 | 41 | 1 | - |
| July 1974 | | | no | samples | | | | |
| July 1975 | | | | | | | | |
| Length | 12.2 | 17.1 | 22.3 | 24.2 | 26.7 | 28.4 | 27.0 | 29.2 |
| Weight | 0.6 | 1.7 | 4.2 | 4.7 | 7.8 | 9.2 | 8.1 | 10.0 |
| Number | 4 | 25 | 33 | 37 | 31 | 29 | 41 | 3 |

Appendix Table D. --Between-year comparison of mean lengths at capture of lake trout by age for certain Statistical Districts. F ratios marked with an asterisk are significant at the 95% level.

| Statistical District, age, and years sampled | | Sources of variation | Sum of squares | Degrees of freedom | Mean square | F ratio |
|---|---|---|---|---|---|---|
| MM1 | | | | | | |
| III | (1971-75) | Between | 25.9118 | 4 | 6.4780 | 2.59* |
| | | Within | 315.3105 | 126 | 2.5025 | - |
| | | Total | 341.2223 | 130 | - | - |
| IV | (1971-75) | Between | 88.7009 | 4 | 22.1752 | 4.58* |
| | | Within | 612.6200 | 134 | 4.5718 | - |
| | | Total | 701.3209 | 138 | - | - |
| V | (1971-75) | Between | 35.2711 | 4 | 8.8178 | 2.03 |
| | | Within | 60.8200 | 14 | 4.3429 | - |
| | | Total | 96.0911 | 18 | - | - |
| VI | (1971-75) | Between | 64.1755 | 4 | 16.0439 | 3.60* |
| | | Within | 124.7600 | 28 | 4.4557 | - |
| | | Total | 138.9355 | 32 | - | - |
| MM3 | | | | | | |
| III | (1971-75) | Between | 7.4444 | 4 | 1.8611 | 1.13 |
| | | Within | 132.3181 | 80 | 1.6540 | - |
| | | Total | 139.7625 | 84 | - | - |
| IV | (1969-75) | Between | 421.7220 | 5 | 84.3444 | 25.58* |
| | | Within | 831.0699 | 252 | 3.2979 | - |
| | | Total | 1252.7919 | 257 | - | - |
| V | (1969-75) | Between | 95.0096 | 5 | 19.0019 | 6.40* |
| | | Within | 344.3557 | 116 | 2.9686 | - |
| | | Total | 439.3653 | 121 | - | - |
| VI | (1970-75) | Between | 57.7571 | 5 | 11.5514 | 3.18* |
| | | Within | 333.9785 | 92 | 3.6302 | - |
| | | Total | 391.7356 | 97 | - | - |
| VII | (1971-75) | Between | 52.0743 | 4 | 13.0186 | 12.97* |
| | | Within | 35.1254 | 35 | 1.0036 | - |
| | | Total | 87.1997 | 39 | - | - |
| MM4 | | | | | | |
| III | (1972-75) | Between | 103.0708 | 3 | 34.3569 | 36.15* |
| | | Within | 44.6690 | 47 | 0.9504 | - |
| | | Total | 147.7398 | 50 | - | - |

(continued next page)

Appendix Table D. --concluded.

| Statistical District, age, and years sampled | | Sources of variation | Sum of squares | Degrees of freedom | Mean square | F ratio |
|---|---|---|---|---|---|---|
| MM4, concluded | | | | | | |
| IV | (1971-75) | Between | 56.6042 | 4 | 14.1510 | 4.90* |
| | | Within | 326.2937 | 113 | 2.8876 | - |
| | | Total | 282.8979 | 117 | - | - |
| V | (1971-75) | Between | 407.6495 | 4 | 101.9124 | 29.70* |
| | | Within | 751.5730 | 219 | 3.4318 | - |
| | | Total | 1159.2225 | 223 | - | - |
| VI | (1971-75 | Between | 50.5753 | 4 | 12.6438 | 4.01* |
| | | Within | 939.7678 | 298 | 3.1536 | - |
| | | Total | 990.3431 | 302 | - | - |
| VII | (1971-75) | Between | 56.1120 | 4 | 14.0280 | 5.12* |
| | | Within | 534.5018 | 195 | 2.7410 | - |
| | | Total | 590.6138 | 199 | - | - |
| VIII | (1972-75) | Between | 5.7866 | 3 | 1.9289 | 0.26 |
| | | Within | 567.1900 | 77 | 7.3661 | - |
| | | Total | 572.9766 | 80 | - | - |
| MM5 | | | | | | |
| III | (1971, 1974, 1975(fall) ) | Between | 22.5086 | 2 | 11.2543 | 4.61* |
| | | Within | 104.9136 | 43 | 2.4399 | - |
| | | Total | 127.4222 | 45 | - | - |
| IV | (1971, 1974, 1975(fall) ) | Between | 5.0753 | 2 | 2.5377 | 1.25 |
| | | Within | 231.7938 | 114 | 2.0333 | - |
| | | Total | 236.8691 | 116 | - | - |
| V | (1971, 1974) | Between | 40.8115 | 2 | 20.4058 | 9.67* |
| | | Within | 423.7348 | 201 | 2.1081 | - |
| | | Total | 464.5463 | 203 | - | - |
| VI | (1971, 1974, 1975(fall) ) | Between | 26.9999 | 2 | 13.5000 | 6.29* |
| | | Within | 210.2581 | 98 | 2.1455 | - |
| | | Total | 237.2580 | 100 | - | - |

Appendix Table E.--Mean total lengths of Lake Michigan lake trout at capture, and their 95% confidence limits (in parentheses) by age group and Statistical District (1969-1975). [a]

| Statistical District and age group | 1969 | 1971 | 1972 | 1973 | 1974 | 1975 |
|---|---|---|---|---|---|---|
| MM1 | | | | | | |
| III | - | 15.5 (15.3-15.7) | 15.3 (15.0-15.6) | 13.6 (13.3-13.9) | 14.0 (13.6-14.4) | 15.0 (14.7-15.3) |
| IV | - | 18.5 (18.2-18.8) | 19.5 (19.2-19.8) | 17.5 (17.2-17.8) | 16.0 (15.7-16.3) | 18.4 (18.0-18.8) |
| MM3 | | | | | | |
| IV | 20.4 (20.2-20.6) | 20.7 (20.5-20.9) | 21.2 (20.5-21.9) | 18.1 (17.9-18.3) | 17.9 (17.7-18.2) | 19.5 (19.3-19.7) |
| V | 22.2 (21.2-23.2) | 23.8 (23.5-24.1) | - | 21.2 (20.9-21.5) | 22.1 (21.8-22.4) | 23.0 (22.7-23.3) |
| VI | - | 26.7 (26.4-27.0) | 26.0 (25.6-26.4) | 27.7 (27.3-28.1) | 28.1 (27.8-28.4) | 27.0 (26.6-27.4) |
| VII | - | - | 28.4 (28.1-28.7) | 27.6 (27.3-27.9) | 28.8 (28.5-29.1) | 30.5 (30.2-30.8) |
| MM4 | | | | | | |
| III | - | - | 16.3 (16.0-16.6) | 12.4 (12.1-12.7) | 14.5 (14.1-14.9) | 16.5 (16.3-16.7) |
| IV | - | - | 21.0 (20.7-21.3) | 17.9 (17.6-18.2) | 18.2 (17.9-18.5) | 18.2 (17.9-18.5) |
| V | - | 24.2 (24.0-24.4) | 24.1 (23.9-24.3) | 23.4 (23.2-23.6) | 23.3 (23.1-23.5) | 20.5 (20.3-20.7) |
| VI | - | 26.4 (26.2-26.6) | 25.4 (25.2-25.6) | 26.0 (25.8-26.2) | 25.3 (25.1-25.5) | 25.6 (25.4-25.8) |
| VII | - | 26.8 (26.6-27.0) | 27.4 (27.2-27.6) | 26.2 (26.0-26.4) | 26.8 (26.6-27.0) | 28.2 (28.0-28.4) |

(continued next page)

Appendix Table E.--concluded

| Statistical District and age group | 1969 | 1971 | 1972 | 1973 | 1974 | 1975 |
|---|---|---|---|---|---|---|
| MM5 | | | | | | |
| V | - | 24.4 (24.2-24.7) | - | - | 25.8 (25.6-26.0) | 25.0 (24.8-25.2) |
| VI | - | 26.5 (26.2-26.8) | - | - | 28.0 (27.8-28.2) | 27.2 (27.0-27.4) |

[a] See Appendix C for sample sizes. Sample size <5 not included above.

Appendix F. Historical plantings of lake trout.

Acknowledging the fact there is no concrete information available on specific reefs where lake trout spawn in Lake Michigan, we reviewed the Charlevoix Federal Hatchery records (daily diaries) from 1903 to 1944 for these data (courtesy of the Jordan River National Hatchery). These diaries were not specific as to locations where lake trout eggs were taken, but they did mention reefs where fry were planted so we presume that they generally were returned to natural spawning areas.

During the early periods (1903-1916), lake trout eggs were taken in the fall (normally late October to early November) and shipped to the Northville Hatchery. Lake trout eggs would usually eye-up in late February and were shipped back to the Charlevoix Hatchery--at that time a small wooden building. The city waterworks building also was used for handling the eggs to the hatching stage. The eggs hatched in late March and the fry were planted in late April.

Total eggs collected from numerous points ranged at least from 10-60 million annually. The following ports were used for lake trout egg collecting points: Charlevoix (primary port), Beaver Island (primary port), Manistique, St. Joseph, Cheboygan, Leland (primary port in later years; always exceeded other ports with high percentage of eyed eggs), Northport (primary port in later years; always exceeded other ports with high percentage of eyed eggs), Detour, Alpena, St. Ignace, Frankfort, and Sutton's Bay (Grand Traverse Bay).

Eggs were taken by commercial fishermen from trout in gill nets during the spawning season. It was quite evident from the records that fishermen were more interested in catching lake trout for sale rather than collecting eggs for the future stocking of fry. There were many comments throughout the diaries where federal personnel encouraged fishermen to handle the eggs better so that there would be a higher eye-up percentage; in fact, during later years, they eliminated certain fishermen because they brought in such poor quality eggs. Fishermen replies were always that

Appendix F. (continued)

they had been collecting eggs for so many years that they knew more about taking spawn than did the hatchery personnel. Northport and Leland fishermen apparently had a serious interest in handling eggs in the best possible manner because those eggs always had a higher survival than those from other ports.

In the early years, most lake trout fry were planted by commercial fishing boats or other vessels that could be hired for the job in the Charlevoix and Beaver Island areas. Sometime around 1920 or earlier, fry were shipped to distant points by railroad car. Many were shipped to the eastern and western states. Also during this time, the federal boat "Fulmar" planted considerable numbers of lake trout on offshore reefs in northern Lake Michigan. The Michigan Department of Conservation Patrol Boat No. 1 also planted fry at these same locations in the early 1930's.

The locations where lake trout fry were planted are listed on the following page.

There was no mention in the diary of any lake trout plantings on the north shore of Lake Michigan east of Point Patterson. Commercial fishermen have advised us many times that the grounds in this area were used by whitefish, not lake trout. We suspect that those fry planted on the north shore of Lake Michigan were from the Manistique area southward to the tip of the Garden Peninsula. We suspect, too, that fry were planted in the same area from which the eggs were taken. If we are to attempt to maximize our success on offshore lake trout plants, we definitely should consider these above-mentioned areas that are documented and not just hearsay information.

Appendix F. (continued)

Locations where lake trout fry were planted are listed below:

Charlevoix Reef (10 miles west of Charlevoix pier heads)

Ile Aux Galets

Big Flat Reef (Boulder reef, west side of Beavers)

Gull Island Reef

Head of the Beavers (south end of the Beavers)

Irishman's Grounds (9 miles northwest Charlevoix pier heads)

Lake Arm (south arm of Lake Charlevoix, year 1908)

Fisherman Island Reef

Norwood Reef

Big Rock Reef (off Big Rock Nuclear Plant)

Cathead Reef (due north of Leelanau Peninsula, year 1910)

9 Mile Point (year 1910)

7 Mile Point Reef (year 1910)

Peninsula Reef (Hemingway Point, Lake Charlevoix)

Fox Island Reef (northwest tip of South Fox Island)

Atwood Reef (Grand Traverse Bay--outer portion)

Beaver Island Reef (east side of the Beavers)

Big Reef (10 miles west of Charlevoix)

Sand Bay (west side of Beaver Island, year 1913)

Beaver Island Harbor Reef (reef at the entrance to St. James Harbor)

Hat Island Reef

Pine Lake (Lake Charlevoix)

Hog Island Reef

Horseshoe Reef (southeast corner of Hog Island)

Cross Village

High Island (west side of the Beavers)

Torch Lake

Elk Lake

Dahlia Shoal

Good Hart

Grand Haven (by railroad)

Green Bay (St. Martin's Island)

St. Joseph (railroad)

Leland

Ludington (railroad)

Manistee (railroad)

St. Ignace

Ironton (Lake Charlevoix)

Eastport Reef (Grand Traverse Bay)

Northport Reef (off Charlevoix)