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Fisheries Research Report No. 1871
October 18, 1979

MICHIGAN DEPARTMENT OF NATURAL RESOURCES
FISHERIES DIVISION

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UTILIZATION OF TRADITIONAL SPAWNING REEFS BY HATCHERY LAKE TROUT IN THE UPPER GREAT LAKES[1]

By James W. Peck

Abstract

Large-mesh gill nets, fished during the spawning seasons in 1973-76, demonstrated that lake trout abundance was sufficient for natural reproduction on 17 of 32 traditional spawning reefs in Lake Superior and 2 of 19 in Lake Michigan. Spawning lake trout also were abundant on six of eight reefs in Grand Traverse Bay, Lake Michigan, that were not traditional reefs. Hatchery fish that strayed from the planting sites comprised 84% of the spawners in Lake Superior and at least 99% in Lake Michigan. Spawning occurred on most reefs as evidenced by the presence of ripe to spent lake trout. On certain reefs, additional evidence of spawning was the occurrence of lake trout eggs in piscine predators and in the substrate.

Male and female spawner lake trout averaged 8 and 9 years old, respectively, in Lake Superior and about 2 years younger in Lake Michigan. Males outnumbered females on spawning reefs in both lakes by a ratio of about 3:1. Spawning lake trout in 1973-76 matured at a younger age and grew faster than natural spawning populations in Lake Superior in 1953, but spawning period and sex ratio were similar.

A list was made of the 123 traditional spawning reefs that were identified in the study.

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

Introduction

An intensive commercial fishery combined with sea lamprey (Petromyzon marinus) predation caused the decline and near extinction of lake trout (Salvelinus namaycush) stocks in lakes Superior, Michigan, and Huron during the 1940's and early 1950's (Pycha and King 1975). State and federal agencies cooperated to implement successful sea lamprey control measures and curtail commercial fishing by the early 1960's. To re-establish lake trout, fin-clipped juvenile lake trout have been planted annually in Lake Superior (0.5 million, 1958-64; 1-2 million, 1965-71) and Lake Michigan (1-2 million, 1965-71). The first plants of these fish were expected to mature and produce young by the mid to late 1960's in Lake Superior and by the early 1970's in Lake Michigan. The hatchery fish had good survival to maturity and their eggs were viable as evidenced by successful incubation under hatchery conditions (Rybicki and Keller 1978) but there was little or no evidence of natural reproduction in the Great Lakes. Natural reproduction has been established in Wisconsin waters of Lake Superior on Gull Island Shoal (Pycha and King 1975) but this reproduction has increased only gradually and was believed to be from remnant populations of wild lake trout. Much less was known about natural reproduction on traditional reefs in Michigan waters of lakes Superior, Michigan, and Huron because little sampling has been done. However, most of the lake trout captured in sports, index, and assessment fisheries in Lake Superior have been hatchery fish and all of those captured in Lake Michigan and Lake Huron were hatchery fish.

The most commonly postulated reasons for lack of natural reproduction were contaminants, such as DDT and PCB's; predation on lake trout eggs and fry; and failure of mature hatchery lake trout to locate and deposit eggs on traditional spawning reefs. Stauffer (1979) concluded that DDT and PCB's were not the cause of reproductive failure by lake trout in Lake Michigan. He incubated eggs from Marquette Hatchery brood stock (low in DDT and PCB's) and eggs from Lake Michigan lake trout (high in DDT and PCB's) in a Lake Michigan bay and found the survival from egg to 5 weeks past swim-up to be similar for both groups of eggs. It seems unlikely that predation was a significant factor. There is no evidence to indicate that predation should be any more severe now than it was when the lakes contained wild lake trout populations. Recent studies in the Great Lakes have indicated little significant predation on lake trout eggs or fry (Stauffer and Wagner 1979).

Failure of hatchery lake trout to locate and deposit eggs on traditional spawning reefs may be the most important factor responsible for lack of successful natural reproduction. This failure may be caused by the tendency of lake trout to home to and spawn at the reef of origin. Wild lake trout tend to home to the same spawning reef each year (Eschmeyer 1955; Martin 1960) and hatchery trout have homed to planting sites in the Great Lakes. Mature hatchery lake trout have homed to planting sites in Lake Superior at Marquette and Black River harbors (Asa Wright, Great Lakes Biologist, Michigan Department of Natural Resources, personal communication), and in Lake Michigan at Charlevoix, Petoskey, Good Harbor, and Leland (Myrl Keller, Great Lakes Biologist, Michigan Department of Natural Resources, personal communication). Most lake trout plants have been made at accessible sites along the Great Lakes shoreline. These sites often afford no suitable spawning substrate, are subject to scouring by waves and ice, or are located in municipal harbors where deposited eggs may be exposed to excessive turbidity or lethal pollutants. Although planting lake trout at accessible shoreline sites is easy, economical, and directly beneficial to the sport fishery, lake trout that home to these planting sites may be "wasted" for reproductive purposes and thus defeat the goal of establishing self-perpetuating lake trout populations. It may be necessary to plant the lake trout yearlings on spawning reefs which is much more difficult and costly, but which should speed restoration of lake trout populations if a significant number home to the reef at maturity. On the other hand, a sufficient number of spawners may be straying from the shoreline planting sites to traditional lake trout spawning reefs, and planting at shoreline sites could continue.

My objectives in this study were to determine if lake trout were present in numbers that were sufficient for successful natural reproduction on traditional spawning reefs in the upper Great Lakes, to determine if these trout deposited eggs on the reefs, to describe these spawning populations, and to compare them with prior natural spawning populations.

Location and background information on traditional lake trout spawning reefs was supplied by U.S. Fish and Wildlife Service personnel and Michigan Department of Natural Resources Great Lakes biologists of the Marquette, Charlevoix, and Alpena Great Lakes units. I did not sample for lake trout spawners on all of these reefs, but as a matter of record they are briefly described in Appendix A and shown in Figures 1, 2, and 3.

Procedures

I examined 51 of 93 traditional lake trout spawning reefs identified in Michigan waters of Lake Superior and Lake Michigan (Figs. 1-2, and Appendix A). In addition, I located and examined eight reefs in the West Arm of Grand Traverse Bay in 1976. These reefs were not known as traditional reefs but they were located in an area where many lake trout had been planted. Lake Huron reefs were not sampled.

Gill nets were fished on the reefs in Lake Superior and northern Lake Michigan during 1973-76 to determine if they were being used by hatchery lake trout and to determine abundance and biological characteristics of the spawners. The gill nets were 100-975 m long and either large mesh (11.4-cm to 15.2-cm extension measure mesh) only, or large mesh along with small mesh (3.8 cm to 6.4 cm). The small-mesh nets were included to capture other fishes that might be eating lake trout eggs. Usually a single overnight set of 20-24 hours duration was made on each reef during 15 October-15 November. The nets normally were set on the slope of the reef exposed to the prevailing wind where wind-generated currents would keep the substrate clean. The substrate was described either from direct observations or, in most cases, by interpretation of a recording fathometer trace. A water temperature, usually a bottom temperature, was obtained for each set.

Data for each set were recorded on a Great Lakes Data sheet (R-8171). For lake trout, I recorded total length (mm), fin clip, sex, and condition of the gonads. No scale samples were collected in 1973 but scale samples were taken in 1974-76 from unclipped trout and from those hatchery trout where the fin clip was no longer reliable to separate year classes. I recorded species and number of individuals for other fishes taken in the nets. In 1973-75, stomachs of those fish considered to be potential lake trout egg predators (including lake trout) were preserved in 10% formalin and the stomach contents examined for the presence of lake trout eggs (except collections west of the Keweenaw Peninsula, Lake Superior). The presence of lake trout eggs in stomachs of lake trout or other fishes captured on the reef was considered to be evidence of egg deposition.

I determined age and year class of most of the hatchery lake trout caught on each reef by their fin clip. The fin or combination of fins clipped represented a specific year class planted in the waters of a Great Lake controlled by a particular state or province (Lamsa 1973; Herbert 1977). As an example, lake trout of the 1967 year class marked with an adipose fin clip were planted only in Michigan waters of Lake Superior. Specific fin clips also were assigned to certain plants made at certain locations which permitted assessment of straying from the planting site. However, in 1973, different year classes with identical fin clip were found to have overlapping length distributions which made age assessment based on fin clip unreliable for those fish within the overlap. Fish with these fin clips were scale sampled in 1974-76 and scales were examined to determine the age of the fish. I determined age and year class of unclipped lake trout collected in 1974-76 by scale examination. I did not scale sample unclipped lake trout in 1973.

The potential for natural reproduction was assessed by CPE (catch per unit of effort), which was the number of spawners captured overnight per 305 linear meters of 11.4-cm mesh gill net. Potential for successful natural reproduction was judged to be excellent (CPE $\geq$50), good (CPE = 25-49), fair (CPE = 10-24), or poor (CPE = $<$10). Judgments were based on the CPE of lake trout spawners from the naturally reproducing populations on Gull Island Shoal in Wisconsin waters of Lake Superior (CPE during 1964-73 = 15-85 spawners; Great Lakes Fishery Commission 1974) and on the CPE of native spawners from reefs near Marquette during the early 1950's (CPE = 7-15 spawners; U.S. Fish and Wildlife Service unpublished data).

Lake Superior results

Abundance of spawners.--Mature lake trout were abundant on most reefs sampled in Lake Superior. Mature lake trout were captured on 28 of 32 reefs and CPE was equal to or greater than 25 on 17 reefs (Tables 1-3) which I classified as having good to excellent potential for successful natural reproduction (Appendix A). Hatchery lake trout made up most of the catch of mature trout on the spawning reefs. The percentage of hatchery lake trout in the catch ranged from 100% on seven reefs to 30% on Huron Island Reef (Tables 1-3). The percentage was highest in the area between Little Girls Point and Manitou Island and lowest between Big Bay Point and Grand Marais. Sexually mature unclipped lake trout were captured on 21 reefs and equaled or exceeded the catch of hatchery trout on three of the reefs. These trout are believed to be wild progeny of hatchery fish and/or remnant stocks of wild trout, although a few could have been unclipped hatchery lake trout. Longnose suckers (*Catostomus catostomus*) and round whitefish (*Prosopium cylindraceum*) were the most abundant fishes other than lake trout in gill net catches on the spawning reefs.

Evidence of spawning.--Lake trout spawned on most reefs sampled in Lake Superior as evidenced by the presence of lake trout in ripe to spent gonad condition (Tables 1-3) and by discovery of lake trout eggs in stomachs of fish captured on some reefs. Lake trout eggs were found in stomachs of fish captured on Partridge Island Reef in 1973, on Big Bay Point Reef, Laughing Fish Point Reef, Brownstone Beach Reef, and Grand Portal Reef in 1974, and on Red Rocks Reef and Buffalo Reef in 1975. The capture of mature wild lake trout was evidence that spawning had occurred prior to 1973-76, but I could not determine whether they were progeny of hatchery or wild lake trout.

Biological characteristics.--Lake trout spawning in Lake Superior began in mid-October and extended into early November. Most netting was done during 20 October-5 November and ripe individuals of both sexes were usually captured (Tables 1-3). None of nine females collected on 15 October were ripe. Lake trout spawned at bottom water temperatures on the reefs of 9-12 C in 1973, 1975, and 1976; the lake cooled earlier in 1974 and temperatures at spawning were 8-9 C.

Hatchery lake trout captured on reefs in Lake Superior during 1973-75 averaged about 8 years old (range, 4-14) for males and between 8 and 9 years old (range, 5-13) for females (Table 4). The 1960 to 1970 year classes were represented in the catch, with the 1964 year class most abundant in 1973 as 9-year-old fish and the 1967 year class predominating in 1974 and 1975 as 7- and 8-year-old trout. The catch in 1976 was too meager for a reliable determination of age composition. Mature wild lake trout captured in gill nets in Lake Superior in 1974-75 ranged in age from 5 to 11 years with an average of 7 years for both sexes. The 1967 and 1968 year classes were the most abundant as ages 7 and 6 in 1974 and as ages 8 and 7 in 1975.

Male lake trout caught in Lake Superior in 1973-75 averaged smaller than females but the largest fish captured were males. Males averaged 645 to 686 mm in total length with a range of 508 to 914 mm and females averaged 701 to 744 mm with a range of 584 to 889 mm. Male lake trout predominated in the total catch on most reefs sampled in Lake Superior during 1973-76 (Tables 1-3) and accounted for 71-81% of the hatchery fish caught annually during 1973-75 (Table 4). The youngest age group in each catch was often composed entirely of males but the sex ratio in older age groups was more nearly even. Males also outnumbered females among wild spawners captured in Lake Superior. They comprised 86% of the catch in 1974 and 64% of the catch in 1975.

Lake Michigan results

Abundance of spawners.--Mature lake trout were captured on 23 of the 27 reefs netted but the abundance was usually much less than on Lake Superior reefs (Tables 5-7). Only eight near-shore reefs had good to excellent potential for reproduction (CPE $\geq$ 25). Six are in the West Arm of Grand Traverse Bay and were not reported to be traditional lake trout spawning reefs. The other two near-shore reefs are Fisherman Island Reef near Charlevoix and Round Island Reef in Green Bay. Lake trout were absent or scarce on most reefs along the north shore and on all of the offshore reefs. The best offshore catch was on Traverse Shoal in Grand Traverse Bay where the potential for reproduction was fair. Round whitefish and suckers were the most common fish other than lake trout captured on reefs in Lake Michigan. Suckers were rather equally divided between longnose and white suckers (Catostomus commersoni). Crayfish (Decapoda) were taken in practically all gill net sets in Lake Michigan and were especially abundant in near-shore sets made in Grand Traverse Bay.

The catch of lake trout was of hatchery origin on all but four reefs where one unclipped trout was taken on each reef (Tables 5-7). Of the four trout, three were too old to be progeny of hatchery fish. These fish were probably hatchery fish without a fin clip. The youngest unclipped trout could have been produced by the first plants of hatchery lake trout.

Evidence of spawning.--Lake trout spawning occurred on most reefs sampled in Lake Michigan during 1973-76 as evidenced by the presence of ripe to spent trout (Tables 5-7), ingested lake trout eggs (in the stomach of a lake trout taken on Traverse Shoal in 1974), and live eggs found by suction pumping on some reefs. Pumping produced live lake trout eggs, including some in the eyed stage, on North Point Reef in 1973, 1974, and 1975, and at Bowers Harbor and New Mission Point in 1976. No eggs were found by pumping on Fishermans Island Reef.

Biological characteristics.--My data indicate that lake trout spawning in Lake Michigan commenced during the last week of October and ended by mid-November. Practically all of the females collected on the earliest sampling dates (19-22 October) were not yet ripe (Tables 5 and 6). Some females had not yet spawned by the second week of November in 1973, but all females captured during 30 October-5 November in 1974 were spent. Bottom water temperatures on the reefs were 9-12 C during the lake trout spawning period.

Mature male and female hatchery lake trout captured on reefs in the three areas of Lake Michigan in 1973-76 were not greatly different in age (Tables 8-9). Overall, males averaged 5 to 7 years old (range, 4-11) and females averaged 6 to 7 years old (range, 5-11). Predominant age groups of lake trout on spawning reefs near Charlevoix included age 7 (1966 year class) in 1973; age 8 and age 5 (1966 and 1969 year classes) in 1974, and age 6 (1969 year class) in 1975 (Table 8). The most abundant age groups found at north shore spawning reefs were age 7 and 6 (1968 and 1969 year classes) in 1975 and ages 7, 6, and 5 (1969, 1970, and 1971 year classes) in 1976 (Table 9). These latter three age groups were found in nearly identical composition on reefs in the West Arm of Grand Traverse Bay in 1976 (Table 9).

The largest lake trout captured in Lake Michigan in 1973-76 were males, but males averaged smaller than females. Males averaged 658 to 696 mm, total length (range, 533-889 mm) and females averaged 711 to 729 mm (range, 559-813 mm). Males outnumbered females on most reefs sampled in Lake Michigan (Tables 4-6) and, with one exception, accounted for 55-76% of the catch in each area (Tables 8-9). The exception was the Charlevoix area in 1974 when sampling did not start until 30 October and most of the catch consisted of spent females. The youngest year class in each sample was often composed entirely of males but the sex ratio was more even or occasionally favored females in older year classes.

Discussion

Abundance of spawners.--I judge that the abundance of spawners on many reefs in Lake Superior and certain reefs in northern Lake Michigan was sufficient for successful natural reproduction. The abundance of spawners on most of the reefs sampled in Lake Superior and eight shoreline reefs in Lake Michigan was comparable to that of the naturally reproducing population of lake trout on Gull Island Shoal. The spawner lake trout populations on most Michigan reefs were comprised mainly of hatchery fish that had strayed from shoreline planting sites. Lake trout were much less abundant on all offshore reefs more than 5 km from a planting site and on most of the inshore reefs sampled along the north shore of Lake Michigan. Lack of sufficient straying is a probable reason for the paucity of spawners on the offshore reefs, whereas absence from north shore reefs may be due to the incidental catch in gill nets used by the commercial fishery for whitefish. Lake trout were generally abundant on shoreline reefs at Charlevoix and in Grand Traverse Bay where commercial fishing had been prohibited.

My sampling may have been inadequate to detect spawning populations on some reefs because most reefs were sampled only once during the spawning period. As an example, the number of lake trout caught in sets made only 3-4 days apart on Red Rocks Reef and Huron Island Reef in 1975 were quite different (Table 1). On the larger reefs it is also possible that sampling was done where lake trout were not spawning even though spawning might have been occurring on other parts of the reef. However, my net sets were made on portions of the reef believed most exposed to currents which are more suitable for lake trout spawning (Royce 1943).

Evidence of spawning.--I found ample evidence of lake trout spawning in both Lake Superior and Lake Michigan. I assumed that ripe to spent lake trout captured on a spawning reef were in fact spawning or about to spawn on the reef. The best evidence of lake trout spawning was the capture of fish that had ingested lake trout eggs on eight reefs and the recovery of eggs by pumping on three reefs. However, the absence of eggs in the stomachs of potential piscine egg predators or failure to recover eggs by pumping does not mean that eggs were not deposited. Few lake trout eggs would be exposed to predation on a good spawning reef characterized by many deep crevices in the substrate (Stauffer and Wagner 1979). Also, eggs in crevices deeper than 15 cm could not be collected by the suction pump. In addition to gonad condition and the recovery of eggs in predator stomachs or by pumping, my assumption that mature lake trout were on the reefs to spawn is supported by the apparent segregation of mature and immature lake trout during the spawning period. Immature lake trout were rarely captured on spawning reefs but were present in waters immediately adjacent to the reef as indicated in the catch from two nets fished concurrently at Laughing Fish Point in 1973. One net was set on the reef and the other set on a flat sand-silt substrate just off the reef. Only mature lake trout were captured in the net on the reef but five of six trout in the net off the reef were immature. Mature and immature lake trout appear to be more evenly mixed during other times of the year as 62% of the lake trout captured in the May-June 1977 assessment fishery in Lake Superior were immature (Michigan Department of Natural Resources unpublished data).

The wild lake trout caught on many Lake Superior reefs indicate prior reproduction by hatchery fish or remnant wild stocks. The virtual absence of wild trout on northern Lake Michigan reefs suggests that the initial plants failed to reproduce and that there were no remnant stocks of wild trout.

Comparison with prior natural spawning populations.--Hatchery lake trout in spawning populations from Lake Superior in 1973-75 and northern Lake Michigan in 1973-76 matured at an earlier age and were growing faster than spawning populations of wild lake trout sampled in 1953 from the Marquette-Munising area of Lake Superior. The youngest mature hatchery trout from both lakes was 4 years old for males and 5 years old for females, whereas the youngest mature wild male and female in 1953 were 7 and 9 years old, respectively (Rahrer 1967). Although the minimum age at maturity of hatchery trout in Lake Superior was almost half that of the former wild population, the minimum lengths at maturity were not nearly as different (508 mm vs. 564 mm for males and 584 mm vs. 673 mm for females) which indicates faster growth for the hatchery trout.

I could not find any data on size and age at maturity for the former wild lake trout populations in Lake Michigan, but Rybicki and Keller (1978) reported that average length and weight of age groups III-VIII in Lake Michigan were much greater in 1972 than in 1947. In my study, hatchery lake trout in Lake Michigan averaged 1-2 years younger and became sexually mature at a younger age than hatchery trout in Lake Superior although there was little difference in average total length of spawners between the two lakes. Lake trout assessment data for 1977 showed that the age at which more than 50% are mature was 5 years for males and 6 years for females in Lake Michigan whereas it was 9 years for both sexes in Lake Superior (Michigan Department of Natural Resources unpublished data). The differences in age at maturity betwen present hatchery trout and former wild trout in Lake Superior, and between hatchery fish in the two lakes are likely due to the faster growth rates. Maturity of lake trout is related to growth with slow growing fish requiring more years to reach maturity (Carlander 1969, p. 189).

The spawning period and sex ratio of lake trout populations from Lake Superior and northern Lake Michigan sampled in 1973-76 were similar to those sampled in the Marquette-Munising region of Lake Superior in the

1940's and 1950's. Eschmeyer (1955) reported that the spawning period during 1944-53 was October-early November which was the same as I found. Eschmeyer also found that the percentage of males on or near the spawning grounds ranged between 60% and 69%. He cited other studies that reported a preponderance of males, some as high as 86%. These percentages were similar to those that I found in Lake Superior and northern Lake Michigan. The earlier age at maturation for males seems most responsible for their preponderance on the spawning reefs but greater longevity and better survival also would result in a sex ratio favoring males. Although I could find no documentation of sexual differences in longevity and survival, I did observe that the oldest individual lake trout captured in areas of Lake Superior during 1973-75 were males and Rahrer (1967) presented data on spawning lake trout from Marquette-Munising waters in 1953 showing a ratio favoring males in every age group (VII-XII).

Straying of hatchery lake trout.--Hatchery lake trout strayed from planting sites and found traditional spawning reefs in Michigan waters of Lake Superior and northern Lake Michigan as evidenced by their capture on traditional reefs in both lakes. Information on distances strayed in Lake Superior was obtained from the capture of trout from a specially marked lot of yearlings planted in Presque Isle Harbor at Marquette in 1969. In 1974-75, seven spawning trout from this plant were caught on spawning reefs 10-114 km from the planting site. In Lake Michigan, there were no mature fish marked to designate a specific planting site but some fin clips were specific to certain areas of the lake. Five percent of the lake trout captured in Grand Traverse Bay and 4% of those captured along the north shore had been planted in other areas of the lake.

Although many mature lake trout returned to the planting site during the spawning period, there was evidence indicating that even some of these fish abandoned the site and located traditional reefs that same spawning period. In Lake Superior, one male lake trout tagged near the planting site in Presque Isle Harbor on 20 October 1973, was recaptured 6 days later on a reef some 10 km away. In Lake Michigan, four males tagged at the Charlevoix planting site were recaptured several days later, one on Dahlia Shoal and three on Traverse Shoal which are 30-35 km from Charlevoix.

Straying also occurs in wild lake trout populations both between years and within years. DeRoche (1969) reported that in Thompson Lake, Maine, some lake trout returned to the same spawning beds each year but that others strayed to different areas and some visited more than one spawning area during the same spawning period. Eschmeyer (1955) reporting on the recapture of wild lake trout tagged on spawning ground near Marquette, could only state that the tagged fish showed a "proclivity" to return to the reef where tagged. Some of the tagged wild trout were recaptured during the spawning period the following year on spawning reefs 29 to 100 km away.

Recommendations

Planting lake trout at shoreline sites need not be abandoned. Lake trout that home to shoreline sites may not necessarily be wasted if suitable substrate is at or near the site or if these fish subsequently stray to traditional shoreline or offshore reefs. Shoreline reefs make up a significant proportion of the known traditional reefs in the upper Great Lakes (Figs. 1-3, Appendix A) so it would seem wise to continue certain levels of stocking at sites near these reefs. Continued stocking of offshore reefs in Lake Michigan and some offshore reefs in Lake Superior is recommended as apparently few lake trout have located these reefs.

The utilization of traditional spawning reefs by hatchery lake trout provides hope that restoration of lake trout populations in the upper Great Lakes may be realized. The numbers of mature naturally reproduced lake trout captured on some Lake Superior reefs are evidence of progress toward this goal. I believe the restoration of lake trout in the Great Lakes will be achieved if we can continue stocking at or near the current level, keep our lakes clean, and minimize natural and fishing mortality.

Acknowledgments

Assisting me with locating and sampling lake trout spawning reefs were U.S. Fish and Wildlife Service personnel from the Biological Station at Ashland, Wisconsin, and Great Lakes Laboratory in Ann Arbor, Michigan, and Michigan Department of Natural Resources Fisheries personnel from Charlevoix, Marquette, and Alpena Great Lakes units, and District III. The manuscript was reviewed by Thomas M. Stauffer, W. C. Latta, and Doris S. Greenleaf.

Table 1.--Condition of the gonads, abundance (CPE), percentage hatchery origin, and sex ratio of mature lake trout captured on spawning reefs in Lake Superior, from Little Girls Point to Manitou Island, during 15-30 October 1975.

Reef no., reef, and date sampled	Number of lake trout and gonad condition				CPE[a]	Percent-age hatchery origin	Sex ratio (% males)
	Males		Females				
	Green	Ripe-spent	Green	Ripe-spent			
1. Little Girls Point							
15 October	1	7	9	0	27	100	47
30 October	0	8	0	7	20	100	53
2. West Ontonagon							
23 October	1	6	5	6	17	94	39
3. East Ontonagon							
23 October	0	0	0	1	<1	100	0
4. Fourteen Mile Point							
23 October	0	7	1	1	7	89	78
5. West Upper Entry							
22 October	0	0	0	0	0	-	-
6. East Upper Entry							
22 October	0	4	0	0	3	100	100
8. Eagle River Shoals							
21 October	2	28	10	8	27	96	62
9. Little Grand Marais							
21 October	1	60	3	19	57	98	73
11. Copper Harbor							
21 October	0	17	9	11	30	97	46
13. Manitou Island							
21 October	0	1	0	0	<1	100	100
21 October	0	0	0	0	0	-	-
29 October	0	0	0	0	0	-	-

[a] Number of mature lake trout captured overnight per 305 m of 11.4-cm mesh gill net.

Table 2.--Condition of the gonads, abundance (CPE), percentage hatchery origin, and sex ratio of mature lake trout captured on spawning reefs in Lake Superior, from Point Isabelle to Huron River Point, during 21-30 October 1975.

Reef no., reef, and date sampled	Number of lake trout and gonad condition				CPE[a]	Percentage hatchery origin	Sex ratio (% males)
	Males		Females				
	Green	Ripe-spent	Green	Ripe-spent			
14. Point Isabelle							
21 October	0	30	6	7	57	98	70
16. Buffalo Reef							
22 October	1	80	5	4	130	100	90
18. Hallberg Reef							
28 October	0	0	0	0	0	-	-
19. Red Rocks Reef							
24 October	0	13	3	1	13	94	76
28 October	1	30	2	7	10	92	73
20. Traverse Island							
22 October	2	39	6	7	83	65	76
21. Trout Reef, No. 1							
23 October	0	0	1	0	<1	0	0
22. Trout Reef, No. 2							
24 October	0	0	0	0	0	-	-
23. Pequaming Reef							
26 October	9	13	5	0	47	100	81
24. Point Abbaye							
26 October	10	17	9	1	47	100	73
25. Huron Island							
27 October	1	6	3	3	27	31	54
30 October	1	7	0	2	7	30	80
26. Huron River Point							
27 October	0	4	3	0	7	86	57
30 October	0	2	3	0	3	100	40

[a] Number of mature lake trout captured overnight per 305 m of 11.4-cm mesh gill net.

Table 3.--Condition of the gonads, abundance (CPE), percentage hatchery origin, and sex ratio of mature lake trout captured on spawning reefs in Lake Superior, from Big Bay Point to Grand Marais, during 22-31 October 1973, 22 October-5 November 1974, and 19-20 October 1976.

Reef no., reef, and date sampled	Number of lake trout and gonad condition: Males		Number of lake trout and gonad condition: Females		CPE[a]	Percentage hatchery origin	Sex ratio (% males)
	Green	Ripe-spent	Green	Ripe-spent			
27. Big Bay Point							
22 October 1974	0	14	4	7	57	88	56
28. Garlic Island Reef							
22 October 1974	0	48	5	8	60	52	79
29. Partridge Island Reef							
26 October 1973	0	78	8	8	65	78	82
23 October 1974	1	63	5	9	180	68	83
30. Laughing Fish Point							
22 October 1973	0	6	3	0	15	100	67
31 October 1973	0	13	0	2	25	93	87
30 October 1974	0	9	0	2	3	67	82
5 November 1974	3	29	0	1	83	79	97
31. Au Train Island							
30 October 1974	0	36	4	16	93	82	64
32. Brownstone Reef							
30 October 1974	0	22	1	4	30	93	81
33. Wood Island Reef							
24 October 1974	1	2	1	3	23	86	43
34. Wood Island Shoal							
5 November 1974	0	0	0	0	0	-	-
35. Grand Portal Point							
24 October 1974	0	38	6	8	93	81	73
36. Au Sable Point							
19 October 1976	0	2	0	0	2	50	100
37. Grand Marais Reef							
20 October 1976	0	8	0	3	8	45	73

[a] Number of mature lake trout captured overnight per 305 m of 11.4-cm mesh gill net.

Table 4.--Percentage age composition by sex and sex ratio of each age group of spawning hatchery lake trout caught on spawning reefs[a] in Lake Superior during October-November, 1973-75. Sample size in parentheses.

Age (years)	1973 Percentage in age group Males	1973 Percentage in age group Females	1973 Sex ratio (% males)	1974 Percentage in age group Males	1974 Percentage in age group Females	1974 Sex ratio (% males)	1975 Percentage in age group Males	1975 Percentage in age group Females	1975 Sex ratio (% males)
14				1 (1)		100			
13				2 (3)	8 (5)	38	1 (2)		100
12	3 (2)		100	4 (8)	10 (6)	57	4 (15)	7 (11)	58
11	10 (6)	30 (4)	60	7 (14)	10 (6)	70	4 (14)	8 (12)	54
10	7 (4)	21 (3)	57	6 (12)	15 (10)	55	9 (33)	12 (18)	65
9	28 (17)	21 (3)	85	15 (30)	8 (7)	81	12 (44)	8 (12)	79
8	13 (8)	14 (2)	80	11 (21)	4 (3)	88	34 (123)	38 (57)	68
7	8 (5)		100	17 (33)	38 (26)	56	15 (55)	16 (25)	69
6	18 (11)	14 (2)	65	21 (41)	6 (4)	91	21 (77)	11 (17)	82
5	13 (8)		100	14 (27)	1 (1)	96	1 (4)		100
4				2 (3)		100			
Average	8.2	9.2		7.7	8.8		8.0	8.4	
Total	(61)	(14)	81	(193)	(68)	74	(367)	(152)	71

[a] See Tables 1-3 for list of reefs.

Table 5.--Condition of the gonads, abundance (CPE), percentage hatchery origin, and sex ratio of mature lake trout captured on spawning reefs along the north shore of Lake Michigan, from Wells State Park south of Cedar River to Naubinway, during October-November 1974-76.

Reef no., reef, and date sampled	Number of lake trout and gonad condition: Males, Green	Males, Ripe-spent	Females, Green	Females, Ripe-spent	CPE[a]	Percentage hatchery origin	Sex ratio (% males)
1. Wells Park Camp							
12 November 1975	0	0	0	1	2	100	0
2. Wells Park Nature Center							
12 November 1975	0	0	0	0	0	-	-
3. Bakers Reef							
22 October 1976	0	0	1	1	2	100	0
4. Halsteads Reef							
22 October 1976	0	1	0	0	1	100	0
5. Round Island Reef							
4 November 1975	3	17	1	6	8[b]	100	74
19 October 1976	0	12	7	0	17	100	63
6. North Round Island							
4 November 1975	0	1	0	0	2	100	100
7. Stonington							
19 October 1976	0	5	7	0	13	100	42
8. Peninsula Point							
5 November 1975	0	0	0	0	0	-	-
9. Eleven Foot Shoal							
6 November 1975	0	3	0	0	6	100	100
10. Minneapolis Shoal							
6 November 1975	0	0	0	0	0	-	-
11. Point Aux Barques							
29 October 1976	0	1	0	1	2	100	50
12. Seul Choix Point							
25 October 1976	0	6	3	1	9	100	60
14. Naubinway Reef							
3 November 1974	0	0	0	0	0	-	-

[a] Number of mature lake trout captured overnight per 305 m of 11.4-cm mesh gill net.

[b] CPE in 3.8-cm mesh was 60 and in 6.4-cm mesh was 47.

Table 6.--Condition of the gonads, abundance (CPE), percentage hatchery origin, and sex ratio of mature lake trout captured on spawning reefs in Michigan waters of Lake Michigan near Charlevoix during October-November 1973-75.

Reef no., reef, and date sampled	Number of lake trout and gonad condition				CPE[a]	Percentage hatchery origin	Sex ratio (% males)
	Males		Females				
	Green	Ripe-spent	Green	Ripe-spent			
24. Richards Reef							
28 October 1975	1	3	1	3	3	100	50
27. N. W. South Fox Island							
30 October 1973	1	0	1	0	2	100	50
13 November 1973	0	3	0	0	3	100	100
28 October 1975	1	2	0	0	2	100	100
32. Dahlia Shoal							
29 October 1973	0	2	1	0	3	100	67
7 November 1973	0	3	0	8	9	100	27
30 October 1974	0	0	0	2	2	100	0
22 October 1975	6	0	5	0	5	100	54
5 November 1975	1	1	0	2	3	100	50
37. Fishermans Island							
31 October 1973	0	111	1	29	117	100	79
39. Irishman Grounds							
30 October 1974	0	3	0	0	2	100	100
5 November 1974	0	3	0	6	8	100	33
21 October 1975	2	0	1	0	2	100	67
4 November 1975	1	2	2	3	3	100	38
44. Traverse Shoal							
11 November 1973	0	15	0	10	22	100	60
5 November 1974	2	2	1	5	8	90	40
20 October 1975	11	0	3	0	6	100	79
3 November 1976	0	5	0	3	6	100	62

[a] Number of mature lake trout captured overnight per 305 m of 11.4-cm mesh gill net.

Table 7.--Condition of the gonads, abundance (CPE), percentage hatchery origin, and sex ratio of mature lake trout captured on spawning reefs in Grand Traverse Bay, Lake Michigan, during 26 October-3 November 1976.

Reef no., reef, and date sampled	Number of lake trout and gonad condition				CPE[a]	Percent-age hatchery origin	Sex ratio (% males)
	Males		Females				
	Green	Ripe-spent	Green	Ripe-spent			
46. Bowers Harbor 2 November	0	5	5	5	46	100	33
47. Marion Island-South 26 October	0	5	2	0	23	100	71
48. Marion Island-North 2 November	0	15	2	12	86	97	52
49. Tucker Point 26 October	0	1	0	0	6	100	100
50. Suttons Point 27 October	1	36	3	4	138	98	84
51. New Mission Point 28 October	1	33	1	3	126	97	89
52. Bellow Island 28 October	1	19	10	2	103	100	62
53. Northport Point 3 November	0	8	2	4	43	100	57

[a] Number of mature lake trout captured overnight per 305 m of 11.4-cm mesh gill net.

Table 8.--Percentage age composition by sex and sex ratio of each age group of spawning hatchery lake trout captured on spawning reefs[a] in Michigan waters of Lake Michigan near Charlevoix during October-November 1973-75. Sample size in parentheses.

Age (years)	1973 Percentage in age group: Males	1973 Percentage in age group: Females	1973 Sex ratio (% males)	1974 Percentage in age group: Males	1974 Percentage in age group: Females	1974 Sex ratio (% males)	1975 Percentage in age group: Males	1975 Percentage in age group: Females	1975 Sex ratio (% males)
10							4 (1)	11 (2)	33
9	2 (1)		100		12 (2)	0	4 (1)		100
8	8 (4)	15 (4)	50		38 (6)	0	14 (4)	17 (3)	57
7	43 (21)	66 (17)	55	14 (1)	19 (3)	25	4 (1)	17 (3)	25
6	18 (9)	19 (5)	64	14 (1)	12 (2)	33	46 (13)	40 (8)	62
5	23 (11)		100	72 (5)	19 (3)	62	21 (6)	11 (2)	75
4	6 (3)		100				7 (2)		100
Average age	6.3	7.0		5.4	7.1		6.2	6.8	
Total	(49)	(26)	65	(7)	(23)	30	(28)	(18)	61

[a] See Table 5 for list of reefs.

Table 9.--Percentage age composition by sex and sex ratio of each age group of spawning hatchery lake trout captured on spawning reefs[a] in Michigan waters of Lake Michigan, along the north shore from Cedar River east to Seul Choix Point, and in Grand Traverse Bay during October-November 1975-76. Sample size in parentheses.

Age (years)	Cedar River to Seul Choix Point						Grand Traverse Bay		
	1975			1976			1976		
	Percentage in age group		Sex ratio (% males)	Percentage in age group		Sex ratio (% males)	Percentage in age group		Sex ratio (% males)
	Males	Females		Males	Females		Males	Females	
11							1 (2)	7 (4)	33
10	4 (1)		100				4 (5)	7 (4)	56
9	4 (1)		100				6 (7)	5 (3)	70
8	4 (1)	12 (1)	50	19 (5)	9 (2)	71	1 (1)	7 (4)	20
7	44 (11)	38 (3)	79	22 (6)	50 (11)	35	39 (46)	30 (18)	72
6	28 (7)	50 (4)	64		32 (7)	42	24 (28)	27 (16)	64
5	12 (3)		100		9 (2)	82	24 (28)	17 (10)	74
4	4 (1)		100				1 (2)		100
Average	6.6	6.6		6.1	6.6		6.7	7.7	
Total	(25)	(8)	76	(27)	(22)	55	(118)	(59)	67

[a] See Tables 4 and 6 for list of reefs.

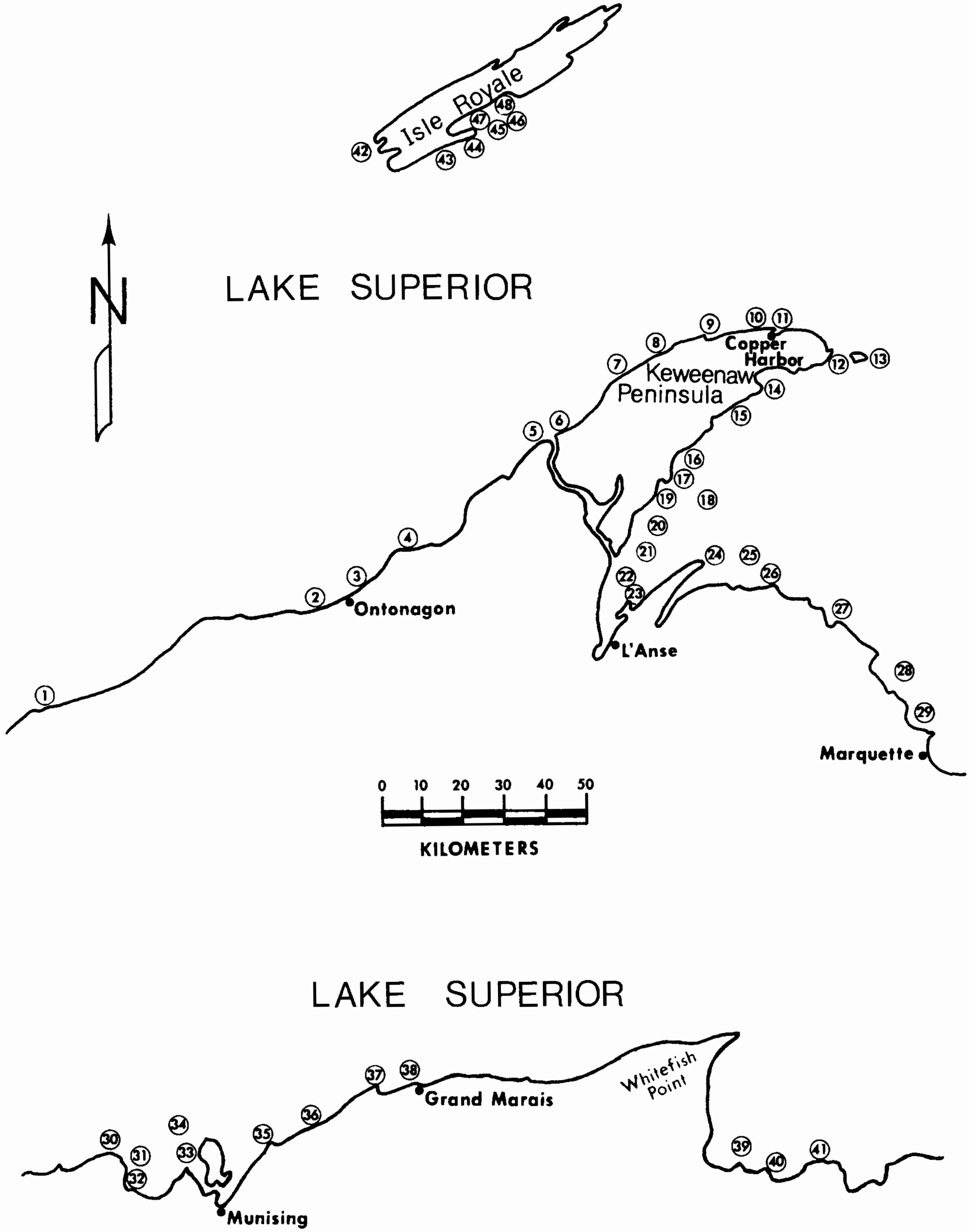

Figure 1.--Lake trout spawning reefs (circled numbers) in Michigan waters of Lake Superior (west half above, east half below). See Appendix A for description of reefs.

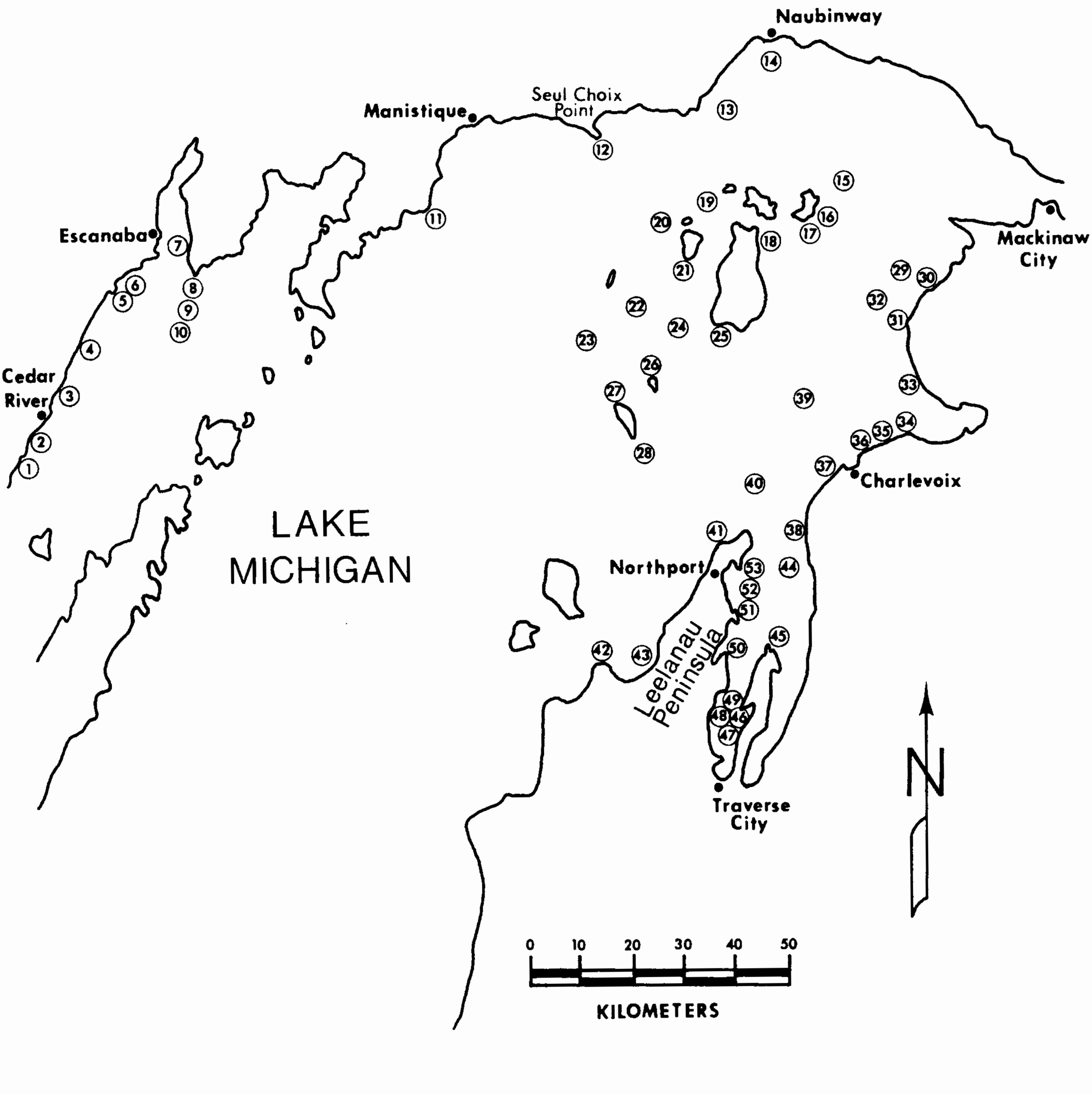

Figure 2.--Location of lake trout spawning reefs (circled numbers) in Michigan waters of northern Lake Michigan. See Appendix A for description of reefs.

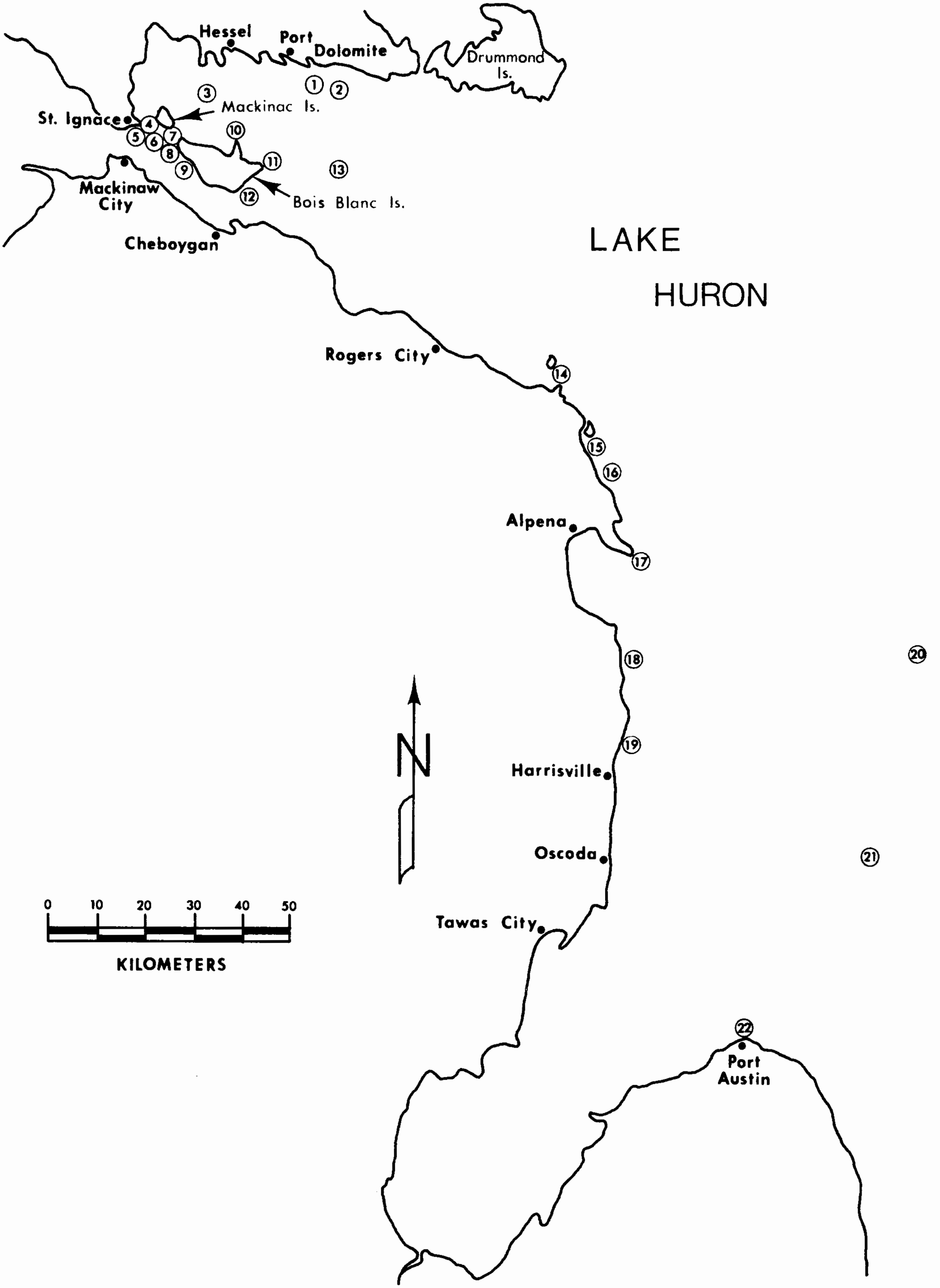

Figure 3.--Location of lake trout spawning reefs (circled numbers) in Michigan waters of Lake Huron. See Appendix A for description of reefs.

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Report approved by W. C. Latta

Typed by M. S. McClure

Appendix A

Lake trout spawning reefs in the upper Great Lakes

Michigan Department of Natural Resources Great Lakes biologists and U.S. Fish and Wildlife Service biologists provided most of the locations of lake trout spawning reefs in Michigan waters of lakes Superior, Michigan, and Huron. Physical data on most of the reefs were obtained by direct observation, use of a recording fathometer, or from National Oceanic and Atmospheric Administration (NOAA) nautical charts. These reefs are those reportedly used by the lean variety of lake trout and do not include reefs used by the siscowet or humper varieties of lake trout in Lake Superior. This list of reefs is not complete as there are undoubtedly other spawning areas of unknown or unreported location. Gill nets were fished on many of the reefs during the 1973-76 lake trout spawning periods. I used the abundance of sexually mature lake trout in the gill nets to establish tentative criteria for judging the potential for natural reproduction. I compared the CPE of mature lake trout (number captured overnight per 305 linear meters of 11.4-cm gill net) with the CPE of lake trout spawners in a naturally reproducing population on Gull Island Shoal in Wisconsin waters of Lake Superior (CPE during 1964 to 1973 = 15-85 spawners; Great Lakes Fishery Commission 1974) and to CPE of native spawners on reefs near Marquette, Michigan, during the early 1950's (CPE = 7-15 spawners; USFWS unpublished data). Based on CPE during 1973-76, lake trout spawner populations were judged to have a poor (<10), fair (10-24), good (25-49), or excellent (≥ 50) potential for successful reproduction. The reefs in each lake are numbered and the numbers correspond to number locations on Figures 1-3.

Lake, reef no., and reef[a]	Latitude deg	Latitude min	Longitude deg	Longitude min	Depth[b] (m)	Bottom type[c]	Type of survey[d]	Net-ted[e]	Repro-ductive potential[f]
Lake Superior									
1. Little Girls Point	46	37	90	20	0-17	-	-	yes	G
2. West Ontonagon	46	52	89	24	0-12	-	-	yes	F
3. East Ontonagon	46	54	89	17	0-12	-	-	yes	P
4. Fourteen Mile Point	47	0	89	7	0-15	-	-	yes	P
5. West Upper Entry	47	14	88	39	5-12	RR	-	yes	P
6. East Upper Entry	47	15	88	36	2-12	RR	-	yes	P
7. Hutchinson Shoal	47	23	88	24	4	RR	-	no	-
8. Eagle River Shoals	47	26	88	17	1-7	RR	-	yes	P
9. Little Grand Marais	47	28	88	6	5	RR	-	yes	E
10. Devils Wash Bowl	47	29	87	57	-	RR	-	no	-
11. Copper Harbor	47	29	87	52	5	RR	-	yes	G
12. Keweenaw Point	47	24	87	43	0-15	RR	-	no	-
13. Manitou Island	47	25	87	37	6-9	RR	-	yes	P
14. Point Isabelle	47	21	87	55	2-12	-	-	yes	E
15. Betsy	47	18	88	3	-	RR	-	no	-
16. Buffalo	47	12	88	12	5-11	RR	F, V	yes	E
17. Traverse Point	47	9	88	14	0-12	RR	F	no	-
18. Hallberg	47	7	88	10	30	-	F	yes	P
19. Red Rocks	47	7	88	17	0-15	RR	F	yes	E
20. Traverse Island	47	4	88	16	2-6	RR	F	yes	E
21. Trout Reef No. 1	47	1	88	19	12-26	-	F	yes	P
22. Trout Reef No. 2	46	56	88	25	18-20	-	-	yes	P
23. Pequaming Point	46	52	88	22	0-14	-	F	yes	G
24. Point Abbaye	46	58	88	6	2-6	B, RR	F	yes	G
25. Huron Islands	46	57	87	58	0-24	RR	F	yes	G
26. Huron River Point	46	55	87	53	2-11	RR	F	yes	P
27. Big Bay Point	46	52	87	41	3-15	RR	F	yes	E
28. Garlic Island	46	44	87	32	15	RR	F	yes	E
29. Partridge Island	46	37	87	25	15	P, C, B	F	yes	E
30. Laughing Fish Point	46	32	86	59	7-20	RR	F	yes	E
31. AuTrain Island	46	30	86	54	7-20	B, C	F, V	yes	E
32. Brownstone	46	27	86	53	4-12	B, C	F, V	yes	G
33. Wood Island Reef	46	31	86	45	6-20	RR	F, V	yes	F
34. Wood Island Shoal	46	35	86	46	15	-	F	yes	P
35. Grand Portal Point	46	33	86	29	0-21	RR	F	yes	E

(continued, next page)

Lake, reef no., and reef [a]	Latitude deg	Latitude min	Longitude deg	Longitude min	Depth [b] (m)	Bottom type [c]	Type of survey [d]	Net-ted [e]	Reproductive potential [f]
Lake Superior, continued									
36. Beaver Hump	46	37	86	21	12-18	-	-	no	-
37. AuSable Point	46	41	86	9	4-20	B	F, V	yes	P
38. Grand Marais	46	42	86	2	12-17	-	F	yes	P
39. Tahquamenon Island	46	32	84	53	10-30	-	-	no	-
40. Salt Point	46	28	84	50	-	RR	-	no	-
41. Iroquois Island	46	30	84	40	-	B, RR	-	no	-
42. Rock of ages	47	52	89	19	1-7	-	-	no	-
43. McCormick Reef	47	51	89	2	-	-	-	no	-
44. McCormick Rocks	47	52	88	57	1	-	-	no	-
45. Brandsford	47	54	88	52	1	-	-	no	-
46. Harlem	47	54	88	50	1	-	-	no	-
47. Hay Bay	47	56	88	55	1	-	-	no	-
48. Domen and Doden	47	58	88	50	1	-	-	no	-
Lake Michigan									
1. Wells Park Campground	45	21	87	23	2-8	RR	F	yes	P
2. Wells Park Nature Center	45	22	87	22	3-7	RR	F	yes	P
3. Bakers	45	28	87	18	2-4	RR	V	yes	P
4. Halsteads	45	32	87	15	3-9	RR	F	yes	P
5. Round Island	45	38	87	10	2-6	B, RR	F, V	yes	E
6. North Round Island	45	38	87	10	2-3	B, RR	F, V	yes	P
7. Stonington	45	43	86	59	2-5	RR, S	V	yes	F
8. Peninsula Point	45	39	86	58	0-15	RR	F, V	yes	P
9. Eleven Foot Shoal	45	38	86	59	3-6	RR	F	yes	P
10. Minneapolis Shoal	45	35	86	59	3-6	RR	F	yes	P
11. Point Aux Barques	45	47	86	20	0-8	RR	F	yes	P
12. Seul Choix Point	45	55	86	54	3-11	RR	F, V	yes	P
13. Potter	46	0	85	31	1-9	C	S	no	-
14. Naubinway	46	3	85	25	1-15	C, B	S	yes	P
15. Hat Island	45	49	85	18	0-9	-	-	no	-
16. Hog Island	45	44	85	21	2-10	-	-	no	-
17. Horseshoe	45	46	85	20	0-9	-	-	no	-
18. Beaver Island Harbor	45	44	85	30	-	-	-	no	-
19. Whiskey Island Shoal	45	48	85	38	1-12	-	-	no	-
20. Trout Island Shoal	45	47	85	44	3	-	-	no	-

(continued, next page)

Lake, reef no., and reef[a]	Latitude deg	Latitude min	Longitude deg	Longitude min	Depth[b] (m)	Bottom type[c]	Type of survey[d]	Net-ted[e]	Repro-ductive potential[f]
Lake Michigan, continued									
21. High Island	45	44	85	40	-	-	-	no	-
22. Gull Island	45	38	85	48	1	-	-	no	-
23. Boulder	45	36	85	58	5	-	-	no	-
24. Richards	45	34	85	44	7	RR	F	yes	P
25. Head of the Beavers	45	34	85	36	-	-	-	no	-
26. North Fox Island	45	30	85	47	-	-	-	no	-
27. N. W. South Fox Island	45	29	85	53	7-20	B, RR	F, V	yes	P
28. South Fox Island Shoals	45	16	85	51	3-7	-	-	no	-
29. Ile aux Galets	45	41	85	10	2	-	-	no	-
30. Cross Village	45	39	85	4	-	-	-	no	-
31. Good Hart	45	34	85	8	-	-	-	no	-
32. Dahlia Shoal	45	38	85	12	4	B, RR	F, S	yes	P
33. Seven Mile Point	45	29	85	7	-	-	-	no	-
34. Nine Mile Point	45	23	85	8	-	-	-	no	-
35. Big Rock Point	45	22	85	12	-	-	-	no	-
36. North Point	45	21	85	15	-	-	-	no	-
37. Fisherman Island	45	18	85	22	2-10	RR, B	F, V	yes	E
38. Norwood	45	13	85	25	-	-	-	no	-
39. Irishman Grounds	45	26	85	22	8	P, C, B	F, S	yes	P
40. Cathead	45	18	85	33	7	S, RR	F, S	no	-
41. Cathead Point	45	12	85	35	-	-	-	no	-
42. Pyramid Point	45	0	85	55	2-6	-	-	no	-
43. Good Harbor	44	59	85	49	2	-	-	no	-
44. Traverse Shoal	45	8	85	26	5	RR	F	yes	F
45. Old Mission Point	45	2	85	29	7	-	-	no	-
46. Bowers Harbor	44	54	85	32	2-8	S,P,C,B	F,V,S	yes	G
47. Marion Island South	44	51	85	36	0-12	S, B	F, V	yes	F
48. Marion Island North	44	53	85	34	2-6	C, B	F, V	yes	E
49. Tucker Point	44	54	85	34	0-15	S, RR	F	yes	P
50. Suttons Point	45	0	85	36	5-12	RR	F	yes	E
51. New Mission Point	45	4	85	34	2-6	C, B	F,V,S	yes	E
52. Bellow Island	45	6	85	34	0-9	C, B	F,V,S	yes	E
53. Northport Point	45	8	85	33	5-14	RR	F	yes	G

(continued, next page)

Lake, reef no., and reef[a]	Latitude		Longitude		Depth[b] (m)	Bottom type[c]	Type of survey[d]	Net-ted[e]	Repro-ductive potential[f]
	deg	min	deg	min					
Lake Huron									
1. Pomeroy	45	56	84	12	6	RR	F, S	no	-
2. Martin	45	55	84	9	2	-	-	no	-
3. Goose Island	45	54	84	29	1	-	-	no	-
4. North Graham Shoal	45	50	84	42	1	-	-	no	-
5. South Graham Shoal	45	50	84	42	1	-	-	no	-
6. Majors Shoal	45	49	84	39	4	-	-	no	-
7. Round Island	45	50	84	37	-	-	-	no	-
8. Lime Kiln Point	45	49	84	36	-	-	-	no	-
9. Zela Shoal	45	47	84	34	-	P, C, B	V	no	-
10. Lighthouse Point	45	49	84	26	-	-	-	no	-
11. Lafayette Point	45	46	84	21	-	-	-	no	-
12. Poe	45	42	84	22	-	-	-	no	-
13. Spectacle	45	46	84	8	-	-	-	no	-
14. Old Presque Isle Lighthouse	45	20	83	30	-	-	-	no	-
15. Rockport-Stoneport	45	14	83	23	-	-	-	no	-
16. Middle Island	45	11	83	18	-	-	-	no	-
17. North Point	45	0	83	15	-	-	-	no	-
18. Black River Island	44	50	83	15	-	-	-	no	-
19. Sturgeon Point	44	43	83	14	-	-	-	no	-
20. Six Fathom Bank	44	36	82	30	11	-	-	no	-
21. Yankee	44	25	82	32	25	-	-	no	-
22. Port Austin	44	4	82	59	-	-	-	no	-

[a] Numbers correspond to those on Figures 1-3.

[b] Range or minimum depth.

[c] RR = rock rubble of unknown size, otherwise substrate classified by size according to Wentworth in Welch (1948) as follows: boulders (B) = >256 mm, cobble (C) = 64-256 mm, pebble (P) = 4-64 mm, granule (G) = 2-4 mm, sand (S) = 0.06-2 mm.

[d] Recording fathometer = F, visually from surface = V, or visually by scuba divers = S.

[e] Spawning population sampled one or more times with large mesh gill nets in 1973-76.

[f] P = poor, F = fair, G = good, E = excellent.