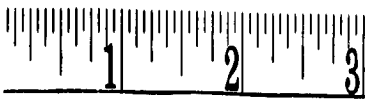
DOCTORAL DISSERTATION SERIES

TITLE Reproduction and Migration of the Yellow Pikeperch, Stizostedion Vitreum Vitreum, in Michigan

AUTHOR Paul Henry Eschmeyer

UNIVERSITY of Michigan DATE 1949

DEGREE Ph.D. PUBLICATION NO. 1188



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Yellow Pikeperch congreated on the spawning beds at Lake Gogebic.

REPRODUCTION AND MIGRATION OF THE YELLOW PIKEPERCH, *STIZOSTEDION VITREUM VITREUM*, IN MICHIGAN

by

Paul H. Eschmeyer

A Dissertation submitted in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy, in the University of Michigan.

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TABLE OF CONTENTS

Page

INTRODUCTION 4

ACKNOWLEDGMENTS 7

PART I. OBSERVATIONS ON THE LIFE HISTORY OF YELLOW PIKEPERCH IN LAKE GOGEBIC, WITH SPECIAL REFERENCE TO REPRODUCTION 8

Description of Lake Gogebic 8

Pikeperch spawning grounds in Lake Gogebic 16

Spawning behavior 28

Progress of the spawning season in terms of numbers of pikeperch on the spawning grounds 42

Sex ratio on the spawning grounds 60

Movement of pikeperch during and immediately following the spawning season 72

Size distribution of pikeperch on the spawning grounds in 1947 81

Species associated with pikeperch on the spawning grounds 87

Identification of sex and development of the reproductive organs 87

Fecundity of pikeperch 102

Pikeperch eggs on the spawning grounds 116

Behavior, growth, and food during the first summer of life 128

Page

PART II. OBSERVATIONS ON THE LIFE HISTORY OF YELLOW PIKEPERCH IN THE MUSKEGON RIVER, WITH SPECIAL REFERENCE TO MIGRATION 148

Introduction 148

The Newaygo transfer 151

Pikeperch spawning runs of 1947 and 1948 162

Movement of tagged yellow pikeperch in the Muskegon River in 1947 and in 1948 179

Migration of pikeperch in inland lakes 200

SUMMARY 207

LITERATURE CITED 215

REPRODUCTION AND MIGRATION OF THE YELLOW PIKEPERCH, STIZOSTEDION VITREUM VITREUM, IN MICHIGAN

INTRODUCTION

The yellow pikeperch, Stizostedion vitreum vitreum (Mitchill), is the largest American member of the perch family (Percidae). In our waters it shares the subfamily Lucioperсinae with two smaller fishes, the sauger, Stizostedion canadense (Smith), and the blue pikeperch, Stizostedion vitreum glaucum Hubbs. The distribution of the latter subspecies is largely confined to Lake Erie, although fish occurring in Lake Ontario, lakes in the St. Lawrence River and Lake Huron drainages in Ontario, and in Lake Winnipeg in Manitoba have been identified with it. The yellow pikeperch and the sauger have a much larger and somewhat similar distribution. For the pikeperch this range is as follows: "From Great Slave Lake, the Saskatchewan River system and the Hudson Bay region to Labrador; southward on the Atlantic slope to North Carolina, and west of the mountains, to the Alabama River system of Georgia to the Tennessee River drainage of Alabama and to northern Arkansas and Nebraska. Common through the Great Lakes and many of the inland lakes and rivers of the basin; in Lake Erie chiefly to the westward" (Hubbs and Lagler, 1947). Recent American workers separate the genus Stizostedion from the Eurasian genus Lucioperca, with which it is closely allied.

The yellow pikeperch has many common names, usually associated with geographic localities. In Michigan and neighboring states it is best

known to anglers as walleye (Outdoor Writers Association of America, 1948) or wall-eyed pike. Commercial fishermen of the Great Lakes prefer yellow pike, yellow pickerel, or merely yellow or pickerel. Among French Canadians it is commonly called the Doré, or Dory. Names with more restricted usage include jack, jack salmon, Susquehanna salmon, white salmon, okow, glass-eye, green pike, grass pike, hornfish, and others.

The yellow pikeperch is among the most important species contributing to the sport fishery of a large portion of the United States and Canada. In addition to the many thousands of pounds taken annually by anglers from streams and lakes throughout its range, the species makes a substantial contribution to the commercial fisheries of the Great Lakes (particularly of Lake Erie which from 1940 to 1944 had an average annual production of nearly 3.7 million pounds) and certain other waters. Thus, those who take their fish with rod and line and those who patronize the fish markets have an equal opportunity to enjoy the widely acknowledged excellence of its flavor.

The pikeperch is highly regarded by anglers in Michigan, and is found in many of the larger lakes and streams of both the Lower and the Upper Peninsulas. For several decades prior to 1945 millions of fry were planted annually, and relatively few of the larger waters of the state have escaped an introduction of the species.

In spite of the importance of the pikeperch, pertinent information concerning its life history is less well known than is that of many of the other important game fishes. It was with the hope of making a contribution to our knowledge of the life history of the species that the present study was undertaken.

The field work was begun in 1941, while the writer was a district fisheries biologist with the Institute for Fisheries Research, stationed near Lake Gogebic in the western part of the Upper Peninsula of Michigan. Observations were continued in 1942. Further work was interrupted by World War II, until 1947, when a more intensive study of the species was undertaken, both in Lake Gogebic and in the Muskegon River, a major tributary to Lake Michigan located in the west-central portion of the Lower Peninsula. This was continued in 1948.

The work was financed and equipment was provided by the Institute for Fisheries Research of the Michigan Department of Conservation.

This paper is divided into two parts. The first deals with observations made at Lake Gogebic, with particular emphasis directed toward various aspects of reproductive behavior. The second concerns the species in the Muskegon River, with special reference to its migration. Pertinent observations made in other waters are included in these sections under the appropriate topics.

In addition to the material here presented, substantial progress has been made in the analysis of additional data collected on body-scale relationship, growth, condition, and food of the species in Lake Gogebic. These data will form the basis for a separate contribution.

ACKNOWLEDGMENTS

The work with which this paper deals would not have been possible without the kind and highly regarded assistance of many persons. To those who assisted in the study in either the field or laboratory, I wish to express my thanks and appreciation.

My special thanks are due Dr. Reeve M. Bailey who, as chairman of the doctoral committee, directed the study, and to Dr. A. S. Hazzard, director of the Institute for Fisheries Research, who originally suggested the problem and who supervised the work. Both contributed valuable suggestions and helpful guidance as the work progressed and took an active interest in all aspects of the study throughout its duration.

The following members of the Institute staff contributed materially to the work in the field: Clarence Taube, Leland Anderson, Floyd Simonis, Walter Crowe, Stanley Lievense, and the late Dexter Reynolds.

Other members of the Institute staff gave unstintingly of their time and advice and offered invaluable aid in many ways throughout the progress of the study.

William Cristanelli drafted the maps and graphs in the following pages and prepared many of the illustrations from kodachrome transparencies.

Helpful advice was given by Dr. Karl Lagler of the Department of Zoology, by Dr. Ralph Hile of the U. S. Fish and Wildlife Service, and by my brother, Dr. R. W. Eschmeyer, of the Tennessee Valley Authority.

PART I. OBSERVATIONS ON THE LIFE HISTORY OF YELLOW PIKEPERCH IN LAKE GOGEBIC, WITH SPECIAL REFERENCE TO REPRODUCTION

Description of Lake Gogebic

Lake Gogebic is located in Gogebic and Ontonagon counties, in the western part of the Upper Peninsula of Michigan. It is about 30 miles east of the city of Ironwood and is near the western headwaters of the Ontonagon River.

The shallow, boot-shaped basin of the lake is about 12 miles long, from 1.5 to 2.5 miles wide, and extends in a north-south direction. It has an area of 14,781 acres and a maximum depth of 37 feet. An aerial view of the lake is shown in Figure 1, and a hydrographic map is presented as Figure 2.

Bottom types consist of muck in the deeper portion of the lake, and of sand, gravel, rubble, boulders, or mixtures of these materials in most of the shoreward areas less than 15 feet in depth.

The lake and its tributaries have a drainage basin of about 160 square miles. The land has a rolling topography, is densely wooded, and has a soil composed largely of sand and clay.

The principal inlet is the Slate River which flows into the south end of the lake. The mouth of the stream is flooded and water is backed up to within a few hundred yards of Judson Falls, which is about 1.5 miles above the lake. At this point the river is about 20 feet wide. Trout Brook and Merriweather Creek are smaller streams entering the lake from the southeast and northwest respectively.

Lake Gogebic's outlet, the west branch of the Ontonagon River, flows from the northeast end of the lake. About one-half mile downstream from

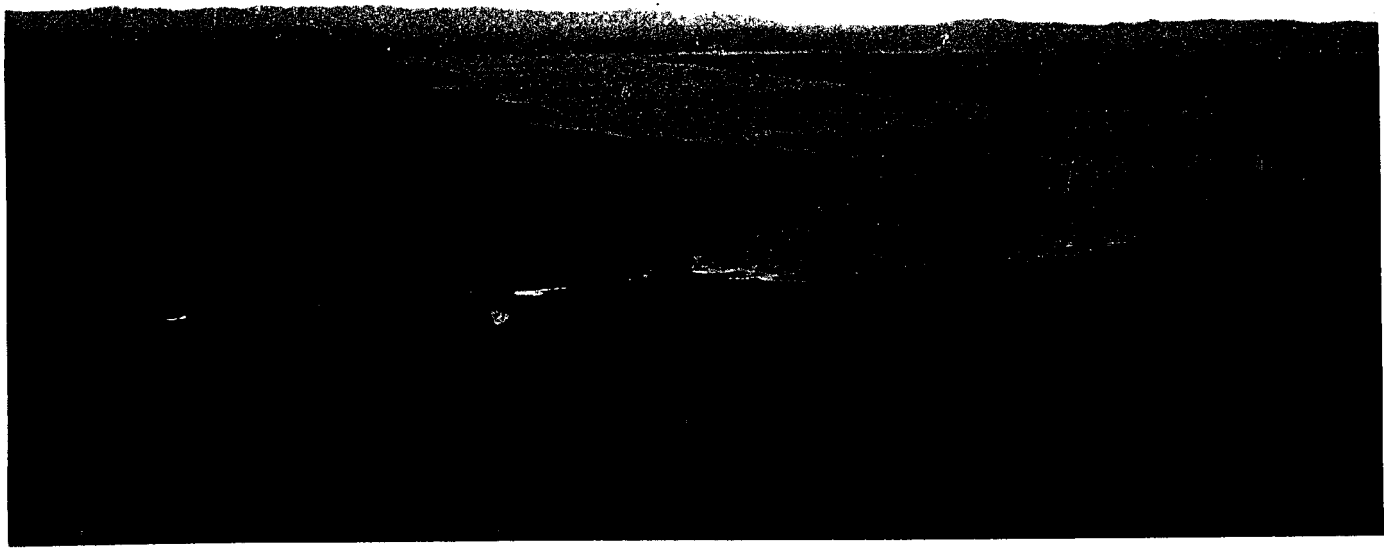

Fig. 1. Aerial view of Lake Gogebic from the south. The stream entering the lake (lower left) is the Slate River.

the lake is a dam owned by the Upper Peninsula Power Company, which raises the level of the lake about 30 inches and floods the mouths of its inlet streams. Fluctuations in water level are not drastic. During most years a gradual decrease in level occurs between the spring break-up of ice and the following winter.

The water is brown in color, the darkest coloration occurring near the mouths of the Slate River and Merriweather Creek. During the period from June 16 to 27, 1938, when a biological inventory was made by the Institute for Fisheries Research, Secchi disc readings ranged from 2 to 9 feet. The water was found to be soft, with a methyl-orange alkalinity of from 18 to 34 parts per million, with a pH varying from neutral to slightly alkaline (7.0-7.8).

Rooted aquatic plants are not abundant in the lake, and occur only in more or less localized areas. The principal plant beds are found in the shallow northern end of the lake and near the mouth of the Slate River. Submerged pondweeds occur at intervals along the east and west shores, but extensive intervening areas here are barren.

Yellow pikeperch and northern pike, Esox lucius Linnaeus, dominate the game fish population in Lake Gogebic. The young of yellow perch, Perca flavescens (Mitchill), are very abundant, but relatively few adults of this species occur. Several other game species are present only in small numbers and contribute little to the fishery at the present time. These include smallmouth bass, Micropterus dolomieu dolomieu Lacépède; largemouth bass, Micropterus salmoides salmoides (Lacépède); black crappie, Pomoxis nigromaculatus (LeSueur); rock bass, Ambloplites rupestris rupestris (Rafinesque); and, seasonally, brook trout, Salvelinus fontinalis fontinalis (Mitchill). The cisco, Leucichthys artedi (LeSueur) is common.

Forage species which have been collected by various members of the staff of the Institute, or which have occurred in stomachs of game fishes, include the following: mudminnow, Umbra limi (Kirtland); western golden shiner, Notemigonus crysoleucas auratus Rafinesque; northern common shiner, Notropis cornutus frontalis (Agassiz); northeastern sand shiner, Notropis deliciosus stramineus (Cope); troutperch, Percopsis omiscomaycus (Walbaum); central Johnny darter, Boleosoma nigrum nigrum (Rafinesque); and ninespine stickleback, Pungitius pungitius (Linnaeus). These species occur only in small numbers. Mudminnows and common and golden shiners are encountered somewhat more frequently than others in the list.

The white sucker, Catostomus commersonii commersonii (Lacépède), is very common, and the American burbot, Lota lota maculosa (LeSueur), is occasionally seen. The bowfin, Amia calva Linnaeus, and bullheads, Ameiurus sp., may have occurred in the lake in the past but none is known to have been collected or observed within the past 20 years.

The past history of the fishing in Lake Gogebic has been reported in part by the late Dr. Jan Metzelaar (unpublished), who made a preliminary biological investigation of the lake during the period from September 17 to 21, 1928. Dr. Metzelaar wrote in part:

"The interesting history of the fishing on Gogebic Lake forms a story which has spread to the four corners of the Great Lakes, but on which it is hard to get accurate details. From miscellaneous information I have sifted the following notes. In the 19th century Gogebic Lake was one of the outstanding, famous bass lakes of the States. Smallmouth bass predominated, next to which came largemouth bass, rock bass, followed by bluegills and sunfish. No strictly predatory fish were present, but 'minnows and shiners' were abundant and in certain seasons could be found

swimming inshore in large numbers.

"In 1897 (some reports say as early as 1892) the grass pike (northern pike) was introduced; 84 good sized specimens of this fish, and also 18 muskies were freed in the Gogebic waters. Soon after this introduction large pike were caught and in goodly numbers, the record being 27 pounds. In later years both numbers and size dwindled and no remarkable pike have been caught since 1924 or 1925, which coincides with the rise of the walleye.

"The pikeperch or wall-eyed pike was successfully introduced as fry around 1913 and its history closely parallels that of the northern pike. Ten years after its introduction the walleye was caught in numbers with hook and line, the weight running up to 16 pounds. At present numbers have dwindled and the record in recent years has been around 10 pounds.

"In both cases we find that the second generation - born from the original stock - offered splendid fishing upon reaching maturity, but that there was no sustained yield.

"What happened in the meantime to the other fishes of the lake? If we may believe the reports of seemingly trustworthy residents, their fate under the combined assaults of the two new predators has been anything but happy. To make a sad story brief: largemouth bass, bluegills, sunfish, minnows and shiners are no more in the lake. Diligent search in the marshes and bays probably would reveal some survivors of the sunfish family in addition to the smallmouth bass (which still persists in moderate numbers) and the crappie."

The degree of dominance of yellow pikeperch in the catches by anglers at Lake Gogebic in recent years is shown by creel census records obtained

there in 1940, 1941, and 1947.* The percentage of the total number of fishermen contacted by the creel census clerks is not known, but it is believed that the records are sufficient in number to show the approximate composition of the total catch during the periods covered. The census began on May 15 each year and ended on October 26, 1940, on October 10, 1941, and on September 30, 1947. The results are shown in Table 1.

Pikeperch constituted about 81 percent of the fish in the 1940 catch and about 89 percent in 1941. In 1947 this percentage dropped to about 54, and northern pike and yellow perch were much more prominent in the catch. The reasons for this change in the proportions of the species are not known.

It is of interest to note in this connection, however, that in Lake Geneva, Wisconsin, Nelson and Hasler (1942) reported that a survey by Pearse in about 1921 showed that pikeperch were more abundant than northern pike. In 1942 the former species had practically disappeared from the lake, whereas northern pike had become the most abundant of the game fish. Rawson (1945) believed that the reduction in numbers of northern pike as a result of angling in Lake Waskesiu, Saskatchewan, may have made possible a great increase in the number of pikeperch, from about 5 percent of the gill-net catch in the years from 1928 to 1934, to 45 percent in 1942. Metzlaar's report, discussed above, indicates that northern pike became much reduced in numbers when pikeperch became established in Lake Gogebic. The possibility is indicated that under certain circumstances dominance among

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*Records were taken in the field by Richard Bohland in 1940, by Dexter Reynolds in 1941, and by Jack Haskins in 1947. Boat liverymen, conservation officers, and interested fishermen assisted in the work. Louis Krumholz summarized much of the data for 1940 and 1941 and Howard Loeb compiled the records for the 1947 census.

Table 1. Summary of creel census in Lake Gogebic showing percentage composition of the catch in 1940, 1941 and 1947.

Year	Number fishermen contacted	Total hours fished	Legal fish taken	Northern pike	Pikeperch	Yellow perch	Small-mouth bass	Large-mouth bass	Rock bass	Black crappie	White sucker	Burbot
1940	2,276	8,051	2,917	12.6	80.9	2.4	2.5	0.2	0.2	1.1	tr	0.1
1941	4,687	16,923	4,835	6.9	89.3	2.0	1.1	tr	tr	0.6	...	0.1
1947	3,165	8,663	4,179	28.7	53.7	16.0	0.8	0.2	0.1	0.3	0.1	0.1

predator species in a given lake may change in degree, or may change from one species to another, particularly where northern pike and pikeperch are concerned. That the creel census results at Lake Gogebic for 1947, as compared to earlier years, may be an indication that such a change is taking place is an interesting conjecture which invites further study.

In size, depth, fish population, and perhaps other characteristics, Lake Gogebic appears to be similar to a large number of lakes in central and northern Minnesota described by Eddy and Surber (1947). In these lakes, which are from 35 to 40 feet deep and from 8 to 15 miles across, pikeperch dominate fish populations which include also perch, northern pike, and suckers. Sunfish, bass, and crappies are not common except in bays. Judging from Dr. Metzelaar's account (above), events following the stocking of pikeperch fry in Lake Gogebic parallel to some degree the unusual success which these authors reported for a number of large, shallow lakes in Cook County, Minnesota, which contained no game fishes except northern pike at the time of planting. In Brule Lake, for example, they said that it was possible to catch the legal limit of pikeperch in any part of the lake three years after the initial stocking with pikeperch fry.

In summary, Lake Gogebic is a large, shallow lake with soft, brown water which is neutral in reaction, with little aquatic vegetation and with a stony shoreline. Yellow pikeperch now strongly predominate the fish population which contains few forage species. Formerly the lake was dominated by smallmouth bass and later by northern pike.

Pikeperch spawning grounds in Lake Gogebic

Pikeperch spawn either in streams or lakes, apparently depending upon local circumstances in the water concerned. The following are among the spawning grounds reported by various workers: mouths of rivers and creeks (Smith, 1892); sandy bars in shallow water (Bean, 1903); along the entire shoreline, near shore, on gravel bottom (Evermann and Latimer, 1910); shallow bars or "flats" at the edge of deep water (Miles, 1915); on sticks and stones in running water, at the foot of waterfalls (Bensley, 1915); on sand and gravel, in shallow water (Henshall, 1919); in lakes, if prevented by weather or other causes from entering streams (Cobb, 1923 - [discussion] -; MacDonald, 1924); in streams or in some cases in shallow sandy bays (Dymond, 1926); shoal waters (Leach, 1927); anywhere near the mouth of streams where depth and other conditions are suitable, or in lakes if prevented by weather or other causes from entering streams (Adams and Hankinson, 1928); small creeks and rivers or in shallow bays near shore (Bajkov, 1930); in streams, on sandy bars in shallow water (Fish, 1932); in tributary streams or in the lake (Stoudt, 1939); on hard bottom, usually in moving water (Hinks, 1943); up tributary streams in riffles or on gravel reefs in shallow waters of the lake (Eddy and Surber, 1947); and tributary streams, over a stony bottom (Derback, 1947).

Spawning of yellow pikeperch along the east shore of Lake Gogebic has been suspected by local residents for a number of years. Richard Bohland and others of the Michigan Department of Conservation observed (unpublished) concentrations of pikeperch on the shoal areas along the east shore of the lake in May, 1940, and suggested that they might be spawning. The writer's first opportunity to observe the fish and to attempt to determine the nature and extent of the spawning grounds occurred during April and May of

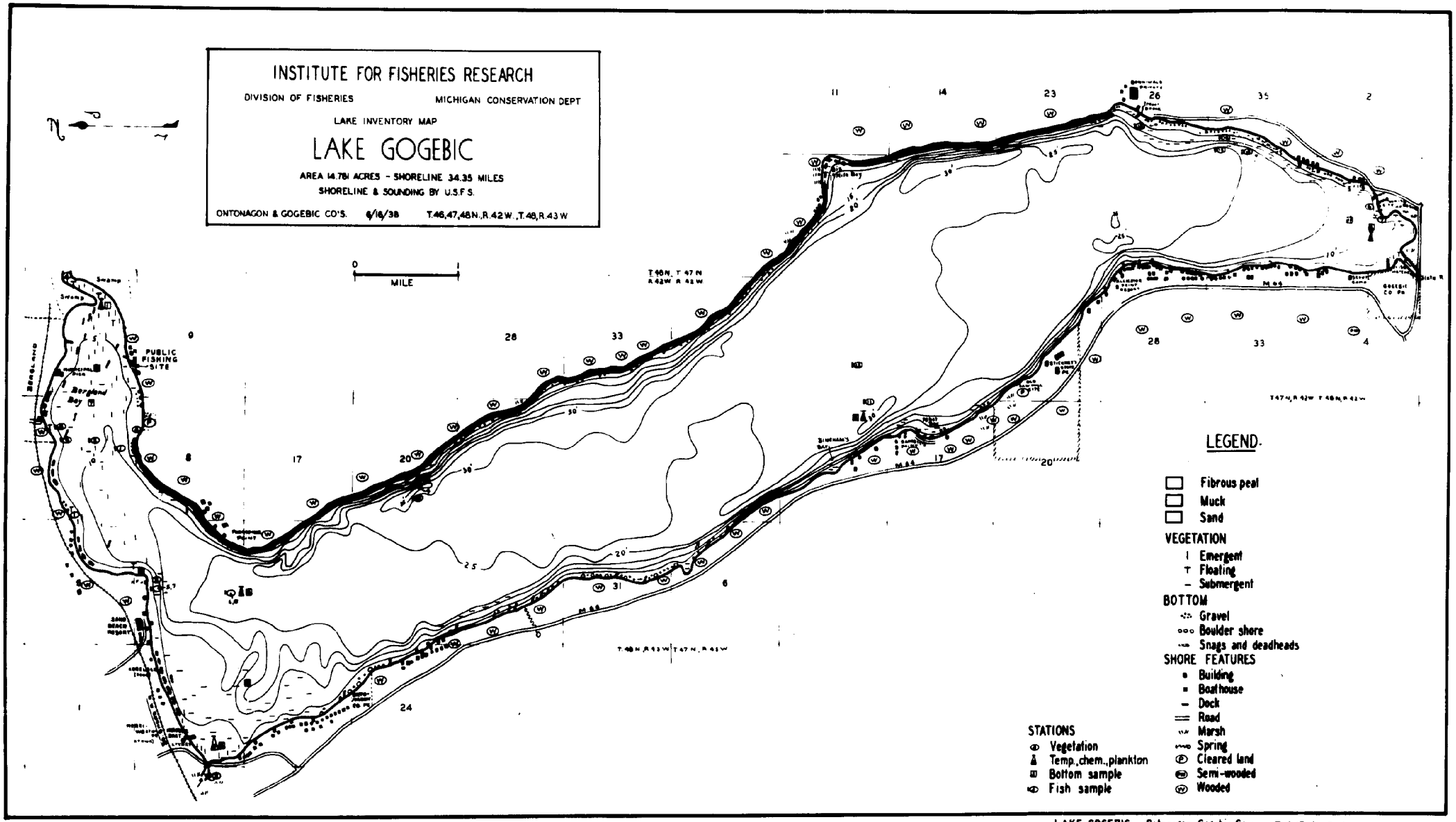
the following year.

The principal spawning grounds of pikeperch in Lake Gogebic extend almost without interruption for a distance of over 10 miles along the east shore of the lake (Fig. 2). The southern end of the grounds is three miles from the south end of the lake, near the north boundary of Section 26 (T. 47 N., R. 42 W.). The northern extremity is located on the south shore of Bergland Bay (Sect. 8, T. 48 N., R. 42 W.).

The bottom along nearly this entire section of shoreline is composed of a mixture of gravel, rubble, and boulders, to depths up to 10 feet. Sand and fine gravel compose the substratum for these materials and extend to a depth of 15 feet in some areas. Typical sections of the shoreline are shown in Figures 3 and 4. These photographs were taken in October, 1947, when the water level was about 30 inches lower than during the spring of most years. Almost all spawning activity which has been observed at Lake Gogebic has occurred within the area exposed by the lowered water level. Figure 3 shows a typical mixture of the bottom materials prevalent over most of the area. In Figure 4 is shown a ridge of boulders located from 5 to 15 feet out from the spring water line. Such ridges offer some protection to inshore areas against wave action; these protected shelves are especially preferred by spawning pikeperch at Lake Gogebic. Sections which are bounded laterally by logs or boulders and overhung by tag alders, white cedars, or other trees, are almost certain to be occupied by pikeperch throughout the spawning season (Fig. 5).

Spawning is not restricted to portions of the shoreline having a rubble bottom, but also occurs in areas having a bottom of rather fine gravel (Fig. 6). Although the bottom in general has a gradual declivity, (Figs. 3 and 4), stretches of bouldery shoreline with a sharp drop-off

Fig. 2. Map of Lake Gogebic, showing location of pikeperch spawning grounds. (Broken lines indicate areas which are little used).



LAKE GOGEBIC Ontonagon-Gogebic Co's. T.46,47,48N.,R.42W.,T.48N.,R.43W

Fig. 3. Typical section of shoreline (exposed by low water) along the east shore of Lake Gogebic, showing bottom type.

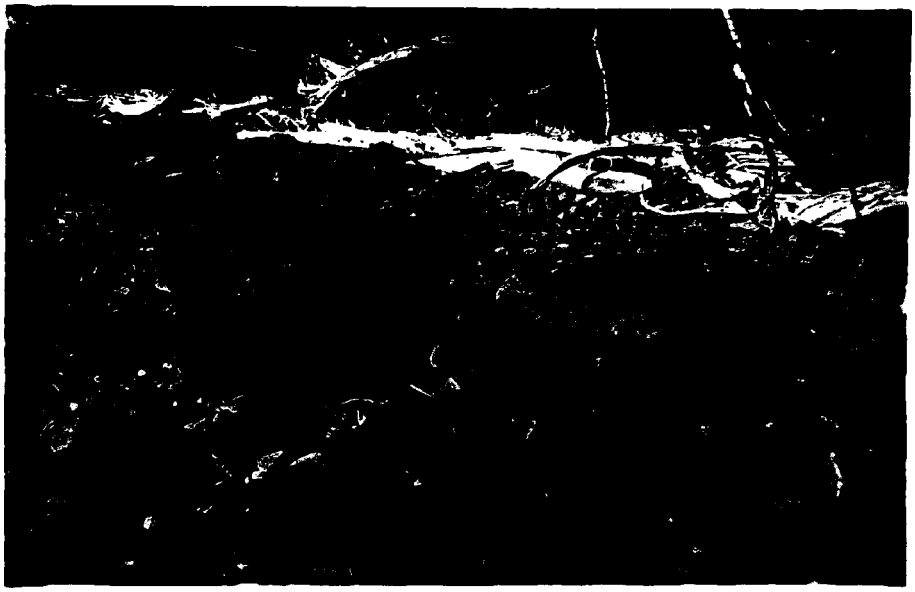


Fig. 4. Exposed shoal along east shore of Lake Gogebic, showing ridge of boulders a short distance from shore. (The measuring board is three feet in length).

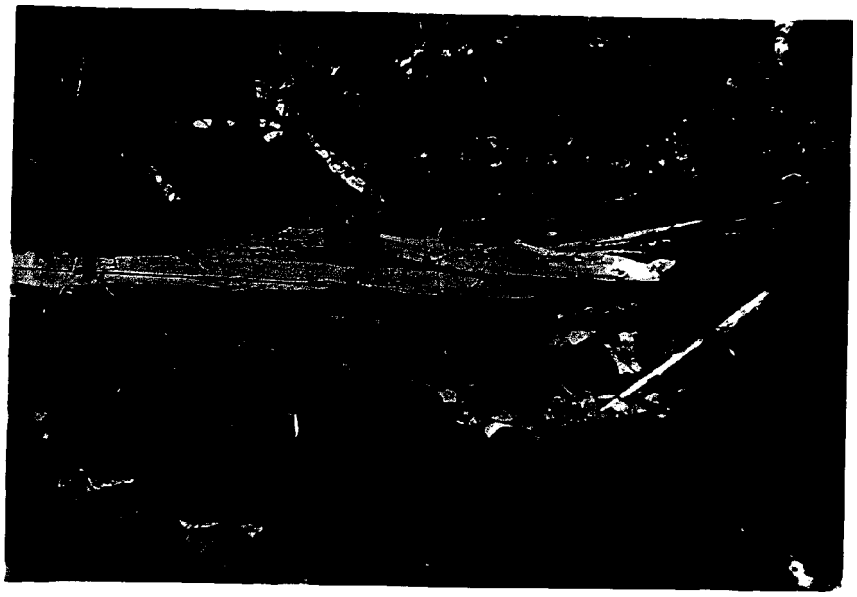


Fig. 5. A sheltered pocket behind a protecting ridge of boulders, along the east shore of Lake Gogebic. Such areas are much used by pikeperch congregated on the spawning beds.

Fig. 6. Fine gravel, used to some extent by spawning pikeperch at Lake Gogebic. The white object is a 6-inch ruler.

also occur (Fig. 7).

Fallen trees are very common along the water line (Figs. 4 and 5). Tag alders, white cedars, and other trees hang over the water at many points, and the entire shoreline is densely wooded. It is openly exposed to the prevailing northwest wind, and is washed by almost continuous wave action.

Sand-bottomed areas are little used for spawning by pikeperch in Lake Gogebic. The bottom along a 1,700-foot section of shoreline in Six Mile Bay near the mouth of a small stream is composed almost entirely of sand (Fig. 8). Although the bay is located well within the limits of the spawning grounds, pikeperch do not frequent the region during the spawning season, except in small, scattered areas where a small quantity of gravel or rubble is mixed with the sand.

In 1947, pikeperch made very limited use of an additional area along the north shore of the lake, as indicated by broken lines in Figure 2. Direct observations of fish were not made, but small numbers of eggs were collected along the shoreline at these points, and spawning had obviously occurred.* Much of this area has a bottom of sand, upon which broken rock has been thrown to form a riprap for an adjacent railroad grade. It is among these rocks that the pikeperch eggs were found.

Most of the remainder of the shoreward area of the lake is not known

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*In egg collection, stones, gravel, and other objects on the bottom are overturned or disturbed by a quick, scraping movement of the foot. Immediately a fine-meshed scap net is passed through the resulting roily area to collect any eggs brought temporarily into suspension. The specific gravity of pikeperch eggs is little greater than water, and this simple technique works effectively even in situations where eggs are relatively scarce. Where much spawning has occurred, 50 to 100 or more eggs often may be collected in a single such effort.

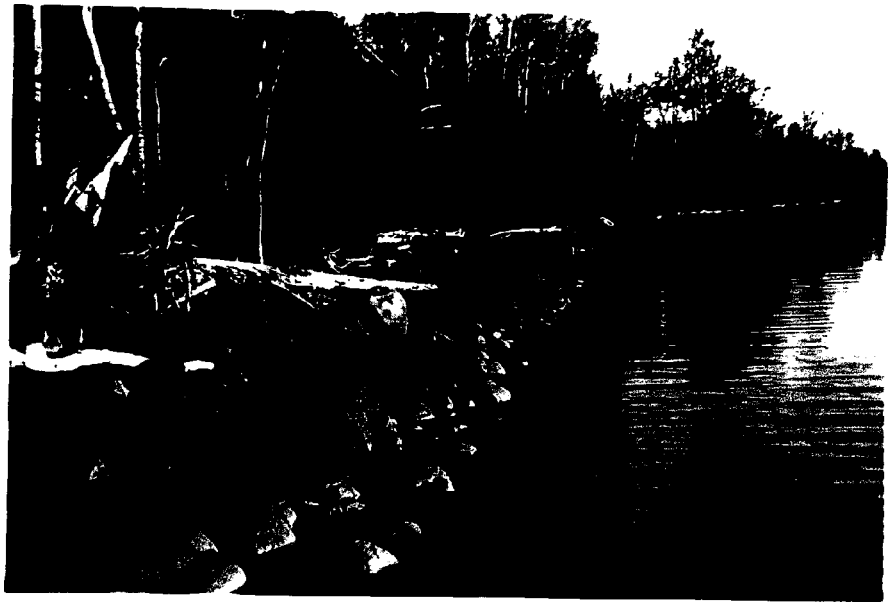

Fig. 7. A bouldery shoreline with a steep declivity along the east shore of Lake Gogebic at pikeperch spawning grounds.

Fig. 8. Aerial view of Six Mile Bay, Lake Gogebic. The sandy shore to the right of the mouth of the stream is not used by spawning pikeperch.

to be used by pikeperch for spawning although the gravel, rubble and boulder bottom is nearly identical to that along the east shore. On May 28, 1947, when eyed eggs were present in great abundance on the spawning grounds, a circuit of the lake was made by boat and attempts were made to collect eggs near shore, at random intervals of approximately three-quarters of a mile. However, eggs were found only along the sections of shoreline described above. Observations with a spotlight at night during the spawning seasons of 1942, 1947 and 1948, have revealed no fish congregated outside the limits of the spawning grounds described above. A few scattered individuals, mostly occurring singly, were seen south of Trout Brook (Fig. 2), in sections 26 and 35, on the night of May 1, 1941. A local resident states that for several years following their establishment in the lake (when the species may have been more abundant than it now is), pikeperch congregated in large numbers along these shores during the spawning season. If this is true, the area has been nearly or completely abandoned as a spawning ground in recent years.

The reason for the concentration of pikeperch along the 10 miles of shoreline described is not clearly apparent. Areas of similar bottom type and depth which are rejected by the fish are less agitated by wave action than is the east shore, and thus are not as cleanly washed. Extensive sections have a somewhat softer substratum and become roiled readily by wave action. The declivity is for the most part less gradual, and shallow wave-washed shelves near shore are less frequent than along the east shore. Some or all of these factors may play a part in decreasing the attractiveness of these areas to spawning pikeperch.

The apparent restriction of spawning to waveswept shoreline in Lake Gogebic is not borne out by observations on other waters.

In Cisco and Thousand Island lakes, Gogebic County (both within 15 miles of Lake Gogebic), pikeperch spawn along the entire shoreline where a suitable bottom type is present. Sand is avoided, but areas of gravel only a few feet in diameter are utilized. In Thousand Island Lake, the stony shorelines of its many islands, such as the tiny Sheepherders Island (Fig. 9) are also used extensively. In Lake Mary, Iron County, pikeperch spawn along a narrow strip of gravel lining both the north and the east shores. In Indian Lake, Schoolcraft County, eggs have been collected along both the east and the west shores. In Lake of the Woods pikeperch spawn along the entire shoreline (Evermann and Latimer, 1910). These observations seem to discount the effect of exposure on the location of the Gogebic spawning grounds. However, in the other Michigan lakes mentioned (with the possible exception of Indian Lake), the water is not discolored, has little sediment, and is, by and large, crystal-clear. Lake Gogebic is darkly colored during the period immediately following the break-up of the ice, and in addition appears to be somewhat turbid at this time. To the observer, the shoreline used for spawning is much cleaner than the rejected shoals in other areas, including the section of shoreline south of Trout Brook. This zone is better protected from wave action than are the shoreward areas farther north (Fig. 2). It seems probable that exposure to prevailing winds, insofar as it functions in keeping the shore cleanly washed, is a factor of significance in the localization of pikeperch spawning beds in Lake Gogebic. In certain other waters, exposure may have no particular importance.

Pikeperch are not known to spawn in the Slate River, although a section of stream several hundred yards in length, about one mile above its flooded mouth, has a gravel and rubble bottom and is accessible to the

Fig. 9. Sheepherders Island, Thousand Island Lake, Gogebic County. Pikeperch spawn along the shore of this and similar islands in the lake.

fish. Gill nets set in the river at various points during the spawning seasons of 1941 and 1947 produced no sexually mature pikeperch; observation with a spotlight in 1947 revealed none; an extensive search for eggs throughout the length of the stream from Judson Falls to the lake in May, 1948, was without result; and a number of local residents who have been questioned have no knowledge of a pikeperch spawning run ever having occurred there. Green females (those with developing eggs which are not yet ripe) are occasionally taken from the Slate River bridge, about one-quarter mile upstream from the lake, during late April or early May, and a trap net set across the mouth of the stream took 7 green females and 21 ripe males during the period from April 29 to May 8, 1947. These catches are probably not an indication that spawning was occurring near by, however, as milt can be expressed from males by the application of slight pressure on the belly for a considerable period before spawning actually occurs. The 21 males taken in early May, 1947, were tagged (method described hereafter) and released at the point of capture. Of these, one tagged on April 30 and another marked on May 2 were recovered in trap nets set near Six Mile Bay, well within the principal spawning grounds, on May 14 and May 12 respectively. Ripe females have not been observed in the stream at any time.

Spawning runs are not known in Merriweather Creek or other smaller inlet streams. Movement of fish up Trout Brook is prevented by a dam near its mouth.

In view of reports (Cobb, 1923; MacDonald, 1924; Adams and Hankinson, 1928) that pikeperch may enter streams during some years, although remaining in the lake during others, it is of course possible that spawning occurs in the Slate River and other inlet streams during some seasons. If

so, its occurrence has not been observed.

Certain observations suggest that a limited amount of spawning may occur in the outlet of the lake. Richard Bohland, who operated a weir at a point about 500 feet above the dam (one-half mile downstream from the lake) in 1940, reported observing (unpublished) from 75 to 100 pikeperch in the area immediately above the weir on May 5. Smaller numbers were seen on May 7, 8 and 9. Weir records show that between April 21 and May 18, 15 pikeperch passed upstream and 47 went downstream through the weir (Carbine and Shetter, 1945). There was more movement of pikeperch in this period than in any comparable period during the operation (April 14 to November 10). The pikeperch were tagged before release. Four which were marked during this period of greatest activity were later recovered by anglers in Lake Gogebic, and seven were taken in the outlet above or below the dam. The fish which were tagged averaged 17 inches in length, and sexually mature fish of both sexes were included. The movement through the weir was very probably related to spawning activity and it thus appears likely that some Lake Gogebic pikeperch spawned in the outlet in 1940. On May 8, 1948, the writer found small numbers of eyed eggs in the outlet, at a point about 100 yards below the dam. The origin of the fish producing the eggs is not known, but it may have been Lake Gogebic.

To summarize, the principal spawning grounds of pikeperch in Lake Gogebic extend for about 10 miles along the leeward east shore of the lake. The bottom consists of a mixture of gravel, rubble and boulders, with a substratum of sand and fine gravel. It is kept cleanly washed by wave action, a factor which may influence its selection as a spawning ground in preference to less exposed areas with similar bottom types. Lake Gogebic pikeperch are not believed to spawn in the inlet streams, but small numbers probably spawn in the outlet.

Spawning behavior

Several workers have described the spawning of yellow pikeperch, but most of the statements have applied to the behavior of the fish under stream conditions.

Reighard (1890) believed that when the female lays the eggs in water, the male no doubt follows immediately after and ejects the milt onto or near the eggs. Goode (1903) wrote that no nest is prepared by the fish, and that the eggs are dropped directly on the bottom in from 3 to 10 feet of water.

The female discharges her spawn in shoal waters, the male following and emitting milt in proximity to the eggs, according to the fish manual of the U. S. Commission of Fish and Fisheries (1903) and Leach (1927). Bean (1913) stated that in spawning the larger female is attended by several males. She rushes up toward the surface but doesn't come out of the water. The males dart about her with fluttering motions, discharging milt while the female discharges the eggs. After this act the female drops back to the bottom, followed by the males. Miles (1915) probably did not himself observe the behavior which he described. He reported that the female swims through the grass, emitting her spawn in passing. She is followed at a distance of from 5 to 25 feet by one or two males, who deliver the milt and fertilize the eggs. Cobb (1923) found pikeperch spawning just below swift rapids. Females came to the foot of the swift water and waited until they "became massed in from the accumulation of numbers." Then they would rush up into the current, come to the surface, and break water. As they broke, they threw part of their eggs. Then they dropped slowly down to clearer water, remained there for a minute or two, and finally came up again. In some cases they were accompanied by a male and

in some cases not.

Hankinson (Adams and Hankinson, 1928) observed the spawning act near the mouth of Scriba Creek, at Constantia, just below a weir crossing the stream, on April 22, 1920. The observations were made in bright sunlight, at 2:00 p.m. He said: "From two to five or six males would gather about a single female near the bottom, and then the whole group would rise to near the surface, all making vigorous body movements and agitating the surface. They then would descend as if exhausted. It is probable that eggs and sperm were emitted during this ascent of the compact company but nothing was seen. Surface disturbances similar to those made by the fish observed were frequent further down stream from the weir, and it is likely that these too indicated spawning acts."

Dr. Jan Metzelaar, in a partially completed (unpublished) report on the pikeperch fisheries of Saginaw Bay, stated that during the first week in April one year, a commercial fisherman, Mr. Lee Lounsbery, saw some pikeperch spawning under the ice in shallow water, and it was noticed that up to nine males accompanied a single female.

Pikeperch arrived on the spawning shoals immediately after the breakup of the ice in the spring at Lake Gogebic. Usually they occurred in small numbers at first, followed by rapidly increasing numbers as the water warmed.

Since spawning of pikeperch occurred almost exclusively at night, most activity of fish on the shoals was observed with an automobile spotlight powered by a storage battery carried in the rowboat from which the observations were made. The eyes of pikeperch reflect light to appear as bright orange-red globes (see frontispiece), thus greatly facilitating the location of fish on the shoals. Unfortunately, detailed observations of

spawning behavior were nearly always prevented by the fact that pikeperch were disturbed by light, a reaction also observed by Derback (1947). With a few exceptions, the fish headed for deep water immediately when a light was directed at them.

Although small numbers of pikeperch were sometimes seen on the shoals during the daytime, particularly near the height of the season, diurnal spawning was a rare occurrence at Lake Gogebic. It was observed by the writer on only two occasions, both on April 29, 1942.

At 1:30 p.m. on that date the lake was calm, the air temperature was 61 degrees F. and the water temperature on the shoals was 56 degrees F. At a point near the center of the east shore of the lake, a group of from 35 to 40 pikeperch was observed. The fish were spread out along an area of shoreline about 25 feet in length, and they were within about 10 feet from shore. The water was 8 inches deep or less in the area which they occupied. There was little activity when the fish were first seen, since they were either motionless or were swimming very slowly. Within a few minutes one of their number (presumably a female) made a sudden forward movement. Immediately four of the others (presumably males) approached the first and the group swam about over the shoals with great vigor, milling about and splashing, with dorsal fins and backs frequently protruding from the shallow water. After from 15 to 20 seconds of such activity, they became quiet again and continued swimming leisurely, as before. Several observations were made, and from 4 to 10 fish at a time were observed to participate in the action. Not all the fish in the group took part each time, but they appeared to be divided into several smaller groups, which participated alternately or at least separately in the more vigorous manifestations of spawning behavior just described.

A second group of pikeperch was observed at 4:30 p.m. on the same date at a point about three miles to the south. This aggregation consisted of 11 fish, presumably males, spaced evenly over an area of shoal about 15 feet long and 8 to 10 feet wide, which was more or less enclosed by boulders. The fish were nearly stationary when first observed, until a larger, slightly darker pikeperch (presumably a female) entered the shoal from deeper water. Immediately 7 of the presumed males gathered about the newcomer and the group began swimming about over the shoal. The males followed immediately behind and beside her, in a manner such that their snouts were even with her soft dorsal fin. Repeatedly one of the males spurted forward in an attempt to get fully alongside her. Vigorous action followed, with much milling and splashing of the whole group. The other participants retained their approximate positions beneath or behind the female and even above her where water depth permitted. It is probable that all fish in the group were discharging spawn. After several seconds, the female left the shoal for somewhat deeper water, apart from the group. The males dispersed over the shoal originally occupied, swimming slowly over the area just covered with the female. This was done methodically and with apparent purposefulness. The fish tilted over to one side from time to time as though they might still be discharging milt. Whether or not this was occurring is not known. After a few minutes had elapsed, either the same or a different female entered the group, and the activity was repeated. Several observations were made of apparent spawning which did not differ materially from that described, but during one a flexure appeared in the body of the female at the vent. She was almost certainly extruding eggs, but these could not be seen. Later examination of the area revealed large numbers of clear eggs, some of which may have resulted from the activity observed.

A considerable amount of splashing, reminiscent of the sound of spawning carp, could sometimes be heard at many places along the shoreline on quiet nights, particularly during the height of the spawning season. This suggested that milling about in shallow water by groups consisting of a female and several males commonly occurred. However, on other nights near the peak of the spawning season, little or no splashing was heard. Chance observations at night suggested that there was a considerable variation in spawning behavior. Such observations were confined to the rare occasions, usually near the height of the season, when the actions of some spawning fish were followed with a light for a few seconds before they became alarmed and dispersed.

On the night of May 1, 1940, a spawning act was observed in which the participants did not appear to be broadcasting their spawn. Two pikeperch, one about 16 inches long and the other about 18 inches in length were observed in a gravel-bottomed opening bordered by three submerged boulders which formed a rough triangle. The water in the opening was found by later measurement to be 4 inches deep and to have a temperature of 47 degrees F. When first observed the two fish were lying parallel facing out toward the lake. They were within an inch of each other, and a barely perceptible movement of the fins was noted. Suddenly and simultaneously, each fish tilted slightly, so that their vents were closely adjacent. Fanning with the caudal fins became more vigorous, and a slight quivering of the abdomen of one fish was observed. The action lasted for only a few seconds, after which the fish resumed their original position, became alarmed, and left for deeper water.

A second observation made during the same night involved a group of five fish, swimming abreast in about two feet of water over a stony bottom.

The group stopped its slow forward progress over a small area of coarse gravel between two large boulders. Members of the group became approximated to the point of touching for a few seconds. They then became alarmed by the light and dispersed to deep water.

A third observation involved only two fish, swimming quietly in water about two feet in depth. Immediately after they were first seen with the light, each turned slightly toward the other, as in the first observation of spawning behavior involving two fish described above, in a manner such that the vents of the fish were near the vertex of an angle made by the short axes of their bodies. There was a quickening of fin action for a few seconds, after which the upright position was again resumed. At this moment the fish appeared to become suddenly aware of the light and fled.

Extensive spawning occurred on the calm night of May 4, 1948. Three separate groups of fish were observed, each composed of an undetermined number of individuals (between 6 and 12) milling about in a circle with a diameter of from three to six feet, next to shore, or beside a large boulder. Movement within the groups was vigorous, and was accompanied by much splashing. These closely grouped, milling fish were undisturbed by the light for several seconds, and were undoubtedly spawning.

Except when specific spawning acts were in progress, the majority of the fish on the shoals, as seen with a light at night, were close to shore, on or near the bottom in water less than two feet deep. Nearly all activity was confined to water depths of less than three feet, although a few pikeperch eggs were collected in four feet of water. Most fish seen showed little activity, but moved about very slowly, or lay motionless, singly, in pairs, or in loosely aggregated groups of from 3 to 15 or more individuals (Fig. 10). Such groups were more readily identifiable early or late in the

spawning season than at the peak of the season, at which time uniformly large numbers of fish were often present over considerable areas, without recognizable division into smaller groups. On April 28, 1941, before the probable peak of the spawning season for that year, the individuals in 40 random groups were counted as they swam toward deep water when a light was turned in their direction. The average number of fish per group was 6.7, with 7 being the number most commonly observed. The sex ratio within such groups is not known. In many or most cases they probably consisted entirely of males, since groups occur both early and late in the spawning season, when few if any females would be expected to be present (judging by a study of the sex ratio of pikeperch occurring on the spawning beds, discussed below).

The frontispiece and Figures 10 to 15 show the disposition of pikeperch over the spawning beds, as revealed by flash photographs taken at night* during the height of the spawning season. The frontispiece shows a number of fish (probably all males, at least in the foreground) dispersed over the shoals in typical fashion. Figures 11 to 13 were taken from a single point on shore, at 15-minute intervals, and again show the pattern-less distribution of males (presumably) over the shoals. Figure 14 shows several good-sized fish (foreground) which may be forming a spawning group. The five fish in the foreground of Figure 15 are almost certainly spawning or about to spawn. At least one or more females are believed to be present

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*The photographs were taken from vantage points on shore, somewhat elevated above the water. A Dollina II (35 mm.) camera, Type A kodachrome film, large size flash bulbs (Mazda Nos. 21 or 50), and an open flash were used. Since pikeperch are disturbed by light, it was necessary to take the photographs without knowing their composition at the time of exposure.

Fig. 10. A group of five pikeperch on the spawning beds, Lake Gogebic, May, 1942.

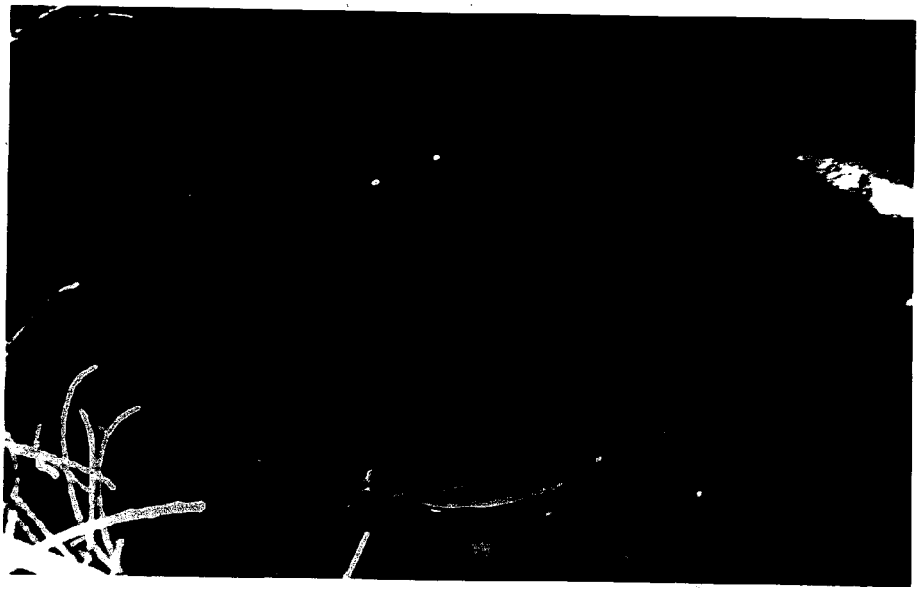


Fig. 11. Pikeperch congregated on the spawning beds, Lake Gogebic, 9:30 p.m., May 18, 1947.

Fig. 12. Pikeperch congregated on the spawning beds, Lake Gogebic, 9:45 p.m., May 18, 1947. Photographed from same point as Fig. 11.

Fig. 13. Pikeperch congregated on spawning grounds, Lake Gogebic, 10:00 p.m., May 18, 1947. Photographed from same point as in Figs. 11 and 12.

Fig. 14. Pikeperch congregated on spawning grounds at Lake Gogebic, May 4, 1948.

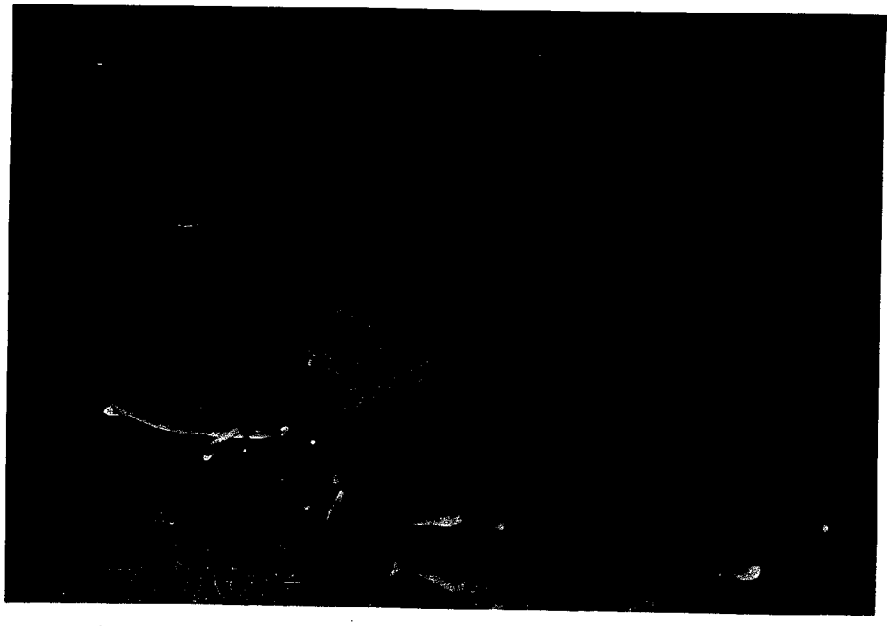


Fig. 15. Pikeperch on spawning grounds at Lake Gogebic, May 4, 1948. The group in the foreground may be spawning or about to begin spawning.

in the group. The orientation is confusing, since in the spawning which has been observed, as described above, the participants were all headed in the same direction. Possibly the photograph was taken at the moment when males were moving from several directions toward a female. No splashing had occurred at this spot before the photograph was taken, but repeated disturbances were heard near by in both directions.

Pikeperch have also been observed congregated on the spawning grounds in shallow water, and eggs have been collected, at Cisco Lake, Gogebic County; at Indian Lake, Schoolcraft County, and at Big Portage Lake, Jackson County. It is interesting to note that in Big Portage Lake the bottom type in the spawning area consists of marl concretions with diameters of one inch and less. In all three waters the fish had the same patternless distribution on the shoals as observed at Lake Gogebic. Many fish were observed at Indian and Cisco lakes, but few were seen at Big Portage Lake, which has a relatively small pikeperch population.

The relationship between the negative phototropism of this species, as displayed normally in spawning and in various other features of behavior, with the structure of the eyes provides an interesting subject for conjecture. Concerning the structure of the pikeperch eye, Moore (1944) stated, "The entire pigment epithelium is packed with guanine; and since the cells of this layer are very large, the space afforded for the rods in the light-adapted condition is so meager that many rods are forced to remain close to the external limiting membrane. The possibility of dazzlement is evident." He considered it likely that it is the development and growing efficiency of the tapetum which causes pikeperch, toward the middle and end of their first summer of life, to retreat to deeper water and to shady places to escape the dazzling rays of the summer sun.

The sensitivity of pikeperch to light is clearly shown by certain observations made at Lake Gogebic.

Reaction to a spotlight at night has already been referred to (above) and has also been noted by Derback (1947). When a light is thrown on fish, particularly from the side, their reaction is immediate. Blind attempts to escape often result in glancing collisions with rocks or other obstacles, and occasionally a fish nearly beaches itself in its efforts to flee. At other times the fish appear much less frightened, but seem to "feel" their way among the rocks by trial and error, often stopping when an unlighted spot, such as the shadow of a boulder, is found. A bright light is not required to cause dispersal, the light from a so-called "pen-light" being sufficient to cause an immediate movement out of range. The disturbance following brief exposure to light is of short duration, at least during the height of the spawning season. On May 4, 1948, a boat was moved along the shoal at slow trolling speed (perhaps two miles per hour) about 20 feet from shore. As a spotlight was thrown on the congregated fish, they immediately headed for deep water - many in great haste. However, when the light was directed back from the stern of the boat, to the area just covered, it was observed that within two or three boat lengths of the stern, fish were again well up on the shoals, near shore, in what appeared to be about the same numbers as had occurred there prior to the disturbance. A photo flash bulb likewise causes an immediate reaction, but the fish return quickly to the area.

On the date on which diurnal spawning was observed, April 29, 1942, shoal-water temperatures had risen to 56 degrees F. (10 or more degrees above the minimum at which spawning occurs) within a week after the ice cover broke up. Quite possibly this sudden warming of the water produced

an urgency to spawn sufficiently intense to overcome the restricting effect of daylight. One group of spawning fish was observed from shore and the other from a boat anchored just outside the spawning shoal. In both cases the fish appeared quite unaware of the presence of the observer, even though some movement occurred, and it was not until the boat moved within a few feet of the nearest fish in the group that they became alarmed.

Although most fish retreated to deep water during the day, small numbers of fish were occasionally found within the limit of visibility of the observer during the spawning season. On May 7, 1942, about 100 pikeperch were observed along about two miles of shoreline near the center of the spawning grounds. They occurred singly, lying on the bottom, in from 3.5 to 5 feet of water, just off the spawning area. All were oriented with their heads toward the shoals. They were for the most part motionless, but fled to deep water when the boat closely approached them. Their uniformly large size (estimated as 20 inches or more) and widely distended abdomens suggested that they were females. No fish were collected for examination, however. Similar observations were made on May 12, 1948, when about 50 pikeperch were seen along about a mile of shoreline. All were lying motionless, with their heads toward shore, as before. Several single pikeperch were seen well up on the shoal, near shore, and in one instance two fish were observed, side by side, about six inches apart, lying under only about one foot of water. In general, the fish appeared unable to detect the presence of the boat until it was almost fully over them. One pikeperch, only slightly less wary than many others, was struck with the blade of an oar. The specimen was a nearly spent male, 18.5 inches long. Some of the fish were smaller, and two were seen to bear tags, suggestive evidence that they also were males (p. 62). Presumably many of the fish which were seen

on this date were males. Probably each sex sometimes exhibits this behavior at Lake Gogebic and when both venture onto the shoals, diurnal spawning occurs.

Pikeperch lying motionless off the spawning beds during the day, as above described, were observed also by Stanley Lievense (oral communication) at Big Portage Lake, Jackson County, in April, 1946.

The observations made during daylight hours suggest that pikeperch may be hampered by poor vision during the day (dazzlement). Their behavior in lying off the spawning beds in the manner described permits one to suppose that the urge to spawn and the negative response to light are in conflict, and that the dazzling effect of daylight may usually be sufficient to keep them in water deeper than that ordinarily used for spawning. Bensley (1915) made the observation that pikeperch bite in early morning and at sundown in clear waters, but in dark inland waters they may be taken at any time of the day, although better when the light is not intense. Nevin (1918) noted that in some lakes pikeperch will not take the bait until after nightfall. Several authors h ave observed that the pikeperch seeks deep water during the hot summer months (when sunlight is most intense), and that it leaves the shallower portions of streams during this time of year. It seems probable that light intensity has a marked influence upon pikeperch behavior.

Observations during the spawning season of 1948 suggest that accidents may occasionally occur among pikeperch, possibly associated with the vigorous milling about which sometimes accompanies spawning. On May 9, the body of a pikeperch which had apparently been dead for several days was found firmly wedged between two boulders, at a water depth of about one foot. On May 12, a second fish, still alive, was observed to be trapped among the

rocks. It was lying on its side, firmly wedged between and beneath two boulders in water two feet deep. It was held almost immobile and undoubtedly would have perished. Upon collection it was found to be an 18.9-inch ripe female. Probably such accidents are unusual, for other instances were not observed during the several years of study at Lake Gogebic.

In summary, spawning females usually broadcast their eggs at night, in water which is three feet or less in depth, over a stony bottom, in the company of one or more males. Spawning may be quiet and leisurely or may be accompanied by vigorous milling and splashing. Males congregated on the spawning beds have a patternless distribution and are nearly motionless or swim slowly over the shoals. Pikeperch are negatively phototropic, a reaction probably related to the structure of their eyes. This response is believed to account for their nocturnal spawning habits and to explain their avoidance of shallow areas (streams or lake shoals) except at night or during the spawning migration.

Progress of the spawning season in terms of numbers of pikeperch on the spawning grounds

Observation of spawning behavior of pikeperch is sharply restricted by the weather, since details are completely distorted by even gentle wave action. However, the presence of fish on the shoals can still be noted even at long range because of the sharply defined reflection from their tapeta lucida. The eyes are clearly visible although the remainder of the fish cannot be seen (Fig. 16). Light to moderate wave action does not greatly interfere with counts of fish numbers when these are made with a spotlight. For good observation the eyes of the observer should be close to the beam of light. The dispersal of the reflected light from a direct

Fig. 16. The eyes of yellow pikeperch, as seen on the spawning grounds with a spotlight, Lake Gogebic, May, 1942.

line to the light source is not wide.

To study the progress of the spawning season, a few counts of numbers of fish present on the spawning grounds were made in 1941 and in 1948, and more extensive observations were made in 1942 and in 1947.

During 1941 the peak of the spawning season probably occurred during the first week in May in Lake Gogebic. The ice left the lake on April 16. The first observations were made on April 25, when from 45 to 50 pikeperch were seen along about 300 yards of shoreline examined near station B, Figure 18. On April 28, along 1.5 miles of shoreline extending north from station A (Fig. 18), 137 groups of pikeperch were seen, which averaged (judging by a count of 40 groups) 6.7 fish per group, or a total of 918. Those which were not assembled into groups of three or more individuals were not counted, however, so the total number present was much larger. On May 1, 1,862 pikeperch were counted in approximately a mile of shoreline extending north from station B (Fig. 18). By the time the next counts were made, on May 14, a sharp diminution of numbers had occurred (based on general observations - no counts were made), and a few fish were still present on May 19.

Air and water temperatures taken during the 1941 season are shown in Table 2. Some fish occurred on the shoals at a water temperature of 39 degrees. Shoal temperatures ranged from 46 to 50 degrees during the following week.

In 1942 and in 1947, attempts were made to estimate the numbers of pikeperch on the shoals along the east shore of the lake throughout the season. In 1942 ten areas of shoreline, each 500 feet in length, were marked out at regular intervals within the known spawning grounds, and in 1947 eleven such areas were selected. The extremities of each sample area,

Table 2. Air and water temperatures during the pikeperch spawning season, Lake Gogebic, 1941.

Date	Time	Degrees Fahrenheit	
		Air	Water
April 25	11:00 p.m.	33	39
28	8:30 p.m.	59	46
29	1:00 a.m.	49	48
29	7:00 p.m.	54	48
29	12:00 midnight	50	48
30	7:30 p.m.	...	50
May 1	7:30 a.m.	...	47
1	7:30 p.m.	56	47
10	2:00 p.m.	...	55
14	7:00 p.m.	63	55

or counting station, were marked with lettered or numbered white muslin flags, about two feet square (Fig. 17). In both years, the first station was located at the southern extremity of the spawning area (Fig. 18). Distances between stations (approximately 5,000 feet) were measured by timed runs with an outboard motor (1942) or by pacing over the ice before the break-up (1947). The southern stations, at least, were nearly identical during the two years, as was observed when fragments of the markers for 1942 were encountered during the measurement of counting areas in 1947. The approximate locations of the stations in 1947 is shown in Figure 18. If it is assumed that the principal spawning grounds were about equal in extent during the two years, which seems likely, the stations constituted a linear sample of 9.1 percent in 1942 and 10 percent in 1947 (considering a 55,000 foot spawning area). Seventeen hundred feet of shoreline near Six Mile Bay were excluded, since the area is not known to be used by spawning pikeperch except in very small numbers (p. 21).

In making counts on the sample areas, a boat was propelled by rowing (1942) or by an outboard motor operated at trolling speed (1947) along the counting station, about 15 to 20 feet from shore. The beam of a spotlight was directed toward the shoal, and the fish were counted as they began swimming toward deeper water.

To determine whether there was a nightly peak of abundance of fish on the shoals which might have an important bearing on the accuracy of a count requiring several hours to complete, hourly counts were made at a heavily used station (near I, Fig. 18) from 8:00 p.m. until 4:00 a.m. on the night of May 7, 1942. These counts (Table 3) show some fluctuation, although the numbers are reasonably constant between the hours of 10:00 p.m. and 4:00 a.m. (average 239; extremes plus 14 percent and minus 8 percent). Except on

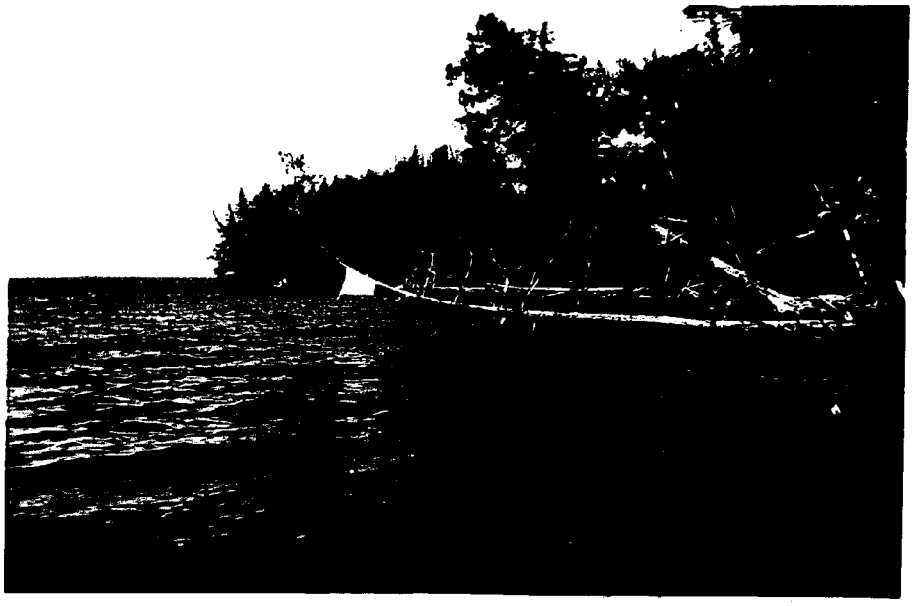
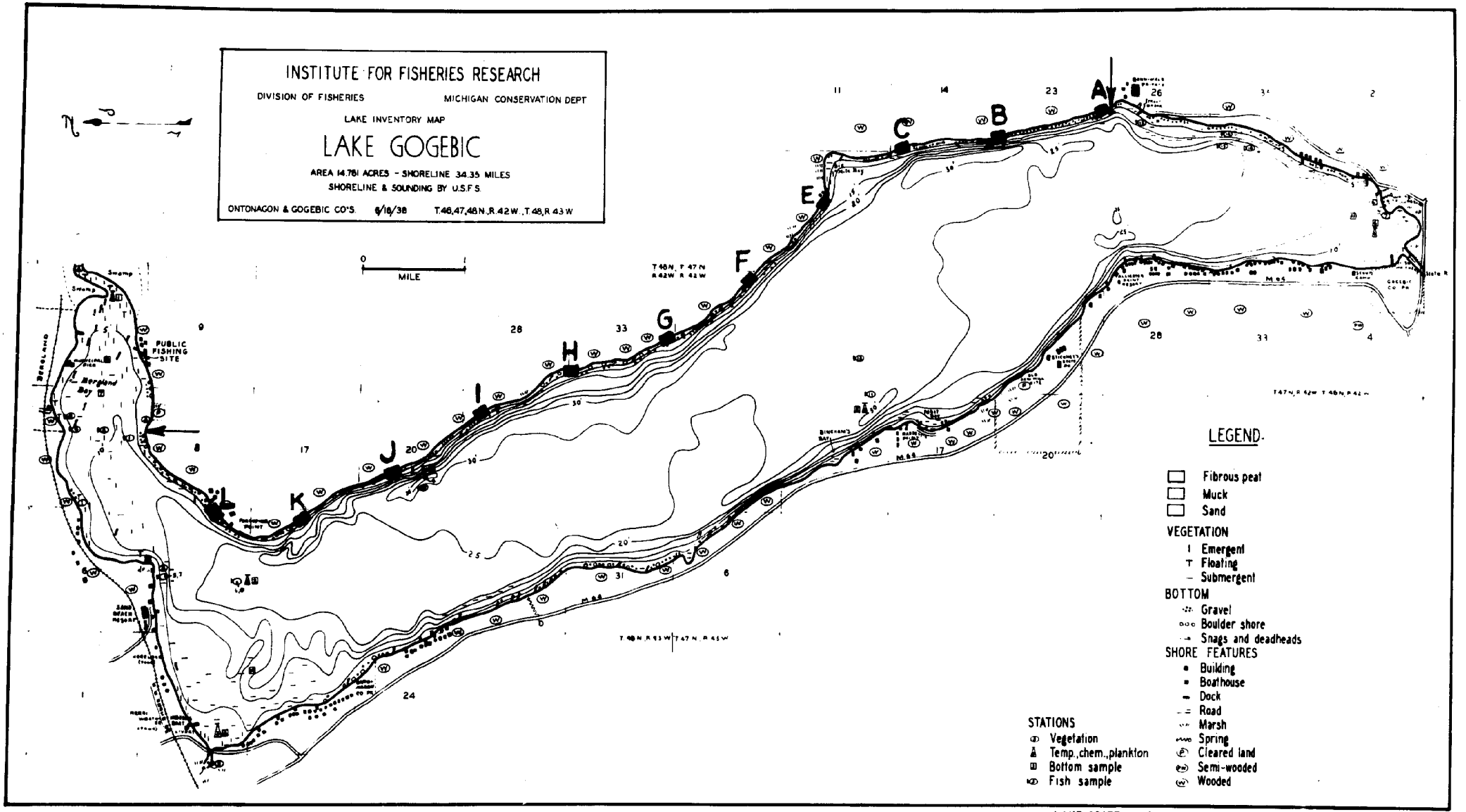


Fig. 17. Counting station used at Lake Gogebic in 1942. The marker at the far end of the station can be seen to the left of the flag in the foreground.

Fig. 18. Map of Lake Gogebic showing locations of counting stations used for estimating numbers of pikeperch on the spawning beds.



LAKE GOGEBIC Ontonagon-Gogebic Co's. T46,47,48N R 42W,T48N,R 43W

Table 3. Counts of pikeperch along a 500-foot section of shoreline (near station I) on May 7, 1942.

Hour	Number of pikeperch counted
8:00 p.m.	0
9:00 p.m.	110
10:00 p.m.	247
11:00 p.m.	232
12:00 midnight	219
1:00 a.m.	234
2:00 a.m.	273
3:00 a.m.	247
4:00 a.m.	222

May 5, 1942, when the census was begun at 9:15 p.m., counts were made between the hours of 10:00 p.m. and 2:00 a.m. during both years.

In a brief test of the accuracy of the counting procedure as outlined, fish present at four stations were counted on May 16, 1947, by two observers (Table 4). The results show reasonably good agreement. Counts tabulated for both years (Tables 5 and 6) were made by myself.

Many of the enumerations were incomplete. Lake Gogebic is well known for the suddenness and violence of its squalls, particularly in spring, and the counts were repeatedly interrupted before completion. The need for devoting some of the quiet evenings to other observations also restricted the time which could be devoted to the census. As a result, the stations nearest the laboratory (which was located at the mouth of the Slate River, at the south end of the lake) were more often included in incomplete counts than were others. This had the effect of reducing some of the estimates, since, by and large, fewer pikeperch occupied these shoals than those nearer the center of the spawning grounds. Nevertheless, the counts show general seasonal trends with respect to spawning intensity, and fairly well define the limits of the period of pikeperch concentration on the shoals in Lake Gogebic during the two years.

The counts and estimates made during 1942 and 1947 are shown in Tables 5 and 6 respectively, and the results are compared graphically in Figure 19.

In 1942, pikeperch began congregating on the shoals in small numbers within a day after the ice left Lake Gogebic (April 22). Water temperature on the shoals was 40 degrees F. By April 25, much larger numbers were present (water temperature 45 degrees F.), and by May 5, the apparent peak of the season was reached, with an estimated 22,000 fish on the spawning

Table 4. A comparison of counts by different observers of pikeperch on spawning shoals at Lake Gogebic, May 16, 1947.

Station	Visiting Observer	Number of fish counted	
		Other observers	Eschmeyer
G	Flaten	185	185
H	Crowe	200	192
I	Cooper	106	92
J	Bailey	348	343

Table 5. Estimated numbers of yellow pikeperch present on spawning grounds in Lake Gogebic, 1942.

Station	Numbers of fish on sample areas							
	Apr. 23	Apr. 29	May 1	May 5	May 7	May 9	May 12	May 22
A	1	53	...	91	...	38	16	1
B	2	195	...	87	...	86	38	2
C	...	189	...	187	...	106	19	5
E	...	...	...	66	...	72	11	2
F	...	...	95	353	...	164	70	3
G	...	...	3	251	211	...	26	1
H	...	...	143	221	142	...	23	6
I	...	...	273	330	273	...	43	3
J	...	...	206	177	179	...	47	5
K	...	...	198	249	128	...	54	5
Total number counted	3	437	918	2,012	933	466	347	33
Percent of spawning area sampled	1.82	2.73	5.46	9.09	4.55	4.55	9.09	9.09
Estimated total numbers of pikeperch	165	16,007	16,813	22,134	20,505	10,242	3,817	363

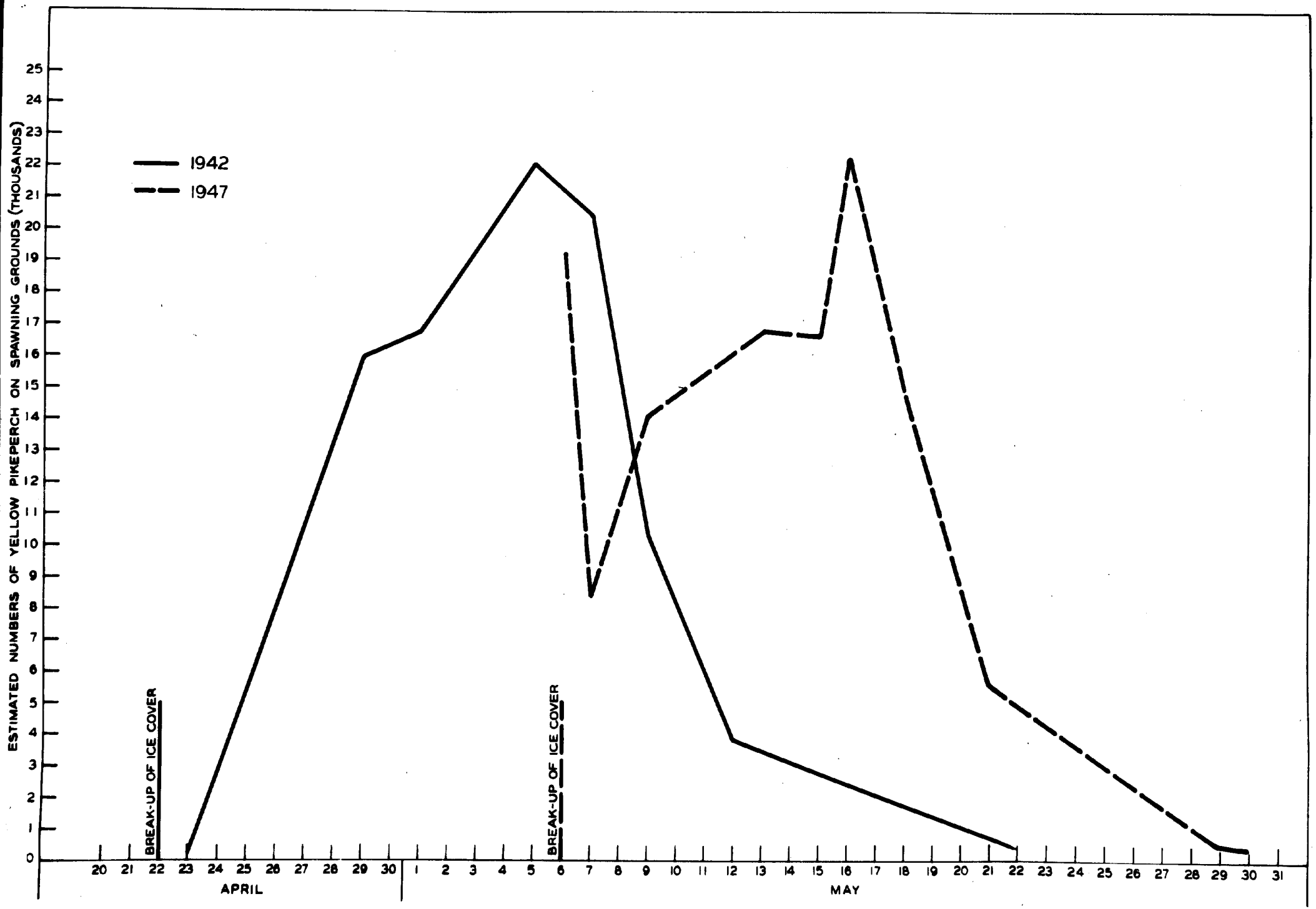
Table 6. Estimated numbers of yellow pikeperch present on spawning grounds in Lake Gogebic, 1947.

Numbers of fish on sample areas

Station	May 6	May 7	May 9	May 13	May 15	May 16	May 18	May 21	May 29	May 30
A	...*	0	31	27	13	...	48	36	3	1
B	...*	0	84	78	57	...	52	41	2	4
C	75**	54	263	263	186	...	172	67	2	5
E	117	192	110	180	179	...	168	61	12	3
F	325	194	157	303	304	...	237	152	...	1
G	38	7	...	111	149	185	...	49	...	...
H	176	7	...	108	...	192	...	42	...	...
I	21***	86	...	...	...	93	...	69	...	...
J	417	64	...	...	...	343	...	...	...	...
K	187	226	...	...	...	...	...	32	...	...
L	40	0	...	...	...	...	...	46	...	...
Total numbers counted	1,396	830	645	1,070	888	813	677	595	19	14
Percent of spawning area sampled	7.27	10.0	4.56	6.36	5.45	3.64	4.56	9.09	3.64	4.56
Estimated total numbers	19,202	8,300	14,145	16,824	16,294	22,335	14,846	5,501	522	417

*Covered by ice floes.
**Two-thirds of station covered by ice floes.
***One-third of station covered by ice floes.

Fig. 19. Estimated numbers of pikeperch present on the spawning beds at Lake Gogebic in 1942 and in 1947.


ESTIMATED NUMBERS OF YELLOW PIKEPERCH ON SPAWNING GROUNDS (THOUSANDS)
1942
1947
BREAK-UP OF ICE COVER
BREAK-UP OF ICE COVER
APRIL
MAY

beds. Shoal temperatures during the night ranged from 46 degrees to 48 degrees F. A decrease in numbers occurred by May 7, and the maximum number had been halved by May 9. There was a further reduction by May 12. A few pikeperch were still present on May 22, when the last count was made. Most of these occurred as single fish. Water temperature on the shoals on this date was 50 degrees F.

In 1947, unseasonably cold weather persisted into early May, and the ice cover did not leave until May 6. On the evening of this date, counts were made along all open stations. Ice floes covered stations A and B, about two-thirds of station C and about one-third of station I (Fig. 18). Shoal water temperature was 34 degrees F., and the air temperature was 29 degrees F. Pikeperch were present in large numbers along the entire open shoreline. One station (J) showed the highest number of pikeperch (417) counted at any station during the two spawning seasons. An estimate of over 19,000 fish was obtained.

On the following night, May 7, pikeperch numbers had decreased to less than half the numbers seen on the previous evening. Water temperature was 36 degrees F., and the air 28 degrees F. The reason for the decline is not explained. A contributing factor may have been the high winds which occurred throughout the day on that date. In certain areas along the north shore, the soil has a considerable clay content, and extensive wave action brings about erosion, with a consequent roiling of the water out to a distance of 50 to 100 feet or more. Such roiliness was very evident along much of the shoreline on May 7, and may have contributed to the decline in numbers on the spawning beds. On May 1, 1942, a similar situation prevailed at station G (or 5) for that year, where only 3 pikeperch were counted, followed by counts of over 200 on May 5 and 7. A portion of the shore at this

station with an eroding clay bank which is reached by waves during windy weather is shown in Figure 20. A decrease in numbers would possibly also have been expected at station E, which is also bounded by a clay bank, but a substantial increase in numbers of pikeperch was observed instead. Whether or not the water was roily at this point on the night of May 7 was not recorded, but this station is better protected from prevailing winds than is station 5. In any event, pikeperch at Lake Gogebic apparently avoid certain areas at certain times during the spawning season, and do not appear in the expected numbers.

Partial counts of the stations on May 9 and May 13 show a gradual increase in numbers, with the peak of the spawning season occurring about May 16 when, as in 1942, an estimated 22,000 fish were present. The incompleteness of the data probably does not permit as clearcut a definition of a peak as the graph (Fig. 19) shows, but the maximum numbers for the season undoubtedly occurred within the period from May 13 to 18. Following this there was a rapid decline in numbers, although a few fish were doubtless still present on the spawning beds during the first several days in June. No counts were made after May 30.

The graph for 1942 (Fig. 19) probably shows fairly well the progress of the spawning season during years when the ice leaves Lake Gogebic during the second or third week in April (as it is reported by local residents to do frequently). The graph for 1947 probably depicts an unusual condition brought on by the tardiness of the spring break-up.

Whether or not pikeperch congregated under the ice before it left in 1947 is not known, but it seems likely. A report by Metzelaar of fish spawning under the ice has already been mentioned (p. 29). Derback (1947) found pikeperch spawning in tributary streams before the ice had left the

Fig. 20. Eroding bank along east shore of Lake Gogebic (see text for discussion).

lake from which they originated. If the fish at Lake Gogebic did congregate on the shoals under the ice, it is doubtful whether they spawned since on May 8, 1947, two days after the ice left the lake, trap net catches on the spawning grounds consisted of 99 percent males (p. 62).

Disregarding the early abundance of pikeperch at break-up time in 1947, both graphs show increasing numbers of fish present as the season progresses until a period of maximum numbers is reached, after which a steady decline occurs. The decrease in numbers after the peak is reached is more rapid than the increase in numbers up to that maximum, even though a few fish remain for a week or more after most have left.

Inclement weather repeatedly interfered with observations in 1948, and little new information was obtained. On the night of May 4, large numbers of pikeperch were observed on the shoals, and much splashing was occurring along the spawning beds. Near-maximum numbers may have been present. By May 8, when observations were again made, the numbers of fish present had decreased markedly, and the peak of the season had apparently passed. Nevertheless, as has been mentioned (p. 40), fish were seen near the spawning beds during the day, on May 12, and a ripe female was collected. No doubt pikeperch were still present on the shoals in small numbers after the opening of the fishing season (May 15).

Three tagged males were speared on May 8, 1948, within 100 yards of the point where they were tagged on May 10, 1947. In a water such as Lake Gogebic, which has only a single major spawning area, pikeperch no doubt return year after year. In certain other waters they appear to return to the same general areas even if there is a choice of spawning grounds. Eddy and Surber (1947) mentioned a large female taken in the Upper Mississippi River, above Wolf Lake, Minnesota, which was caught at about the same

location on several successive seasons. Stoudt (1939) found that 90 percent of the fish recovered during the 1938 spawning run in Lake Winnibigoshish, Minnesota, had returned to the same location where they were tagged during the run of 1937. The remainder had changed spawning grounds.

Pikeperch spawning seasons as reported by other workers in various localities extend from late March to early June, but always include a portion of April or May. Among the spawning seasons given by various writers are the following: late March to late May (U.S. Commission of Fisheries, 1903; Leach, 1927); late March and April (Raney and Lachner, 1942); April (Smith, 1892; Hinks, 1943); April and May (Evermann and Latimer, 1910; Eddy and Surber, 1947); April, May and June (Bean, 1903); May (Derback, 1947); and May and June (Dymond, 1926; Bajkov, 1930).

To summarize, during most years small numbers of pikeperch appear on the shoals soon after the ice leaves Lake Gogebic, reach a peak of abundance during the first week of May, when water temperatures range between 45 degrees and 50 degrees F., and then decline in numbers. In 1947, when the break-up of the ice occurred at least two weeks later than normally, large numbers of pikeperch were present on the evening of the date of the break-up, when water temperature was 34 degrees F. In 1942 and in 1947 estimates based on counts of sample areas indicated that over 22,000 pikeperch (probably mostly males) were present on the shoals at the peak of the spawning season. A few fish (presumably males) are found on the shoals for two weeks or more after the season's peak.

Sex ratio on the spawning grounds

Adams and Hankinson (1928) reported that there were about four times as many males as female pikeperch taken in trap nets near the mouth of Scriba Creek, Oneida Lake, near the height of the spawning season. Schneberger (1938, 1939, and 1940) found that of pikeperch taken in nets during the spawning run in the Wolf River, Wisconsin, males constituted 93 percent (April 1 to 9, 1938), 74 percent (March 30 to April 19, 1939) and 78 percent (April 5 to 21, 1940) of the catch. Eddy and Surber (1947) found two males to one female during the course of a season's run (two to three weeks) at the Bemidji, Minnesota, station, and they indicated that this proportion is in agreement with the records kept at other similar stations. Derback (1947) reported a ratio of four males to one female in a tributary of Heming Lake, Manitoba.

An opportunity to handle and sex considerable numbers of fish was provided by an extensive tagging program undertaken during the spring of 1947 at Lake Gogebic. The sex of mature pikeperch is determined during the spawning season by applying pressure to the abdomen and noting the sexual products forced from the genital aperture (Schneberger, 1938). Males are immediately recognizable when abdominal pressure is exerted, since milt flows from the genital aperture (Fig. 21). Females are recognized by their widely distended abdomens (if green), by the loss of eggs when light pressure is exerted (if ripe), or by their lean appearance, collapsed abdomens, and often by the expression of only a few eggs when heavy abdominal pressure is applied (if spent). Eggs cannot always be produced from fish which are obviously spent females. Immature females more than 14 inches in length in Lake Gogebic are usually recognizable as such merely because they do not release milt, although they are not always

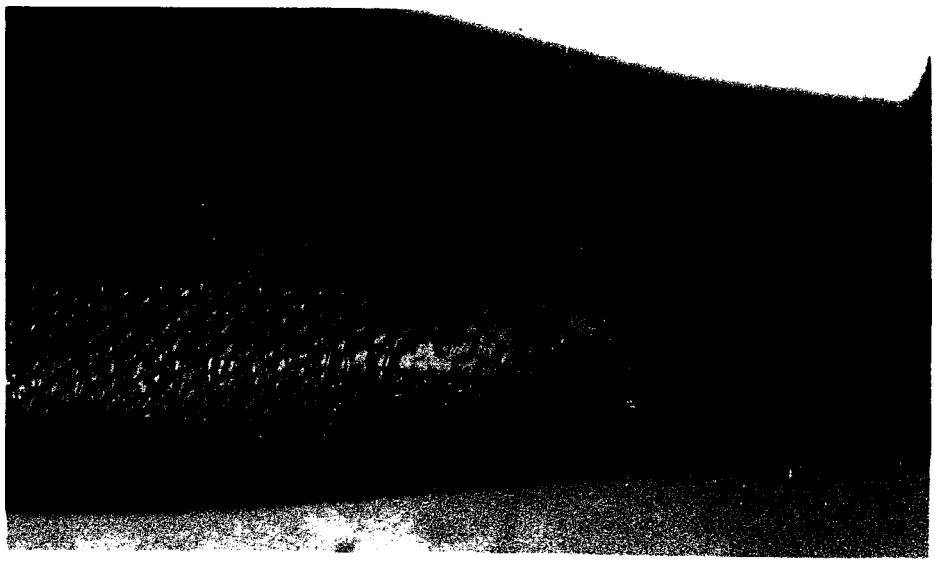


Fig. 21. Midventral view of male pikeperch, showing milt released from genital aperture when slight pressure is exerted on abdomen. Lake Gogebic, May 5, 1947.

distinguished from spent females of small size. No immature males were encountered on the spawning grounds, and only two immature females (determined by dissection) occurred, both late in the season (May 23).

In capturing the fish for examination and tagging, commercial fish nets known to the trade as "small subs" were used. These are trap nets with 300-foot leads, wings, a heart, and a double trap into which the fish are directed and held (Fig. 22). Fish are removed by means of a dipnet after the trap has been partly lifted and brought alongside the boat (Fig. 23).

Three trap nets were set along the spawning grounds. One (No. 2) was just inside Six Mile Bay, another (No. 4) was placed at a point 0.5 mile south of this point, and a third (No. 3) was located 0.5 mile north of the Bay (Fig. 24). The composition by sex of the pikeperch from each net lift is shown in Table 7.

A total of 4,317 fish was examined during the period from May 9 to May 27. Of these, 3,841, or 89 percent, were males. The percentage of males present varied constantly with the progress of the spawning season. A sample of 525 pikeperch taken from a net set on May 8 and lifted on May 9, three days after the ice left Lake Gogebic, showed 99 percent males. On May 10, this figure was 95.5 percent, and by May 11 it had decreased to 80.9 percent. In net No. 2, a steady decrease in the proportion of males occurred up to May 15, when 71.9 percent of the catch consisted of this sex. Net No. 3 had been collapsed on May 10 and was not thought to be fishing. However, on May 14, when it was reopened, it was found that a large number of pikeperch had been trapped in the forward areas of the net. The results with regard to sex ratio are thus somewhat obscured, as fish taken at any time between May 10 and May 14 are included. The net was

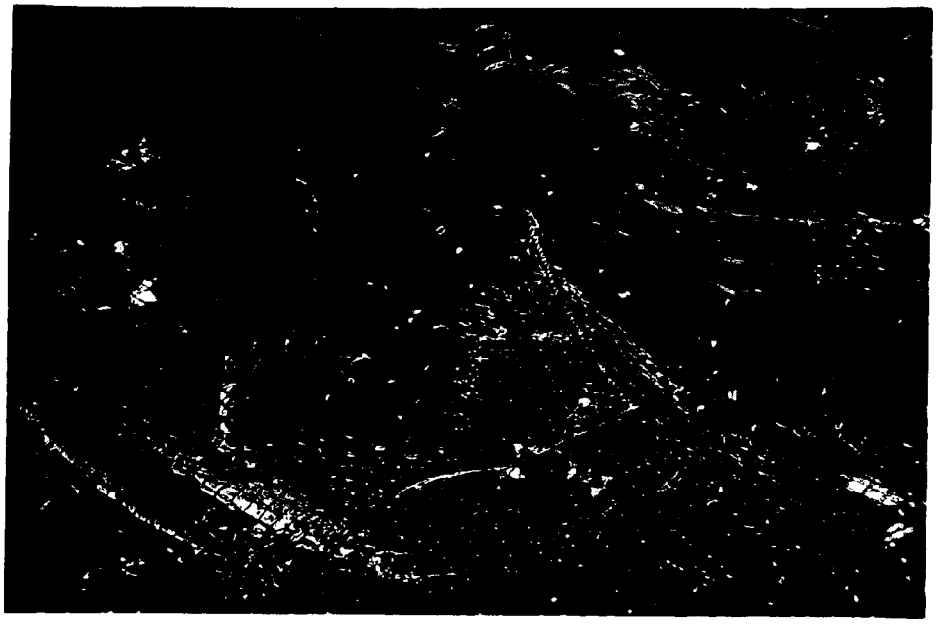


Fig. 22. Pikeperch in a trap net set at the spawning grounds, Lake Gogebic, May, 1947.

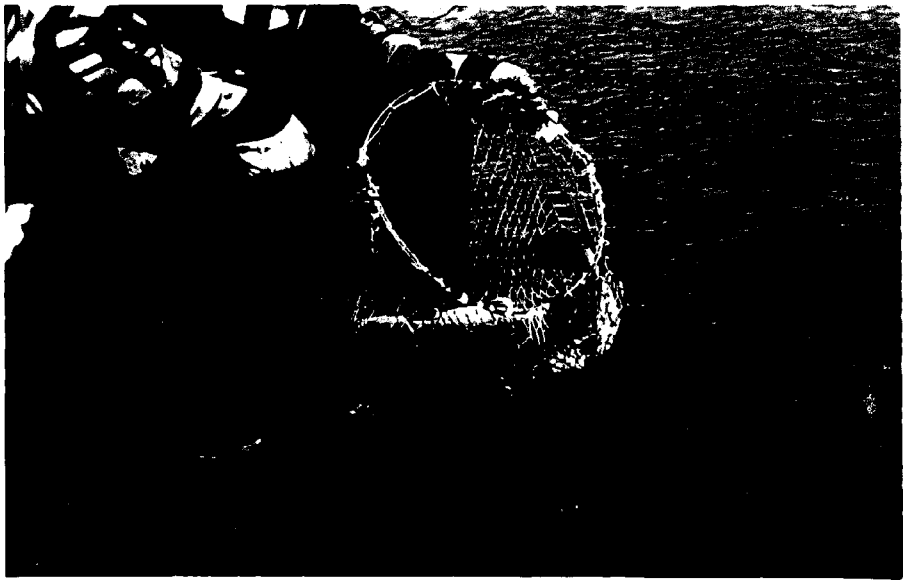


Fig. 23. Removing pikeperch from trap net, Lake Gogebic, May, 1947.

Fig. 24. Map of Lake Gogebic showing locations of trap nets (May, 1947).

INSTITUTE FOR FISHERIES RESEARCH

DIVISION OF FISHERIES MICHIGAN CONSERVATION DEPT

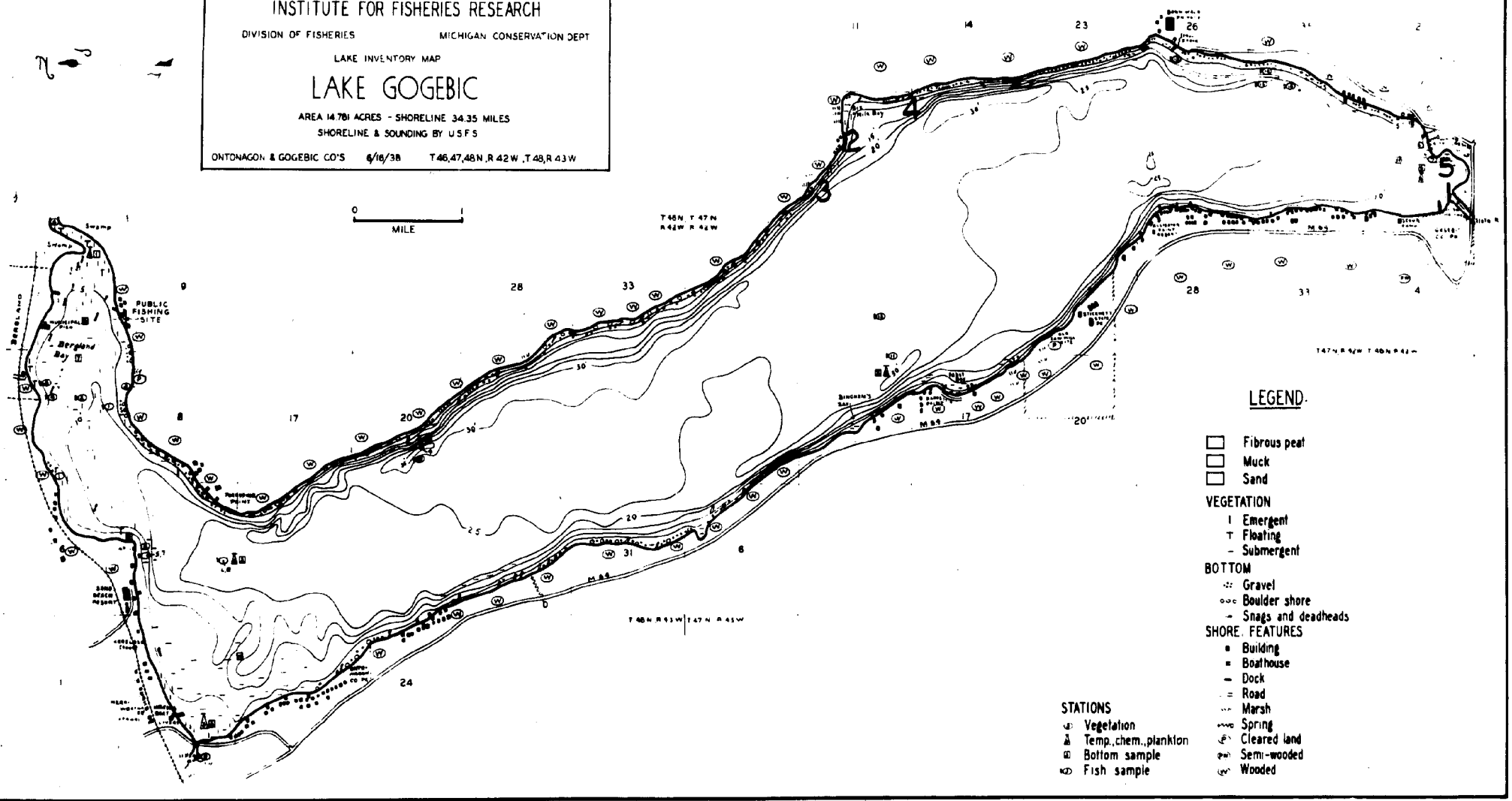
LAKE INVENTORY MAP

LAKE GOGEBIC

AREA 14.781 ACRES - SHORELINE 34.35 MILES

SHORELINE & SOUNDING BY U.S.F.S.

ONTONAGON & GOGEBIC CO'S 6/16/38 T.46,47,48 N.,R.42 W.,T.48,R.43 W.



LAKE GOGEBIC Ontonagon-Gogebic Co's. T.46,47,48N R.42W T.48N R.43W

Table 7. Sex composition of mature pikeperch taken in trap nets on the spawning grounds near Six Mile Bay, Lake Gogebic, May 8-27, 1947.

Date	Net No.	Fish caught	Number sexed	Percentage		Number females per 100 males
				Males	Females	
May 8-9	2	695	525	99.0	1.0	1
9-10	3	1,566	623	95.5	4.5	5
9-11	2	838	430	80.9	19.1	24
11-12	2	594	519	78.8	21.2	27
12-14	2	264	164	75.0	25.0	33
10-14	3	1,543	372	89.0	11.0	12
14-15	2	586	545	71.9	28.1	39
15-16	2	68	67	79.1	20.9	26
16	gill nets	133	133	100.0	...	0
16-18	4	268	268	100.0	...	0
18-20	4	284	284	100.0	...	0
20-23	4	357	357*	100.0	...	0
23-25	4	13	13	100.0	...	0
25-27	4	15	15	100.0	...	0
Totals		7,224	4,315	89.0	11.0	12

*Two immature females also caught, not included.

removed on the latter date.

The maximum proportion of females on the spawning grounds coincides fairly well with the peak of the spawning season, as determined by counts on the spawning beds (Fig. 19). A sample of 67 fish sexed on May 16, however, showed a slight increase in the number of males, to 79.1 percent. The small catch of fish in net No. 2 on this date suggested that pikeperch had discontinued using this area in numbers, and it was moved to net station No. 4 (Fig. 24).

Gill nets set near station H and I (Fig. 18) during a portion of the night of May 16 yielded 133 pikeperch, all of which were males. The nets were set parallel to the shore, 15 to 20 feet out, and the fish located between the nets and the shore were then driven into them.

Net No. 4 yielded no sexually mature female pikeperch during the period from May 16 to May 27. This sudden and decided increase in the proportion of males is not easily explained, since on May 16, 12 of the fish in net No. 2 were females and of these 8 were either ripe or green (i.e., were still spawning, or had not begun). Fish were still present in large numbers at near-by station C (Fig. 18), as revealed by counts on the area on the night of May 18 (Table 6), when 172 fish were enumerated within the 500-foot counting plot. Either females frequented this area much less than that near net station No. 2, or else there was a sharp reduction in the number of females after May 16 and none of the few which remained were caught in net No. 4.

The trap net data show that males were the first to arrive on the spawning grounds in numbers, that an increasing number of females occurred until a maximum of 28 percent of the total was reached, and that a sharp diminution in numbers of females occurred after this time. Males remained

on the area for a number of days after females had left.

That females are the first to leave the spawning grounds, and that males remain, is further indicated by trap net catches at the mouth of the Slate River and in the adjacent bay (net station Nos. 1 and 5, Fig. 24) about three miles south of the spawning grounds. The catches in these nets are summarized in Table 8.

Net No. 1, at the mouth of the Slate River, took only one mature male pikeperch between May 10 and May 18. The fish was diseased (Fig. 25) and may not have spawned. All others, insofar as could be determined, were spent females or immature fish. This is based on the assumption that milt could be expressed from all males by abdominal pressure during this period, an assumption which seems valid, since milt was released readily by males handled through May 27. A sample of 10 fish which did not produce milt when pressure was applied, during this period, was found upon dissection to consist entirely of immature females. Sixty-seven of the 161 females taken were definitely recognizable as spent, since a few eggs (often only one or two) were forced from each of them. Others showed the lean appearance and flaccid abdomens of spent females, but eggs could not be obtained. Females were dominant in numbers in the nets set at the south end of the lake through May 22. However, the number of immature females included in the totals is not known.

Of 73 mature pikeperch taken by anglers (35) or in gill nets (38) between May 23 and August 26, 1947,[37] or 50 percent, were females. Each of the three samples which made up this total consisted of about equal numbers of fish of each sex. Although the results are based on a total which is too small to be conclusive, a 50:50 ratio of the sexes among the mature fish in the lake is suggested.

Table 8. Sex composition of pikeperch taken in trap nets at the south end of Lake Gogebic, April 29 - May 24, 1947.

Date	Net No.	Fish caught	Number sexed	Percentage		Number females per 100 males
				Males	Females	
April 29 - May 8	1	50	50	42.0	58.0	138
May 8-10	1	14	14	...	100.0	...
10-13	1	68	68	...	100.0	...
13-16	1	73	73	1.4*	98.6	...
16-18	1	7	7	...	100.0	...
18-19	1	22	22	22.7	77.3	340
19-20	1,5	194	194	19.6	80.4	411
20-22	1,5	164	164	39.0	61.0	156
22-24	1,5	178	174	54.0	46.0	85
Totals		770	766	29.1	70.9	243

*One diseased male.

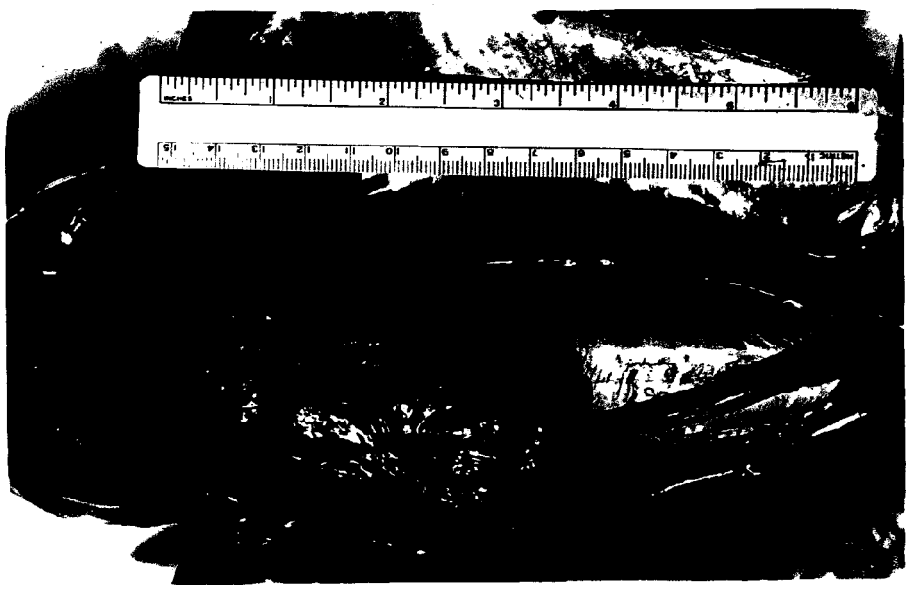


Fig. 25. Diseased adult male pikeperch taken in a net at the mouth of the Slate River, Lake Gogebic, May 16, 1947 (see text for discussion).

The condition of the ovaries of 455 pikeperch taken in trap nets on the spawning beds is shown in Table 9. The data show that females in each of the three classes of condition (green, ripe, and spent) were present throughout the period when females were taken (except on May 9). Green females were most abundant early in the season, on May 10 and 11; ripe females were most numerous on May 12 and 14 (disregarding the small samples on May 9 and 16); and spent females were more common on the spawning beds after May 12 than before that time, and constituted over one-half the catch of females on May 15. The data suggest that females came to the vicinity of the shoals before they were fully ready to spawn, although usually half or more of the fish present were in spawning condition. The significance of the gradual increase of spent females with the progress of the season is not clear. It may mean that some females remained near the spawning grounds after spawning, thus becoming more numerous as a group as the season progressed.

In Burt Lake, Cheboygan County, a sample of 346 pikeperch removed from trap nets on April 29 and 30, 1948, was examined. Of these fish, 259 (74.9 percent) were males and 87 (25.1 percent) were females. Of the females, 30 percent were green, 22 percent were ripe, 38 percent were spent, and 10 percent were immature. The percentage of ripe fish is markedly smaller than that observed on the spawning grounds at Lake Gogebic. The fish examined at Burt Lake may have entered the nets green and ripened there, since the nets had not been tended for from two to seven days. The catches appear to offer no clinching evidence that spawning was occurring in the immediate vicinity, for males and green and spent females may have been merely passing through the areas, enroute to and from the spawning grounds.

Table 9. Condition of ovaries of yellow pikeperch taken near Six-Mile Bay, Lake Gogebic, May 9 - 16, 1947.

Net No.	Date	Number examined	Condition (percentage)		
			Green	Ripe	Spent
2	May 9	5	20.4	80.0	...
3	10	28	42.9	50.0	7.1
2	11	82	52.4	43.9	3.7
2	12	110	18.2	72.7	9.1
2	14	37	13.5	56.8	29.7
3	14	35	8.6	54.2	37.2
2	15	146	11.6	37.7	50.7
2	16	12	16.7	50.0	33.3
Totals		455	22.6	51.7	25.7

In summary, male pikeperch composed 89 percent of the catch in trap nets set on the spawning grounds at Lake Gogebic from May 9 to May 27, 1947. Females attained their maximum numbers (28 percent of the catch) near the peak of the spawning season. All mature fish caught after May 16 were males. In contrast, the sexes were about equally represented among fish taken by angling and in gill nets during the summer months. The sex ratios in trap net catches on the spawning grounds and in those at a point three miles away indicated that females preceded the males in leaving the spawning grounds.

Movement of pikeperch during and immediately following the spawning season

That pikeperch concentrate in large numbers and that they are easily taken in nets during the spawning season is well known. Bean (1910) quoted the foreman of the Oneida, New York, hatchery as saying that nearly 100,000 pikeperch were caught in the vicinity of Scriba Creek during the 1909 spawning season. Adams and Hankinson (1928) reported that for a two-year period, enough pikeperch were taken on about one-third of a mile of shoal to obtain 1900 quarts of eggs, and that in 1927, seventeen trap nets placed in four to eight feet of water a short distance from the mouth of Scriba Creek, secured an average of 2,000 fish daily during the height of the season. Butler (1937) wrote that from 15 to 20 thousand pikeperch were taken each year during the spawning run from a single pound net near the mouth of Swan Creek, Manitoba. Eddy and Surber (1947) reported a single night's catch with one pound net of 36,000 adult fish, some weighing 12 to 14 pounds. The fish were taken in the Rat Root River, Minnesota, one of the many tributaries of Rainey Lake up which pikeperch migrate to spawn.

The fact that pikeperch move very extensively along the spawning grounds at Lake Gogebic, particularly early in the season, is shown by the fact that a single over-night catch in a trap net (net No. 3, May 9-10, 1947) yielded 1566 pikeperch. Three sets in another area produced over 500 fish per night.

In order to study the movement of pikeperch during and after the spawning season, 3,364 males and 428 females were tagged and released at the place of capture. The manner of capture and removal has been described (p. 63 , Figs. 22 and 23). After removal, the fish were placed in a tub of water in the boat, in groups of from 8 to 20 (Fig. 26). After measurement to the nearest one-tenth inch, and determination of sex, a No. 3 monel metal strap tag was fastened securely to the jaw. Two pairs of long-nosed pliers were used in the operation (Fig. 27). For fish under 19 inches in length the tag was placed around the lower jaw (Fig. 28) and on larger fish the tag was placed around the maxillary and premaxillary (Fig. 29). The lower jaw of fish over about 19 inches in length is too large for convenient application of the No. 3 tag, and at about this length, the width of the maxillary becomes sufficient to prevent the tag from slipping backward off the bone. The fish were handled by one person wearing canvas gloves, as suggested by Stoudt (1938); a second applied the tag, and a third recorded. When fish were available in numbers and little time was consumed in removal of fish from the net, about 100 fish per hour were marked by this crew.

A total of 184 tagged pikeperch was recovered in the nets on the spawning grounds during the netting period (May 10 to 23). One hundred fifteen of these were taken in the same nets in which they were originally captured. A large recovery might be expected at the place of release, since fish were

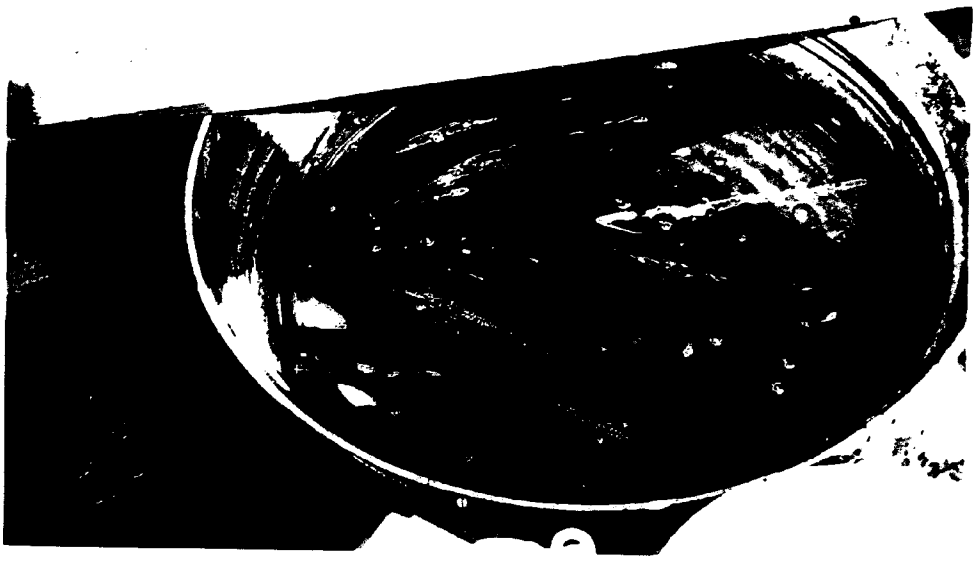


Fig. 26. Pikeperch which have been removed from a net and placed in a tub in preparation for tagging, Lake Gogebic, 1947.

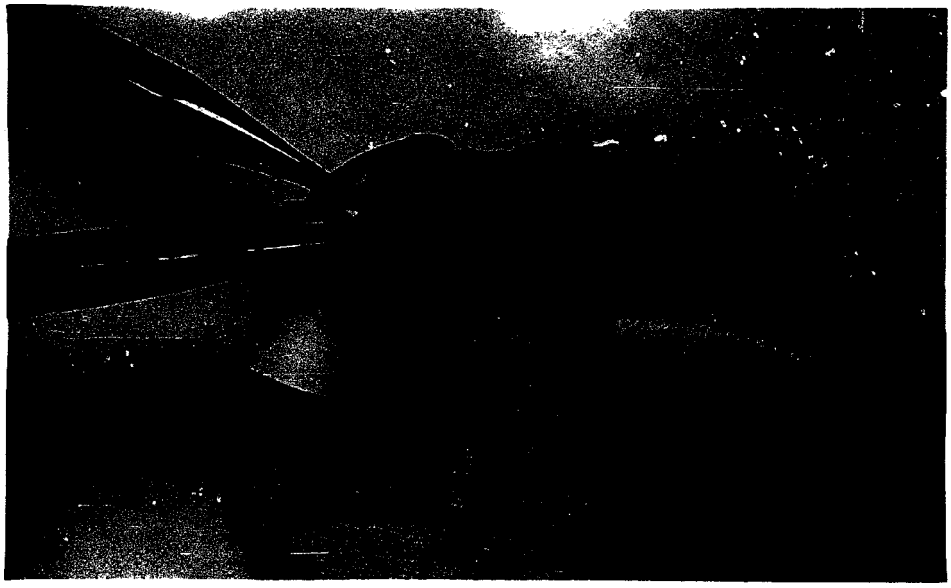


Fig. 27. Demonstration of method used for tagging pikeperch at Lake Gogebic, 1947.

Fig. 28. Position in which tags were placed on pikeperch under 19 inches in length, Lake Gogebic, 1947.

Fig. 29. Position in which tags were placed on pikeperch 19 inches or more in length, Lake Gogebic, 1947.

tagged and returned to the water at the net, and many of these may have reentered the trap immediately. However, 47 of the group were recaptured after an interval during which the net had been lifted at least once, and all fish removed. These recaptures are summarized in Table 10. Five fish were recovered at an interval of 3 days; 14 after 4 days; 13 after 5; 11 after 6; and 4 were recovered after a week. All fish were males. Seven days was the maximum period that a net was set at a given spot on the spawning grounds, with the exception of No. 4, which was set for 11 days, but which was not functioning properly for the last four days of this period.

The returns occurring in the net of capture indicate that some of the pikeperch revisited or passed identical areas along the shoreline on more than one occasion during the season, or remained in a restricted area for a number of days.

Sixty-nine pikeperch were recaptured in a net on the spawning grounds other than that where they had been caught when tagged. A summary of these recaptures is shown in Table 11. Twelve fish were caught at a distance of 1 mile from the point of tagging (moved from net No. 3 to No. 4, Fig. 24), whereas the remainder had moved a minimum distance of 0.5 mile. Of these 23 moved from No. 3 to No. 2, 14 from No. 2 to No. 3, and 20 from No. 2 to No. 4. Movement from net No. 4 to nets No. 2 and 3 could not be observed, because the latter nets were removed before net No. 4 was set.

Only two females were included among these recoveries. They moved from net No. 2 to net No. 3 at intervals of 2 and 3 days respectively. Eleven other females were recovered, but in the same nets at which they were tagged and in the first lift following tagging.

In addition to the trap net recoveries, three fish were recaptured on

Table 10. Tagged yellow pikeperch recovered in the same net at which tagged (after an intervening lift of the net) on the spawning grounds at Lake Gogebic, May 12 - 23, 1947.

Net No.	Date	Number recovered	Days out
2	May 12	4	3
2	14	7	5
2	14	1	3
2	15	11	6
2	15	12	4
2	16	3	7
2	16	1	5
2	16	1	4
2	16	1	7
4	23	5	5
4	23	1	4
Total		47	

Table 11. Marked yellow pikeperch recovered in a trap net other than that at which tagged on spawning grounds at Lake Gogebic, May 10 - 23, 1947.

Tagged		Recovery			Minimum distance travelled	Days out
Date	Net No.	Date	Net No.	Number recovered		
May 10	3	May 11	2	1	0.5	1
10	3	12	2	5	0.5	2
9	2	14	3	8	0.5	5
11	2	14	3	2	0.5	3
12	2	14	3	4	0.5	2
10	3	14	2	6	0.5	4
10	3	15	2	8	0.5	5
10	3	16	2	2	0.5	6
14	3	16	2	1	0.5	2
9	2	18	4	2	0.5	9
10	3	18	4	2	1.0	8
11	2	18	4	1	0.5	7
14	3	18	4	1	1.0	4
14	2	18	4	1	0.5	4
9	2	20	4	1	0.5	11
10	3	20	4	2	1.0	10
11	2	20	4	3	0.5	9
12	2	20	4	2	0.5	8
14	3	20	4	2	1.0	6
15	2	20	4	1	0.5	5
10	3	23	4	5	1.0	13
11	2	23	4	5	0.5	12
12	2	23	4	4	0.5	11
Total				69		

May 16 in gill nets set at a point near station G (Fig. 18) after moving about two miles from the point of tagging. Two tagged on May 12 at net No. 2 were recovered by anglers; one on May 19, near shore, at station K, after moving about five miles from the point of tagging; the other on May 17 at station J, slightly over four miles from the net where released.

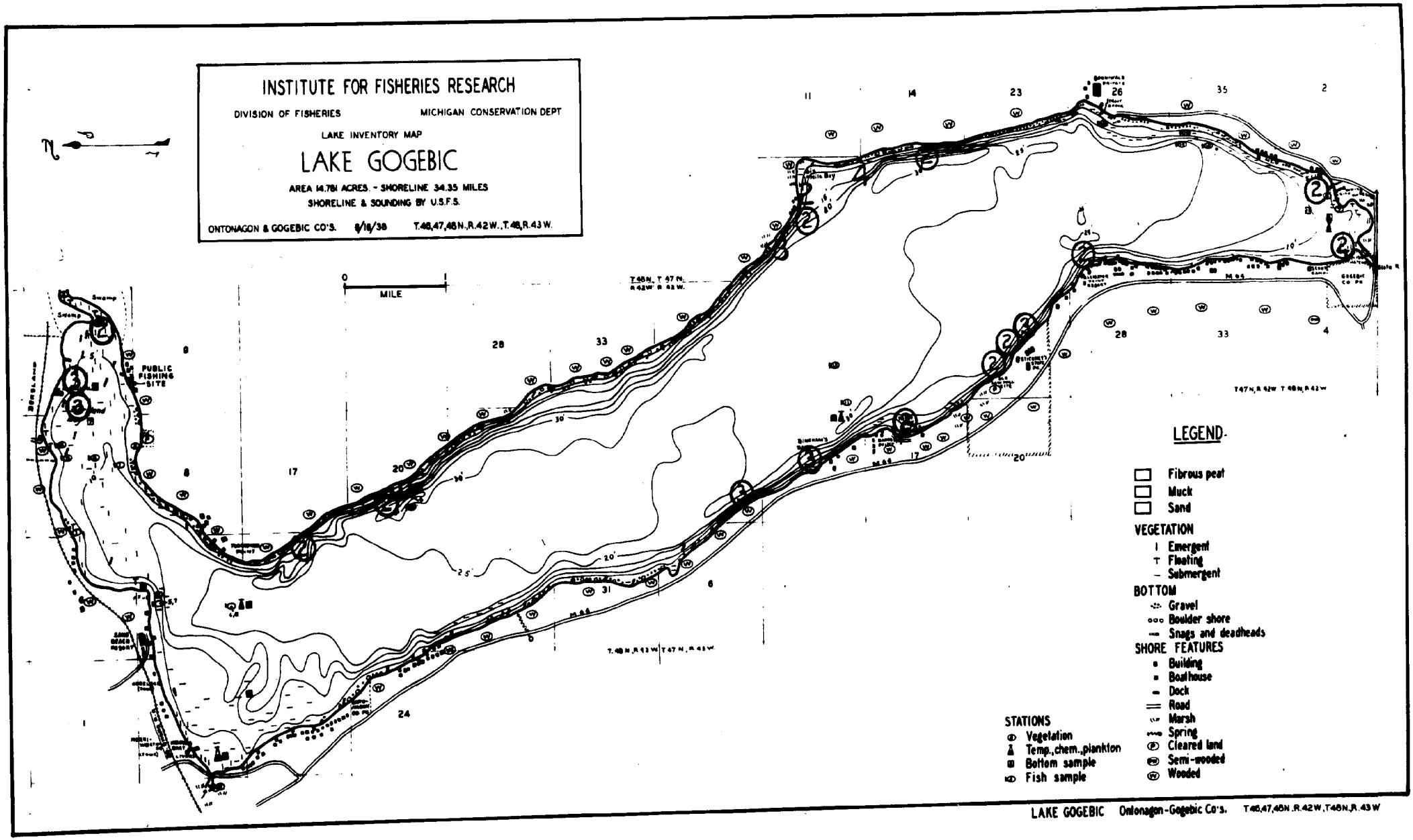
Of the 116 pikeperch recovered from nets other than those at which they were tagged, or in the same net after an intervening lift and removal of fish had occurred, 31 were recovered after an interval of one week or more. One was recovered after a 1-day interval, 10 after 2 days, 7 after 3 days, 22 after 4 days, 30 after 5 days, 15 after 6 days, 5 after 7, 4 after 8, 5 after 9, 2 after 10, 5 after 11, 5 after 12, and 5 were recovered after an interval of 13 days.

A wide dispersal of pikeperch in the lake following spawning is shown by recoveries of tagged fish made by anglers between the opening date of the fishing season (May 15) and June 15. These recoveries are shown in Figure 30.

Further evidence of widespread movement after spawning is indicated by tag recoveries in nets at the south end of the lake. The recapture of unmarked spent females (which had very probably been on the spawning grounds), at the mouth of the Slate River, is discussed above (p.67). Two females tagged at net No. 2 on May 11 and 12, were recovered in net No. 5 on May 20; eight females from net No. 2 and one from No. 3 were retaken in No. 5 on May 22; and five from No. 2, one from No. 3, and one from No. 4 were recaptured in net No. 5 on May 24.

Pikeperch have also been observed to distribute themselves throughout Lake Winnibigoshish, Minnesota, within a short time after spawning (Stoudt, 1939; Stoudt and Eddy, 1939).

Fig. 30. Dispersal of pikeperch from the spawning beds in Lake Gogebic as revealed by returns from anglers, May 15 to June 15, 1947. Each circle represents one recovery. The number inside the circle indicates the number of the net at which the fish was tagged.


INSTITUTE FOR FISHERIES RESEARCH
DIVISION OF FISHERIES
MICHIGAN CONSERVATION DEPT
LAKE INVENTORY MAP
LAKE GOGEBIC
AREA 14,781 ACRES. - SHORELINE 34.35 MILES
SHORELINE & SOUNDING BY U.S.F.S.
ONTONAGON & GOGEBIC CO'S. 6/16/38 T.46,47,48N.,R.42W.,T.48,R.43W.
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1
MILE
PUBLIC FISHING SITE
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Snags and deadheads
SHORE FEATURES
Building
Boathouse
Dock
Road
Marsh
Spring
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Vegetation
Temp.,chem.,plankton
Bottom sample
Fish sample
LAKE GOGEBIC Ontonagon-Gogebic Co's. T.46,47,48N.,R.42W.,T.48N.,R.43W

In brief, male pikeperch exhibited no established territoriality, but showed a general movement in both directions along the spawning beds at Lake Gogebic in 1947. This was for distances of up to 5 miles and covered a period of as many as 13 days. Pikeperch dispersed widely in the lake after the spawning season.

Size distribution of pikeperch on the spawning beds in 1947

In connection with the study at Lake Gogebic, 3,791 pikeperch were measured on the spawning grounds between May 9 and May 27, 1947. Average total lengths of fish taken during the period are given for each sex in Table 12.

Male pikeperch ranged from 12.2 to 22.1 inches in length, and averaged 16.9 inches for the period. The length of fish taken before the probable peak of the spawning season, May 16, usually averaged less than for the season, whereas those taken between May 18 and May 27 were consistently larger than the season average. Sexually mature males caught at a distance of three miles from the spawning beds (net Nos. 1 and 5) after May 19 were of smaller average size (Table 13) than those being taken on the spawning beds at the same time, and averaged consistently smaller than the male pikeperch measured on the spawning beds. The data indicate that on the average small males left the spawning area before the large fish.

Female pikeperch taken on the spawning grounds ranged from 15.4 to 28.8 inches in length, and averaged 18.8 inches. Except for the few fish taken on May 9, females averaged larger up to May 12 than after that date. The average size of females taken at points away from the spawning grounds (net Nos. 1 and 5) was below that for those taken on the grounds. These data are probably not significant, however, because of the occurrence of

Table 12. Average total lengths of 3,791 yellow pikeperch measured and tagged near Six-Mile Bay, Lake Gogebic, May 9 - 27, 1947.

Date	Males		Females	
	Number	Average total length	Number	Average total length
May 9	520	16.3	5	18.6
10	595	17.1	28	19.5
11	334	16.7	66	19.8
12	390	16.7	107	19.1
14	365	16.9	68	18.3
15	323	16.3	142	18.3
16	40	16.2	12	18.2
18	257	17.4	...	...
20	262	17.3	...	...
23	258	17.6	...	...
25	13	17.5	...	...
27	6	19.1	...	...
Total	3,363	16.9	428	18.8

Table 13. Average total lengths of 683 yellow pikeperch measured at the south end of Lake Gogebic, April 29 - May 24, 1947.

Date	Males		Females	
	Number	Average total length	Number	Average total length
April 29 - May 8	21	16.1	29	17.3
May 10	...	...	13	18.2
13	...	...	67	17.7
16	...	...	70	18.2
18	...	...	7	17.6
19	5	16.5	16	17.6
20	34	16.1	144	18.3
22	54	16.3	96	17.5
24	76	16.1	51	18.2
Total	190	16.2	493	17.9

some immature females in the catch at the south end of the lake.

The size frequencies of pikeperch measured and tagged near Six Mile Bay (net Nos. 2, 3 and 4) are shown in Table 14. Males ranging from 15 to 18.9 inches in length composed over 80 percent of the catch for the period, whereas females from 17 to 19.9 inches long constituted about 64 percent of the total number of females taken. At the south end of the lake, males in the 15 and 16 inch classes composed 58 percent of the total males, while the 15, 16, 17 and 18 inch groups contributed about equally to the two-thirds of the total catch of females which they aggregated (Table 15).

In Burt Lake, Cheboygan County, 222 mature males measured on April 29 and 30, 1948, averaged 17.4 inches in total length, and 70 mature females averaged 19.4 inches.

Stoudt (1939) found that 543 males in Little Cut Foot Sioux Lake, Minnesota, averaged 16.0 inches in standard length; 20 females from Dixon Lake averaged 16.0 inches and 2,075 males averaged 14.9 inches.* Measurements of 11,611 male and 6,254 female spawning pikeperch from 15 localities in Minnesota showed the average lengths to be 15.0 to 20.2 inches and 16.5 to 24.2 inches respectively (Smith, 1943).

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*Using the factor given by Carlander and Smith (1945), these lengths are equivalent to total lengths of 18.4, 18.4, and 17.2 inches respectively. (Total length equals standard length x 1.153).

Table 14. Size frequencies of 3,791 yellow pikeperch tagged near Six-Mile Bay, Lake Gogebic, May 9 - 27, 1947.

Total length inches	Males		Females	
	Number	Percentage of total males	Number	Percentage of total females
12.0 - 12.9	5	0.2	...	...
13.0 - 13.9	55	1.6	...	...
14.0 - 14.9	299	8.9	...	...
15.0 - 15.9	657	19.5	6	1.4
16.0 - 16.9	599	17.8	48	11.2
17.0 - 17.9	809	24.1	86	20.1
18.0 - 18.9	671	20.0	112	26.2
19.0 - 19.9	217	6.4	75	17.5
20.0 - 20.9	41	1.2	49	11.5
21.0 - 21.9	9	0.3	34	7.9
22.0 - 22.9	1	0.03	11	2.6
23.0 - 23.9	...	...	3	0.7
24.0 - 24.9	...	...	1	0.2
25.0 - 25.9	...	...	2	0.5
28.0 - 28.9	...	...	1	0.2
Total	3,363		428	

Table 15. Size frequencies of 683 yellow pikeperch measured at the south end of Lake Gogebic, April 29 - May 24, 1947.

Total length inches	Males		Females	
	Number	Percentage of total males	Number	Percentage of total females
13.0 - 13.9	2	1.1	1	0.2
14.0 - 14.9	29	15.2	19	3.9
15.0 - 15.9	60	31.6	82	16.6
16.0 - 16.9	50	26.3	81	16.4
17.0 - 17.9	24	12.6	82	16.6
18.0 - 18.9	22	11.6	79	16.0
19.0 - 19.9	2	1.1	57	11.6
20.0 - 20.9	...	...	48	9.7
21.0 - 21.9	1	0.5	23	4.7
22.0 - 22.9	...	...	16	3.3
23.0 - 23.9	...	...	2	0.4
24.0 - 24.9	...	...	1	0.2
25.0 - 25.9	...	...	...	...
26.0 - 26.9	...	...	1	0.2
27.0 - 27.9	...	...	1	0.2
Total	190		493	

Species associated with pikeperch on the spawning grounds

No fish of species other than pikeperch have been seen (other than in nets) on the spawning grounds during the four seasons of observation at Lake Gogebic.

The trap netting near Six Mile Bay during the 1947 spawning season resulted in the capture of 7,226 pikeperch between May 8 and May 27. Only 18 fish of other species (less than 0.25 percent of all fish) were taken. These included 7 northern pike, 5 yellow perch, 1 rock bass, 3 burbot, and 2 white suckers. Although this constitutes a remarkable dominance of a species on its spawning grounds, it should be added that the picture is not greatly different in October, except for the presence of white suckers. Many of these were on spawning runs up inlet streams during the pikeperch spawning season. Two of the trap nets were set again in October, along the east shore, about one mile south of Trout Brook (slightly more than one mile from the south end of the pikeperch spawning grounds). Twelve net days (one net day = one trap net set for approximately 24 hours) yielded 565 pikeperch, 4 northern pike, 4 smallmouth bass, 3 yellow perch, 1 rock bass, and 96 white suckers. The dominance of pikeperch along the west shore was much less pronounced. In 15 net days of fishing during the period from October 13 to 20, 57 pikeperch, 41 northern pike, 2 yellow perch, 5 smallmouth bass, 2 rock bass, and 1 burbot were taken.

Identification of sex and development of the reproductive organs

That the identification of sex of pikeperch is sometimes perplexing has been recognized by several workers. Deason (1933) mentioned the difficulty of sex determination in immature individuals. Carlander (1945)

indicated that the recognition of sex of pikeperch in summer is difficult, and Eddy and Surber (1947) commented on the uncertainty in determining the sex of pikeperch less than 13 or 14 inches in length, even during the spawning season.

On the other hand, Adams and Hankinson (1928) reported that females in Scriba Creek, New York, could be distinguished readily by the indistinctness of the white on the tip of the lower lobe of the caudal fin. Bean (1913) stated that the female can be distinguished on the spawning beds by her larger size and by the fact that she is attended by several males.

Examination of Lake Gogebic pikeperch has revealed no external characteristic by which the sex of pikeperch can be determined throughout the year. No sexual difference has been observed in the distinctness of the white on the lower lobe of the caudal fin. Size is not a valid criterion, except perhaps in very large fish. Although females in a given population usually are larger than males, the largest in a group of spawning fish is not necessarily a female, although this is likely. In this connection Eddy and Surber (1947) made the curious statement that the length of males rarely exceeds 15 inches in length (presumably standard length) when, in a study made in 1937 at Lake Winnibigoshish (Stoudt, 1939), with which the senior author was familiar (Stoudt and Eddy, 1939), 2,618 male pikeperch averaged 15.1 inches in standard length.

By dissection the sex of pikeperch can be distinguished with facility during any season of the year. Although ability to recognize sex improves quickly with the experience of the worker, little difficulty is encountered if both sexes are present for comparison in a given collection.

The gonads of pikeperch lie close to the ventral wall of the air bladder and often extend nearly as far forward as its anterior end. The right

and left members are free for most of their length, but are united posteriorly, just anterior to the genital aperture.

In female pikeperch from 2 to 3 inches in length, the ovaries are small and little developed. Under magnification they are seen to possess an abundance of large melanophores throughout their length, so that their location is first revealed by the presence of a double row of large melanophores lying along the ventral surface of the air bladder. By the time the fish are from 4.5 to 5 inches in length the ovaries are markedly increased in size. They are often flattened dorso-ventrally and opaque (if preserved), or more cylindrical and transparent (if fresh). Melanophores are either scattered over much of the surface of the organs or (more often) are confined to a rather narrow dorsal band along each side of the mesovarium. Pigment persists in adult females, although it is usually confined to a few scattered melanophores located far anteriorly and dorsally on the organs.

Immature females of larger sizes have transparent ovaries (opaque after preservation) which are more or less cylindrical in form. Transverse blood vessels are present throughout their length, and these become increasingly conspicuous, with increase in size of the fish, until maturity is reached. The anterior end of the ovary is often broadly rounded, or comes to a blunt point (Fig. 31).

In mature, spent females the ovaries consist of a pair of elongate, thin-walled sacs, collapsed against the air bladder (Fig. 32). Often they have a light bluish-red coloration, and transverse blood vessels are clearly evident. Small round yellowish-white spots are often scattered irregularly about the ovary. These are residual eggs which have come to lie against the inside of the ovary wall. Other eggs occur in the lumen, or are buried

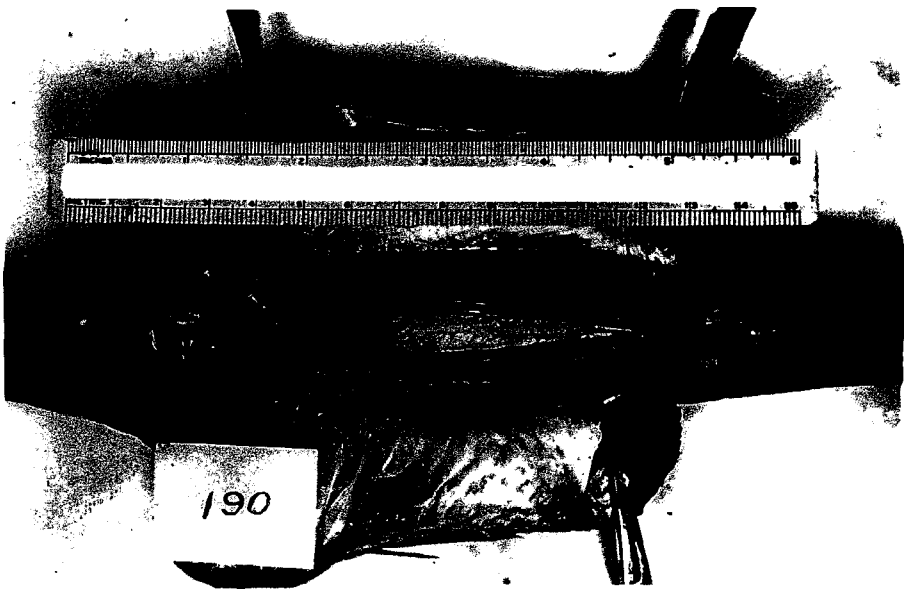


Fig. 31. Immature female pikeperch, showing ovaries. Length, 12.6 inches; weight, 11 ounces. Lake Gogebic, August 23, 1947.

Fig. 32. Spent female pikeperch, showing ovaries. Length, 15.6 inches; weight, 18 ounces. Lake Gogebic, May 22, 1947.

in the fleshy interior. They are easily exposed by a longitudinal dissection of the ovary (Fig. 33). Some eggs are round, turgid, and translucent, whereas resorption of others has begun and they are white, often soft, and no longer round. The eggs which come to lie free in the lumen may persist in the organs for months. The dissection of 12 ovaries in mid-August at Lake Gogebic revealed a few residual eggs in 4 of the specimens (Fig. 34). Several of the dozen fish dissected were of small size and may have been maturing for the first time, so that residual eggs would not be expected. The incidence of such eggs as late as August is not known, but their presence offers an opportunity to check the sex of at least some mature females throughout the year. Females at Lake Gogebic may be recognized at a glance at any time after mid-August by the presence of small eggs which are visible through the ovary wall.

The ovaries steadily increase in size after August until, by early spring, they cause the abdomen to become much distended and occupy a large portion of the body cavity (Fig. 35).

In male pikeperch from 2 to 3 inches in length the testes appear as fine white threads, markedly smaller in cross section than the ovaries of fish of similar size, and with little or no pigmentation. When melanophores occur they are few and are nearly always restricted to the anterodorsal portion of the gonad.

Testes of immature males are much smaller in cross section than are ovaries of immature females. They are elongate and of about equal diameter throughout their length, lacking the bluntly tapered anterior ends which nearly all ovaries possess. Transverse blood vessels, so characteristic of ovaries, are scarcely evident (Fig. 36).

The testes of spent males are much smaller than are ovaries of females

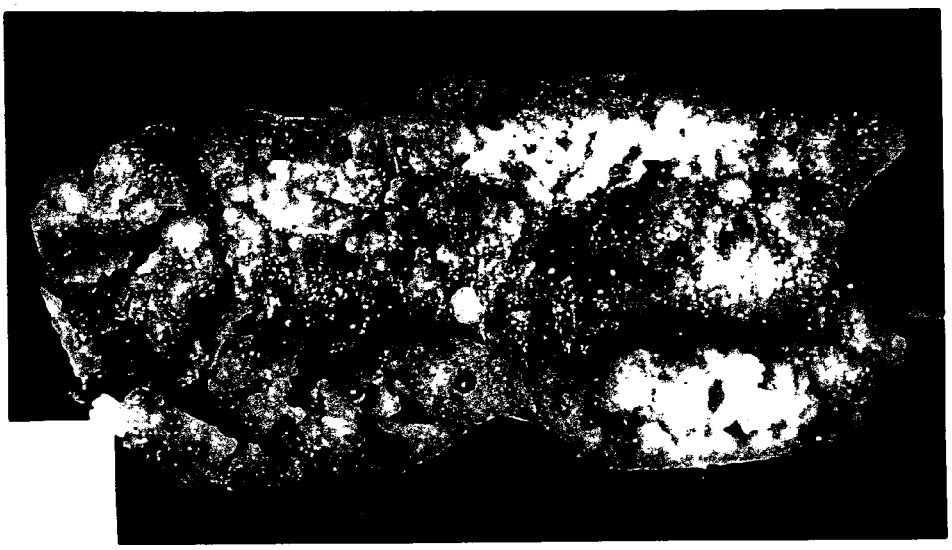


Fig. 33. Dissection of spent ovary, showing residual eggs. Length of fish, 19.3 inches. Lake Gogebic, May 19, 1947.

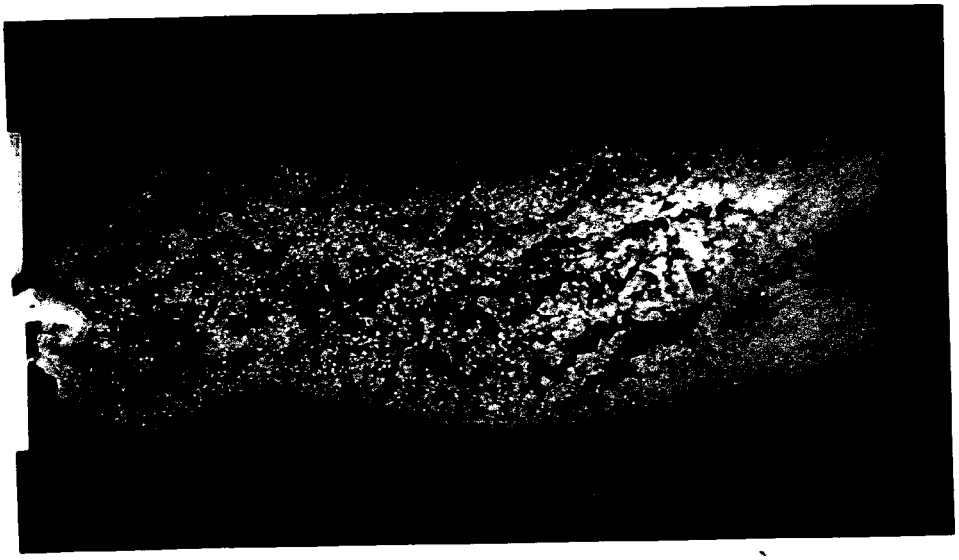


Fig. 34. Dissection of a pikeperch ovary, showing developing eggs and residual eggs from previous spawning season (lower left portion of ovary). Length, 17.2 inches; weight, 30.5 ounces. Lake Gogebic, August 23, 1947.

Fig. 35. Female yellow pikeperch, showing ovaries. Length, 19.1 inches; weight, 2 pounds, 11 ounces. Lake Gogebic, May 2, 1947

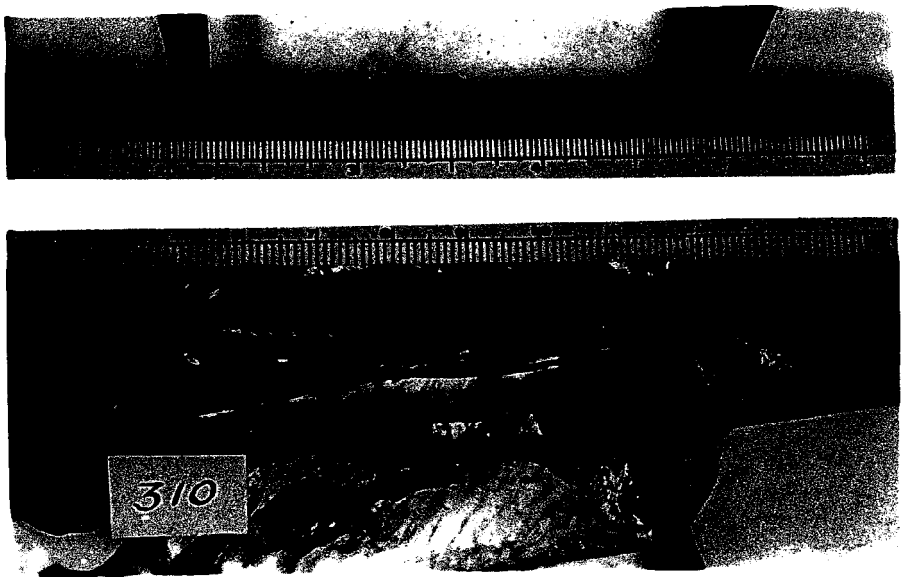


Fig. 36. Immature male yellow pikeperch. Length, 9.6 inches; weight, 4 ounces. Lake Gogebic, October 22, 1947.

of similar size. They are grayish-white (not greatly different in color from mesenteric fat), and have a smooth, glossy appearance (Fig. 37). Anteriorly they are sharply tapered, in contrast to ovaries.

Little change takes place in the male reproductive organs in July and August, but by mid-October a remarkable increase in size has taken place (Fig. 38). The testes are probably larger at this time than during the spawning season. They are milky-white, glossy, soft in texture, and easily torn when removed from the fish. In preserved specimens the interior of the testes has a soft, doughy texture and, if broken, is observed to have a striated structure. The striations run from near the center of the organ toward the periphery.

In Lake Gogebic in October, 1947, the reproductive organs of males and females attained about the same size and weight for fish of about equal length (Fig. 39; Table 16).

During the spawning season the testes are large and milky-white (Fig. 40) although neither larger nor whiter than in October. Their texture is firmer than during the late fall, and pressure on the abdomen causes milt to exude or to spurt from the genital aperture (Fig. 21). The milt of some males is exhausted during the spawning season, whereas some fish retain a large portion of it - or at least this occurred at Lake Gogebic in 1947. All males handled at Lake Gogebic released milt in quantity throughout the period that nets were set (to May 27), although it seemed more viscous late in the period than earlier. The gonads of several males which were dissected during late May were not recognizably different from those shown in Figure 40.

In general, testes are more compact, tougher and "stringier" than ovaries. The female organs open readily into a lumen when dissected,

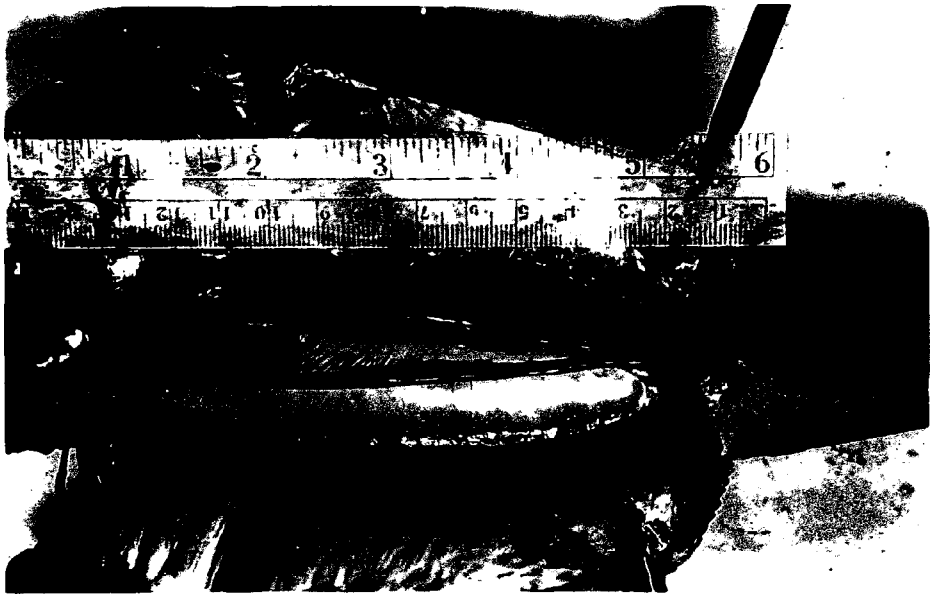


Fig. 37. Spent male pikeperch, showing testes. Length, 15.4 inches; weight, 22 ounces. Lake Gogebic, July 9, 1947.

Fig. 38. Mature male pikeperch, showing testes. Length, 15.6 inches; weight, 19 ounces. Lake Gogebic, October 22, 1947.

Fig. 39. Reproductive organs of mature male pikeperch (above) and female (below) taken from Lake Gogebic on October 22, 1947.
Male: Length, 17.6 inches; weight, 32 ounces.
Female: Length, 17.2 inches; weight, 28 ounces.

Fig. 40. Mature male pikeperch during the spawning season. Length, 15.6 inches; weight, 23 ounces. Lake Gogebic, May 6, 1947.

whereas it is difficult to locate the lumen of testes. The location of the longitudinal blood vessel in the gonads is of some help in recognition of sex of mature fish. In ovaries, the vessel always occurs at the surface of the organ, whereas in testes it lies in a dorsal groove. The groove is shallow in spent fish, but becomes increasingly deep with approaching maturity until by October the blood vessel comes to lie at the bottom of a groove which sometimes extends almost to the center of the testis.

The examination of female pikeperch in various stages of development reveals that one ovary is usually longer than the other. Of 60 females (immature and mature) examined at random, the right ovary was longer in 39, the left in 9, and the ovaries of 12 were of approximately equal length. Testes are more often of equal length, although in these organs, also, one is sometimes longer than the other.

The development of the reproductive organs with the progress of the season can be traced in Table 16, which shows the proportion of the total body weight of pikeperch contributed by the ovaries or the testes. In determining the values shown, the fish were weighed at the time of collection, and the gonads were preserved in 10 percent formalin. Later the organs were weighed and examined after surface moisture had been removed by blotting and exposure to the air. The weights are not claimed to be highly accurate because of the variable amount of moisture occurring inside the various gonads. Fully developed ovaries from 46 fish weighed both in the field and after preservation averaged 5.1 percent heavier in the field than after formalin fixation. Thus, the averages given are known to be somewhat low. In other stages of development no weights were obtained of gonads in the fresh condition, so there are no figures for comparison.

The data in Table 16 show that the ovaries of immature females averaged

Table 16. Proportion of body weight made up by gonads of pikeperch during progress of the season in 1947.

Sex	Maturity	Locality	Date	Number	Total length, inches		Total weight, grams		Percentage of body weight made up by gonads	
					Range	Average	Range	Average	Range	Average
Female	Immature	Lake Gogebic	May 4-23	6	15.1-16.8	15.6	510-737	567	0.2-0.4	0.3
			June 23-26	6	13.1-16.1	14.7	326-652	481	0.2-0.3	0.3
			Aug. 20-23	7	14.3-17.3	15.7	383-865	555	0.3-0.4	0.3
			Oct. 14-22	8	11.5-17.5	15.7	248-907	642	0.2-0.4	0.3
Female	Mature	Lake Gogebic	Aug. 23-26	12	16.1-19.5	17.5	595-1134	840	0.5-1.1	0.7
			Oct. 16-22	22	15.8-21.8	18.0	624-1899	971	3.1-7.9	4.7
			May 3-15	31	16.0-22.7	18.7	680-1871	1163	10.3-24.4	16.3
Female	Mature	Muskegon River	April 21	11	19.3-28.0	23.6	1021-4508	2469	17.2-28.9	24.1
Female	Mature	Saginaw Bay	April 28	5	28.0-31.2	30.2	4593-6018	5411	23.7-31.6	27.8
Female	Mature	Lake Gogebic	May 16-22	7	15.6-19.7	18.3	510-1191	927	1.0-1.8	1.4
			June 23-26	16	16.1-22.1	17.9	595-1843	880	0.6-1.0	0.8
			July 8-9	3	18.1-20.5	19.1	850-1474	1096	0.6-0.8	0.7
Male	Immature	Lake Gogebic	Oct. 14-22	2	12.6-13.2	12.9	255-340	298	0.06-0.1	0.1
Male	Mature	Lake Gogebic	Aug. 20-26	15	14.1-19.3	16.1	425-1262	677	0.1-0.3	0.2
			Oct. 14-22	20	12.1-19.5	16.3	298-1219	695	3.2-5.7	4.3
			May 5-22	3	14.8-17.1	15.8	496-709	619	1.8-3.8	3.0
			June 23-26	10	14.7-16.6	15.6	383-765	530	0.2-1.0	0.4
			July 9	4	13.9-17.2	15.5	397-801	596	0.1-0.2	0.2

0.3 percent of the total weight throughout the period when collections were made. In 12 mature females collected in August this percentage was 0.7, whereas in 22 fish examined in mid-October the ovaries made up an average of 4.7 percent of the body weight.

The gonads comprised an average of 16.3 percent of the weight of 31 pikeperch collected in Lake Gogebic just before spawning, in May, 1947. In 11 large pikeperch taken from the Muskegon River, in April, 1947, the ovaries averaged 24.1 percent of the body weight and in Saginaw Bay this percentage was 27.8. Considering the weight of the ovaries in a fresh condition, the last three percentages named were 17.3 (range 11.2 to 23.9) in Lake Gogebic, 25.2 (range 17.6 to 31.0) for the Muskegon River, and 27.9 (range 25.1 to 32.8) in Saginaw Bay.

Whether the difference in the proportion of the body weight made up by fully developed ovaries at the three localities can be attributed to increasing size alone is not known. In 13 Lake Gogebic fish 19 inches in length or over, the average proportion of the body weight composed by the ovaries just before spawning was 17.4 percent (preserved), whereas in 18 fish under 19 inches in length this percentage was 15.5.

In spent mature fish taken in May, immediately after spawning, the ovaries averaged 1.4 percent of the body weight. This decreased to an average of 0.7 by early July, or about the same percentage as that observed in August (above).

The weights of reproductive organs of males compared to the weight of the fish are also shown in Table 16. Only two immature males, 12.6 and 13.2 inches in length, taken in October, were included in the study. Their gonads constituted 0.06 percent and 0.1 percent, respectively, of their body weight. In 15 males collected in August, the weight of the gonads was

equal to 0.2 percent of the body weight. Between August and October, their average weight increased tremendously (over 2,000 percent, judging by the averages of the specimens examined), to reach 4.3 percent of the body weight. This was only slightly less than the proportion of the body weight made up by the ovaries of females at this season (4.7 percent). From this point on, the testes showed little or no weight increment, whereas the ovaries continued a steady increase. Unfortunately no winter collections are available to trace these developments.

Few testes were preserved in May, but three taken before and immediately after the spawning season had an average weight equal to three percent of the weight of the fish. By late June resorption or loss of milt had not been entirely completed in some fish, since some gonads were still somewhat enlarged. A collection of ten averaged 0.4 percent of the weight of the fish from which they were taken. By July this figure was reduced to 0.2 percent, the same figure which was found in the August collection of males (above).

Curious anomalies occur occasionally among pikeperch ovaries. Dence (1938) has described a case of hermaphroditism in which each ovary had attached to its anterior end a knob-like sac containing spermatozoa.

In the Muskegon River, a much deformed ovary was removed from a 21.5-inch pikeperch, collected on April 25, 1947 (Fig. 41). In addition to being distorted in shape, it was adnate to the swim bladder at three points. One small section of the ovary (inset in figure) was completely independent of the remainder, and was attached separately to the air bladder. Eggs developed in this isolated section had no access either to the ovary or to the body cavity. Dissection revealed a central core composed of a brownish to orange mass composed of remnants of eggs from one or more previous

Fig. 41. An anomaly in the ovary of a pike-perch collected in the Muskegon River, April 25, 1947 (see text for discussion).

seasons, and around this core was a thick peripheral layer of eggs of normal size and appearance, not different from those in the remainder of the ovary. The pouch contained 2,842 eggs of the year, and the entire ovary contained an estimated 126,200 eggs, a figure possibly not below average for a fish of its size in the Muskegon River. The reason for the anomaly is not known. It may have resulted from the rupture of the ovary earlier in the life of the fish as the result of an injury or it may have been congenital.

In summary, ovaries of pikeperch are more heavily pigmented (in small fish), larger in size, and more bluntly tapering anteriorly than are testes. Ovaries of immature females are transparent and more or less cylindrical. They have many transverse blood vessels, whereas these are scarcely evident in testes. The dorsal blood vessel of ovaries lies at the surface; that of testes is located in a groove. Eggs are visible through the ovary wall of mature females by mid-August; residual eggs from the previous spring may also be present at this time. By mid-October, ovaries and testes of adult fish are of about equal size and weight. Just before spawning, ovaries averaged from 17.3 percent of the body weight (in fish from Lake Gogebic) to 27.9 percent (in large fish from Saginaw Bay). In August, this percentage was about 0.7. Testes of three males taken just before and during the spawning season averaged 3.0 percent of the body weight; in August this percentage was 0.2.

Fecundity of pikeperch

Several estimates have been made of the number of eggs produced by pikeperch. Some are based on counts of eggs in the ovaries and others on the numbers of eggs produced in spawn-taking operations. Among the accounts

appearing in the literature are the following:

Cheney (1897) stated that the fish (in spawn taking) average about 150,000 eggs, but if the run is of good-sized fish, they may furnish 200,000 each. He added that M. B. Hill took 609,176 eggs from one Lake Ontario fish, which, after stripping, weighed 13½ pounds. Bean (1903) said that a single female has been estimated to contain from 200,000 to 300,000 eggs. These figures were repeated by Evermann and Clark (1920). According to the fish manual of the U. S. Commission of Fish and Fisheries (1903) and Leach (1927), about 90,000 would be a fair average production for two pound fish from Lake Erie. Thus 45,000 eggs per pound of fish would approximate the true figure. Miles (1915) stated that the average spawn is about 30,000 to 40,000 per pound of fish, and Henshall (1919) reported that the eggs average 50,000 to the female. At the Oneida hatchery, the average number of eggs per fish was determined to be between 50,000 and 60,000 (Adams and Hankinson, 1928).

Smith (1941) showed that the number of eggs produced by pikeperch may vary with locality or rate of growth. In four pikeperch from Norris Reservoir, ranging from 25 to 33 inches in length and from 6 to 13 pounds in weight, he calculated the number of eggs per fish as being between 77,500 and 171,300, or from 12,916 to 14,876 eggs per pound of fish.

Hinks (1943) reported an egg production of 45,000 per pound of body weight. Carlander (1945) estimated (by water displacement) an egg production which increased from 35,000 to 137,000 as the size of fish increased from 343 to 556 mm. in standard length [equivalent to 15.6 to 25.2 inches in total length]. He found an average of 50 eggs per gram of body weight [22,700 per pound]. Eddy and Surber (1947) gave an account of a 12-pound female taken in the upper Mississippi River, above Wolf Lake, Minnesota,

which produced 388,000 eggs from which 270,000 fry were hatched. They reported the average production per female at Bemidji spawning station as 49,614, and stated that average ovary counts indicate that there are about 26,000 eggs per pound of fish. Individual variation was reported high, with the number of eggs from 3- to 3.5-pound females varying from 72,000 to 111,000.

To determine the fecundity of pikeperch at Lake Gogebic, a total of 34 ovaries was preserved during and before the spawning season. Four were collected from the trap net at the mouth of the Slate River, between May 3 and May 7, 1947; three were taken in Lake Gogebic in late October; and the remainder were collected on the spawning grounds between May 11 and May 15 of that year. These fish ranged from 16.0 to 22.7 inches in total length.

In addition to the collections at Lake Gogebic, 11 green females, ranging from 19.3 to 28.0 inches in length were collected from the Muskegon River on April 21, 1947. Five large fish, ranging from 28.0 to 31.2 inches in length and from 10 pounds, 2 ounces to 13 pounds, 4 ounces in weight, were obtained from commercial fishermen at Saginaw Bay on April 28, 1947, through the efforts of Conservation Officer A. J. Neering, Pigeon, Michigan.

In collecting pikeperch for ovary counts, it was assumed that if the abdomen was widely distended, and that if heavy pressure anterior to the vent produced no eggs at all, the fish had not spawned, and was thus suitable for use in the egg production study. That this assumption may be correct is suggested by the collection made in the Muskegon River on April 12. Thirteen fish were originally included among those selected for egg counts. They were placed in a live box, held for several hours, and then transferred by tank truck to a hatchery, for dissection. Although the fish had shown no sign of ripening at the time they were selected, two of

these were releasing eggs freely upon arrival at the hatchery. The contents of the ovaries of both fish consisted of a fluid mass of eggs. Upon removal from the fish and lateral puncture of the ovary wall, the contents poured out of the opening until the pressure within had become quite completely dissipated. It seems apparent that in pikeperch the eggs ripen within a short period of time once a certain point in development is reached and all of the eggs are prepared for spawning simultaneously. This conclusion is substantiated by comparison of egg production based on spawn-taking operations and that based on ovary counts. These methods reveal no consistent discrepancies in estimates which could be attributed to circumstances involving the release of only a portion of the eggs when pikeperch are stripped.

Because of the high fecundity of the pikeperch the time required to determine egg production by actual count is prohibitive, and some method of sampling is desirable. The weight-method was used. As employed it involved taking the weight of the complete ovary and then the weight and count of transverse discs of varying widths. Direct computation then gave the estimated count. To test the accuracy of this method complete counts were tabulated for six specimens after the estimated counts had been computed. In order to determine whether or not samples from diverse sections of the ovaries would result in different estimates, from one to six samples were taken from various loci (Fig. 42). Sample No. 1 was taken in the portion of the left ovary anterior to the vent; No. 2 was taken from the middle of the left ovary; and No. 3 was taken from a point near the anterior end of the organ. Sample Nos. 4, 5 and 6 were taken at the same points, respectively, in the right ovary. Weights of both the ovaries and the samples were obtained to the nearest 0.01 gram on a chemical balance after

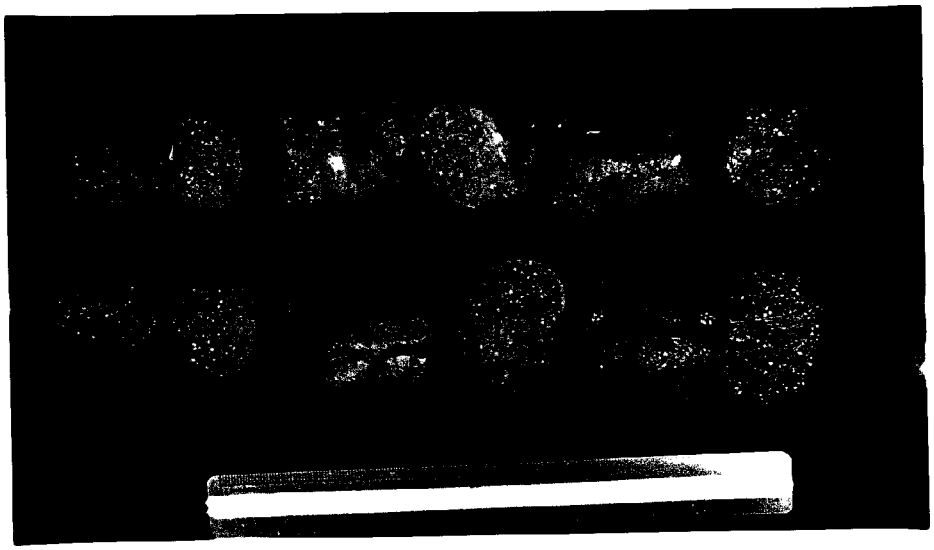


Fig. 42. Ovaries of a yellow pikeperch, divided into sample portions upon which estimates of total egg numbers were based. The sections shown in transverse view were the samples used.

surface moisture had been removed by blotting followed by several minutes exposure to the air.

The results of the counts and estimates made are shown in Table 17. Weights of the samples ranged from 3.0 percent to 9.8 percent of the total weight of the ovaries. Errors in estimate ranged from minus 9.4 percent to plus 4.4 percent; the average error of the estimates for the 27 observations was minus 0.86 percent. Samples 2 and 5, taken from the middle of the ovaries, gave somewhat better results than the other areas, with a range of from plus 4.4 percent to minus 5.1 percent, and an average error of minus 0.38 percent. Therefore, the samples for the remainder of the study were taken as transverse discs from the middle of the right ovary and ranged from 2.7 percent to 5.7 percent (average - 3.9 percent) of the total weight.

The results of the counts and calculations are shown in Table 18. The specimens are segregated as to source, a division which serves also to divide them roughly into size groups, since the Muskegon River fish collected were intermediate in size between those from Lake Gogebic and those from Saginaw Bay.

In Lake Gogebic, 34 pikeperch ranging in total length from 16.0 to 22.7 inches yielded from about 37,000 to nearly 155,000 eggs per fish. Fluctuation in number of eggs per female was great in each size class. In the 20-inch group it was particularly large, the estimate for the heaviest producer (of five specimens) being more than twice that of the fish with the fewest eggs. The estimated totals were 151,579 and 71,270 respectively. The estimated average production of eggs per pound of fish was reasonably uniform, fluctuating between the limits of 26,010 and 30,472. As a grand total for the 34 specimens from Lake Gogebic, 88.8 pounds of fish yielded an estimated 2,531,086 eggs, or an average of 28,503 per pound of fish.

Table 17. Percentage of error in estimating numbers of eggs in pikeperch ovaries by counts of weighed samples.

Specimen number	Weight of ovaries, grams	Sample number	Percentage of weight of ovary in sample	Number of eggs in sample, by count	Estimated number of eggs in ovaries	Number of eggs in ovaries, by count	Percentage error
1	184.29	1	3.294	2,366	71,828	72,252	-0.59
		2	5.084	3,711	72,994		+1.03
		3	4.748	3,352	70,598		-2.29
		4	5.041	3,676	72,922		+0.94
		5	5.795	4,200	72,476		+0.31
		6	6.403	4,548	71,029		-1.69
5	93.70	1	5.660	2,668	47,138	48,507	-2.82
		2	6.840	3,370	49,269		+1.57
		3	6.486	3,061	47,194		-2.71
		5	7.665	3,535	46,119		-4.92
		6	5.896	2,811	47,676		-1.71
8	167.10	1	9.814	5,137	52,344	52,921	-1.09
11	114.55	1	6.635	3,384	51,002	53,116	+3.98
		2	7.246	4,018	55,451		+4.40
		3	6.722	3,635	54,076		+1.81
18	264.45	1	3.290	2,964	90,091	99,477	-9.44
		2	3.006	2,969	98,769		-0.71
		3	3.214	3,002	93,404		-6.10
		4	3.006	3,004	99,933		+0.46
		5	3.290	3,286	99,878		+0.40
		6	3.316	3,133	94,481		-5.02
24	158.30	1	3.917	2,731	69,722	67,879	+2.72
		2	6.241	4,021	64,429		-5.08
		3	4.308	2,960	68,709		+1.22
		4	4.251	2,901	68,243		+0.54
		5	3.759	2,544	67,678		-0.30
		6	3.146	2,173	69,072		+1.76
	Average		5.114				-0.86

Table 18. Production of eggs by pikeperch in Michigan.

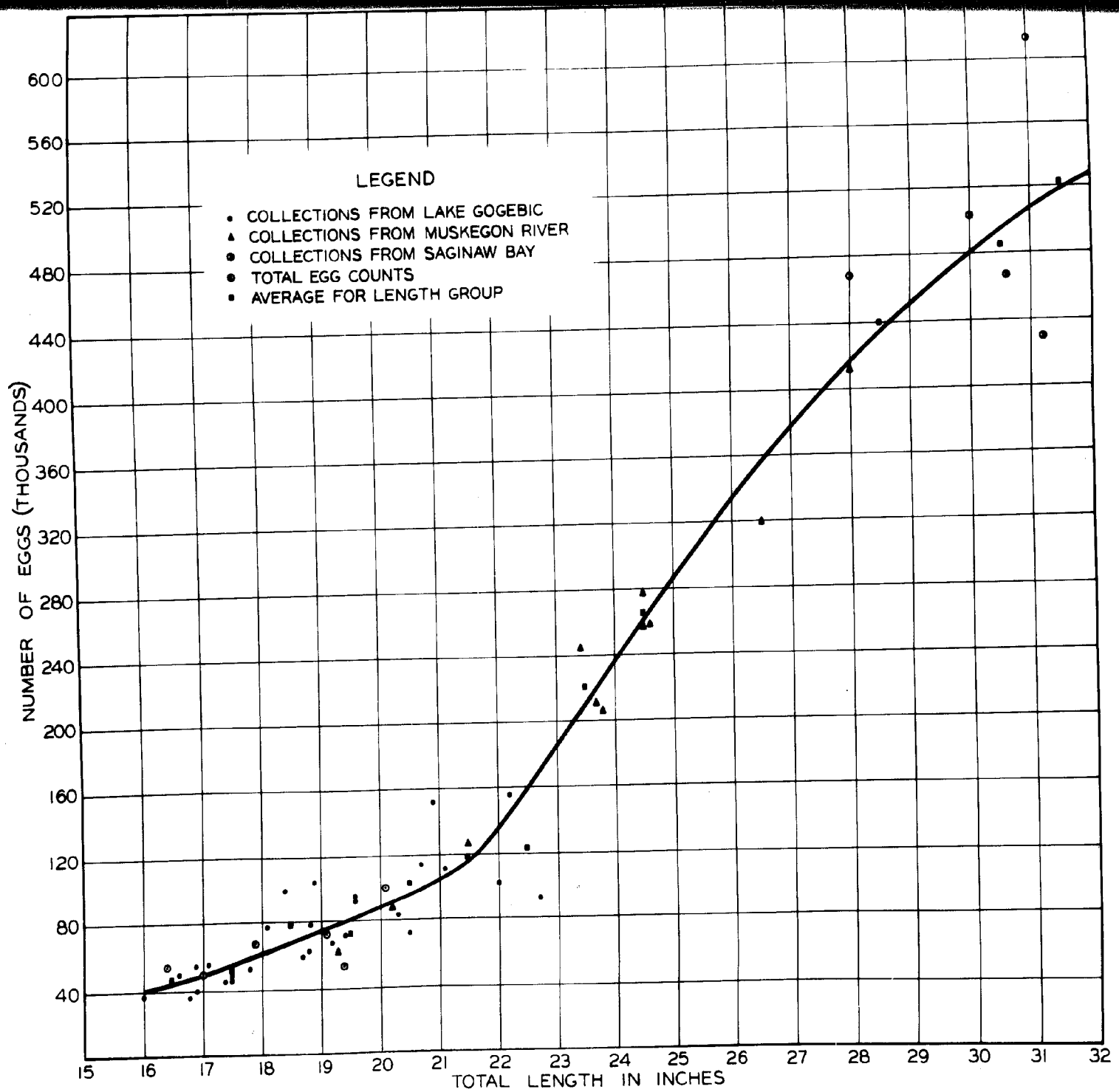
Source	Number of specimens	Length class	Average total length	Number of eggs			Average weight of fish, pounds	Number of eggs per pound of fish
				Minimum	Maximum	Average		
Lake Gogebic	6	16.0-16.9	16.6	36,871	53,970	44,854	1.7	26,385
	7	17.0-17.9	17.5	44,618	67,879	52,020	2.0	26,010
	6	18.0-18.9	18.6	57,816	102,811	79,227	2.6	30,472
	6	19.0-19.9	19.4	52,921	92,795	74,392	2.8	26,569
	5	20.0-20.9	20.5	71,270	151,579	103,574	3.4	30,463
	1	21.0-21.9	21.1	110,571	110,571	110,571	4.0	27,643
	3	22.0-22.9	22.3	91,349	154,906	115,888	4.1	28,265
Muskegon River	3	19.3-21.5	20.3	60,788	126,202	91,397	3.0	30,632
	3	23.0-23.9	23.6	206,596	244,177	220,589	5.1	43,253
	3	24.0-24.9	24.5	257,816	277,172	264,373	6.1	43,340
	2	26.5-28.0	27.3	320,241	412,246	366,244	8.4	43,600
Saginaw Bay	5	28.0-31.2	30.2	428,885	615,166	495,834	11.9	41,667

In the collection of fish from the Muskegon River, a pronounced and stable increase in egg production was observed. Although the production of three fish between 19.3 and 21.5 inches in length was reasonably close to that for fish of similar size in Lake Gogebic, it jumped to over 43,000 eggs per pound in the 23-inch class, and remained near this figure among the larger size classes. This figure was close to that attained by fish from Saginaw Bay, five of which produced nearly as many eggs (or an estimated total of 2,479,169) as the 34 fish from Lake Gogebic, at the rate of 41,667 eggs per pound of fish.

The egg counts are plotted in Figure 43. A curve has been drawn by inspection, to indicate average production, but it is not certain that counts from collections in three localities may properly be shown on the same graph. There are insufficient data in various size groups from each locality to warrant a conclusion that Great Lakes fish (from Lake Michigan, via the Muskegon River, and Saginaw Bay) produce larger numbers of eggs per pound than do those of the same size in Lake Gogebic. The fact that the three fish from the Muskegon system, averaging 20.3 inches in length, had an egg production comparable to that of Lake Gogebic fish is also insufficient evidence to conclude that increased production is based on size alone. The data strongly suggest that either locality or increasing size (over about 23 inches in length or 5 pounds in weight) are associated with an increase in egg production of about 50 percent per pound of fish.

Estimates of egg production in pikeperch appearing in the literature have not, insofar as is known, taken into consideration the number of eggs remaining in the ovary after spawning has been completed (except insofar as these have not been included in estimates based on spawn-taking). In view of the wide variation in the number of eggs present in the ovaries of fish

Fig. 43. Egg production of yellow pikeperch in Michigan (see text for discussion).


LEGEND
COLLECTIONS FROM LAKE GOGEBIC
COLLECTIONS FROM MUSKEGON RIVER
COLLECTIONS FROM SAGINAW BAY
TOTAL EGG COUNTS
AVERAGE FOR LENGTH GROUP
NUMBER OF EGGS (THOUSANDS)
600
560
520
480
440
400
360
320
280
240
200
160
120
80
40
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
TOTAL LENGTH IN INCHES

of equal length or weight, and the relatively few eggs retained in the ovaries after spawning, it is of little importance that they be considered in any practical approach to problems of egg production. However, their occurrence in small numbers has already been noted (Fig. 33).

The examination of the spent ovaries of 29 pikeperch collected at Lake Gogebic between May 16 and August 26, 1947, reveal that the resorption of eggs may be either a rapid or a slow process, probably depending in part on the location of the eggs within the ovary after spawning has been completed.

The promptness with which resorption begins to occur cannot be judged accurately from the specimens at hand because of the uncertainty as to the date or dates that a given fish spawned. Fish collected for counts of residual eggs were not taken at the spawning beds because there was no assurance that these fish, although they appeared spent, were entirely through spawning. The seven specimens taken in May were collected after the fish had left the spawning beds and traveled at least three miles, to the south end of the lake. Notes on the counts made in ovaries of these fish, as well as certain others collected later in the season are brought together in Table 19. It was soon realized, as the ovaries were being examined, that the counts might not be complete because some eggs, even in two fish occurring in the earliest collections, appeared only as tiny orange or whitish flecks in the ovarian tissue, and one could scarcely avoid being convinced that resorption of some eggs had proceeded to a point where they could no longer be distinguished.

Over 800 eggs, in various stages of resorption, were found in one ovary of a fish collected on May 16, in addition to 15 eggs, which showed no sign of such action, lying loose in the lumen. The resorption was far advanced in some eggs and it appeared that an undetermined number already had been

Table 19. Notes on the number and nature of residual eggs in ovaries of spent pikeperch, Lake Gogebic, 1947.

Date	Total length	Weight, pounds	Number of eggs	Remarks
May 22	15.6	1.1	239	All but 21 normal in appearance; absorption not far advanced.
20	16.6	1.4	97	Very few eggs in advanced state of resorption.
20	17.9	2.3	116	Plus many eggs in advanced stages of resorption.
19	19.3	2.4	74	No evidence of advanced resorption.
17	19.5	2.6	146	Count is for one ovary only; believed to be nearly complete.
20	19.7	2.3	165	No evidence of advanced resorption.
16	19.7	2.1	831	Count is for one ovary only; the other is similar. 12-15 unresorbed eggs in lumen of each ovary; remainder buried in ovarian tissue and partly resorbed.
June	16.1	1.4	200	Count is for one ovary only; many in advanced state of resorption.
23-26	16.1	1.3	66	Plus many partly resorbed.
	16.7	1.5	16	Free in lumen; others nearly resorbed.
	16.8	1.5	64	No evidence of resorption noted.
	17.0	1.5	35	Plus many in various stages of resorption.
	17.0	1.5	112	Mostly eggs buried in ovarian tissue, but no advanced resorption.
	17.2	1.8	57	None showing advanced resorption.
	18.0	1.9	60	Eggs hard and well-formed.
	18.1	1.8	"few"	Plus many nearly resorbed.
	18.1	2.0	9	Plus many nearly resorbed.
	18.2	2.0	38	Unresorbed.
	18.3	1.9	86	Plus many nearly resorbed.
	18.7	2.0	43	Plus some nearly resorbed.
	19.8	2.6	78	Plus many nearly resorbed.
	22.1	4.1	51	Unresorbed.
July 9	18.1	1.9	19	Plus many nearly resorbed, buried in ovarian tissue.
9	18.6	2.1	25	Eggs counted barely recognizable as such, nearly resorbed and appearing as discolored spots in ovarian tissue.
August	17.3	1.9	"few"	Located near the vent.
	17.3	1.7	15	(Approximately) in one ovary (see Fig. in text).
20-26	18.2	2.1	10	Located near the vent.
	19.5	2.5	7	
	No residual eggs in other specimens examined.			
October				
14-22	No residual eggs seen in 22 specimens examined.			

completely resorbed. The second ovary closely resembled the first, although counts were not made. It may be assumed that approximately 1600 residual eggs had been left in the ovaries. This was by far the largest number found in any ovary examined. At an average production of 28,500 eggs per pound of fish, as determined for Lake Gogebic, this fish may have developed about 70,000 eggs in its ovaries. The residual eggs thus amount to about 2.2 percent of the total. In other fish examined, this percentage was far smaller.

The resorption evident in the ovaries discussed above had presumably taken place within a period of 8 days or less, since spawning had scarcely begun by May 8 (p. 58). This suggests that the process may begin immediately after spawning has taken place, or perhaps even before it has been completed. Conceivably some eggs might be trapped in the ovary as it contracted while spawning progressed, and would begin being resorbed before the last eggs had been deposited by the fish. In any event, the resorption of some eggs, especially those buried in the ovarian tissue, is quite rapid, whereas others, lying free in the lumen, may persist for months (see below).

Counts made in five ovaries in May are believed to be quite complete. In other words, resorption was not sufficiently advanced to lead one to believe that some eggs had already disappeared. Assuming an average production of eggs per pound of fish in each of the specimens, the percentage of the total production retained in the ovaries amounted to 0.6 percent, 0.2, 0.1, 0.2 and 0.3 percent, or an average of about 0.3 percent for the group. The figures suggest that in most Lake Gogebic pikeperch, the residual eggs present after spawning amount to less than one percent of the total production.

Ovaries taken after May are not considered suitable for determination

of number of unspawned eggs because of resorption (see remarks in Table 19).

Egg counts in late June and early July show that moderate numbers of eggs remained in the ovaries, ranging from very few to possibly 400 or more. The average number was lower than that occurring in May, as is revealed by inspection of Table 19. Some eggs remained in the ovaries at least until late August, as has been mentioned earlier (p. 91; Fig. 34), but they were few in number and probably did not occur in all fish which spawned during the preceding spring. New eggs were being formed in the ovary, and the remnants were hardened, distorted in shape, and dark orange or brown in color. In two of the ovaries examined the residual eggs occurred at the junction of the two ovaries in the immediate vicinity of the vent. Whether they are finally resorbed, or are expelled, is not known, although the first alternative seems the more likely. It does not appear that pressure could be brought to bear to move them out of the ovary. This is particularly true in the case of one of the other ovaries, in which the eggs were located far forward. In any event, the eggs of the previous spring are believed to be gone from the ovaries by late October, for an examination of 22 specimens at this time revealed no trace of residual eggs.

To summarize, there is a wide variation in egg production among fish of similar size. In Lake Gogebic, fish ranging from 16.0 to 22.7 inches in length yielded an average of 28,503 eggs per pound of fish. For larger fish from the Muskegon River and Saginaw Bay, the average production was over 41,000 eggs per pound of fish. Residual eggs averaged 0.3 percent of the total estimated egg production in 5 out of 6 Lake Gogebic pikeperch examined after the spawning season. They decreased in number with the progress of the summer, and none was observed in females collected in October.

Pikeperch eggs on the spawning grounds

As is well known, pikeperch generally broadcast their eggs and exercise no parental care. The eggs ordinarily lie loose upon the substratum, and live adhesive or adhering eggs have been seen infrequently at Lake Gogebic. Reighard (1890) stated that when first laid the eggs are very adhesive, and added (1893 a) that for the first hour or two the eggs adhere to one another and to the vessel which contains them. He regarded adhesion as due to the action of water on the outer egg membrane, which behaves in this respect like other mucous bodies. He further indicated (1893 b) that adhesion is at first slight, but that after one-half hour it becomes so great that the egg is likely to burst if removed. Water then hardens the external egg membrane and it loses its adhesive qualities. Reighard's findings suggest that the reason for the few observations of adherent eggs at Lake Gogebic is due to the fact that most collections were made several hours after spawning had occurred. When egg collections were made immediately after spawning acts were observed, no adhesive eggs were seen. However, they were not sought specifically.

On April 30, 1941, an attempt was made to determine the number of eggs deposited on a portion of the spawning beds overnight. The rubble and coarse gravel were carefully removed from an area along the shoreline on which a number of pikeperch had been seen during the previous night. A substratum of fine gravel and sand was exposed. Over this was spread a length of cheesecloth which covered an area of 28 inches by 82 inches. The rubble was carefully replaced, so that the cheesecloth was concealed. Water covered the plot at depths of from 2 to 6 inches. On May 1, after a calm night had intervened, the rubble was carefully removed, piece by piece.

Many pikeperch eggs were found to be present, lying loosely among the stones which had covered the cloth. None was adhesive. A count revealed a total of 9,050 eggs. These had been deposited at some time between 7:30 p.m. and 5:00 a.m., which were the hours when the net was laid down and lifted, respectively. Water temperatures on the shoals ranged from 47 degrees F. to 50 degrees F. during the night.

The percentage of fertility was not determined for this sample, but repeated attempts were made at later dates to obtain a collection which might be used for this purpose - all proved fruitless. Twenty plots, each two square yards in area, were laid out in 1942, and 10 in 1947, but no satisfactory sample of eggs was collected. Providence was indifferent about making identical the spawning areas chosen for the pikeperch by the writer for any given night, and those chosen by the pikeperch themselves. Plots left for longer periods were frequently torn up or buried by fine gravel and sand during periods of severe wind. Also, dead eggs from other areas were washed in upon the plots, and the value of collections was obscured.

Samples of eggs collected with a scap net on the spawning grounds, as described earlier (p. 21), contained four classes of eggs (Fig. 44) which could be readily differentiated. All four were found within about a week after spawning began, and were present in large numbers after the peak of the spawning season arrived.

Viable eggs are easily recognized since they are hyaline, turgid, and the developing embryo can be clearly seen.

Egg shells, though more difficult to detect than entire eggs, are often present. It is probable that some of these arise from causes other than the escape of an embryo at the time of hatching. They have been found on the spawning beds before hatching is believed to have occurred and when viable

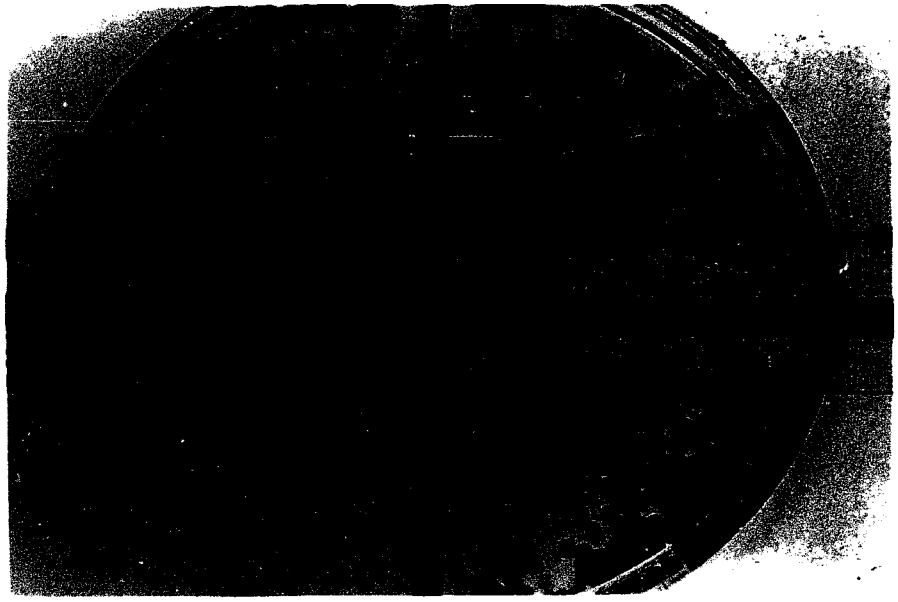


Fig. 44. Pikeperch eggs occurring on the spawning grounds at Lake Gogebic, May 21, 1947. Upper right: dead, heavily-fungused eggs. Lower right: infertile and dead eggs which have not yet been attacked by fungus. Lower left: egg shells, resulting from hatching and from unknown causes. Upper left: hyaline viable eggs.

eggs collected at the same time were not in advanced stages of development. Those which result from hatching and those resulting from unknown causes are difficult to differentiate.

Dead and infertile eggs are opaque and appear as various shades of white and gray. They have not reached the fungused stage described below, and thus are probably of more recent deposition.

Eggs which have been dead for some time are covered by a thick mat of fungus. They are essentially white in color and are often misshapen and soft. Frequently, particularly after mid-spawning-season, such eggs are attached to each other in groups of from a few to several hundred. These then adhere as a layer over the unexposed surfaces of rocks. The presence of a pikeperch spawning area can often be detected by examining the undersides of rocks; if fungused eggs are present, viable eggs can usually be collected near-by.

To obtain data on egg fertility, several samples of eggs were secured by passing a scap net through a previously roiled area, as described earlier. Whether or not the method results in the collection of unrepresentative numbers of any of the four classes of eggs present is not known, and the method has not been adequately tested. The specific gravity of viable eggs is close to that of water, however, and one is led to believe that vigorous disturbance of the bottom followed by immediate use of the scap net should collect living and dead eggs which are lying loose on the bottom in proportion to their abundance on the area sampled. Some fungused eggs, however, adhere tightly to the rocks, and are not subject to such sampling. Waves are constantly washing eggs about - particularly dead ones - and whether a given sample is taken in a spot where such eggs are present in either above-average or below-average numbers is largely a matter of chance.

There arises the problem of whether egg shells should be considered as viable or dead, since they may originate from either type of egg. As is shown below, a high degree of variability exists in the percentage of fertility among eggs located in adjacent sample areas, and the percentage changes likewise with the progress of the season. A large number of egg collections, made during calm nights by spreading cheesecloth or screen as described earlier, and held until viability can be determined, seems called for to ascertain accurately the percentage of fertility in naturally spawned eggs. This has not been done, but the available data on other collections are presented with the hope that they may be evaluated by the reader in the light of the above remarks.

A sample of 3,781 eggs was collected south of Six Mile Bay (near station C, Fig. 18), at Lake Gogebic, on May 21, 1947, in water from 12 to 18 inches deep. Of these, 2,191 (58 percent) were dead (either fungused, white, or gray); 289 (7.6 percent) were shells; and 1,301 (34.4 percent) were viable. In a second sample of 10,712 eggs collected on May 25, at Six Mile Bay, near station E, 4,344 (41.5 percent) were dead; 480 (4.5 percent) were shells, and 5,888 (55.0 percent) were viable. If shells are not divided, but are considered with the dead eggs, the combined samples from Lake Gogebic show an average viability of 50 percent.

A sample of 1,945 eggs from Cisco Lake, Gogebic County, collected on May 21, 1947, revealed 1,462 (75.2 percent) dead eggs, 157 (8.1 percent) shells and 326 (16.7 percent) viable eggs.

A collection of 279 eggs was made at Big Portage Lake, Jackson County, on April 10, 1946. Of these, 77 (27.6 percent) were dead and the remainder (72.4 percent) were viable. No fungused eggs were seen. This collection was brought into the laboratory and placed in a test tube filled with lake

water. Bubbles from an air outlet in the tube agitated the eggs and aerated the water, and an improvised water jacket on the outside of the tube kept the contents at a temperature of 62 degrees F. The eggs began hatching by the afternoon of April 15. A total of 194 (69.5 percent of the sample and 96.0 percent of the viable eggs) hatched.

An examination of the shoreline of Cisco and Thousand Island Lakes, Gogebic County, on May 14, 1948, revealed a large number of eyed eggs and very few which were dead. Dr. E. W. Roelofs, formerly a member of the staff of the Institute for Fisheries Research, reported (unpublished) that pike-perch eggs were found along the shoreline of Gulliver Lake, Schoolcraft County, on April 21, 1942. On another visit, on May 5, he found a much smaller number of eggs, but all were eyed, and no infertile eggs were found. Twenty-four eggs placed in a two-quart jar hatched within a period of two hours. The observations at the Gogebic County lakes and Gulliver Lake suggest that in at least some lakes, under certain situations, many of the dead eggs originally present on the spawning beds are destroyed or are removed before hatching of viable eggs, or at least before hatching is completed. Thus proportionally fewer dead eggs are likely to occur on the beds late in the season than earlier, and counts made late in the season give a distorted picture of natural fertility.

That some lots of eggs may have a markedly lower fertility (or viability) than others is indicated by observations at Lake Gogebic on May 9 and 12, 1948. Unusual concentrations of dead eggs, adhering to the substratum, were noted. The areas of such concentrations were from 2 to 4 feet across. Along 150 linear feet of shoreline in the Six Mile Bay area, where the incidence of such groups was exceptionally high, no less than 80 clusters of dead eggs were observed. They were found in water ranging from 3 to 19

inches in depth, which averaged 8.5 inches. All eggs adhered to the stony bottom. In a given group the eggs were of the same color and apparently in the same stage of decay, although the decomposition varied among groups. In the more recently deposited groups, eggs were marked by only a single white spot; in others the entire egg had become milky white (Figs. 45 and 46); and still others had already become fungused (Fig. 47). Based on partial counts, several of the areas contained in excess of 5,000 eggs each. Cursory inspection of a sample of an estimated 20,000 eggs taken from these areas revealed only 8 which were viable, and these may have been included accidentally from outside the group which was being examined. Between the areas of concentration of dead eggs the percentage of viable eggs was estimated at about 50.

The appearance of the groups of eggs, particularly with regard to their restricted distribution and stage of decay strongly suggested that the eggs in each group had been deposited at the same time by a single female, or by a single group of spawning fish. In view of the large number of aggregations of dead eggs, a general broadcasting of eggs, as seen in the observation of spawning during daylight hours (p. 30) possibly occurs less commonly than spawning involving only a minimum of movement along the breeding area, such as the movement of the group in concentric circles (p. 33). It should be noted that the concentrations of dead eggs, being white, were conspicuous, whereas similar aggregations of viable eggs would be difficult to locate.

The reason for this unusual egg mortality, not otherwise observed by the writer, is not known. It is not certain that the eggs were infertile, as they may have died from unknown causes after fertilization. Cobb (1923) reported that females which sometimes "throw" their eggs at the surface of a stream are not always accompanied by males. This would seem unlikely in

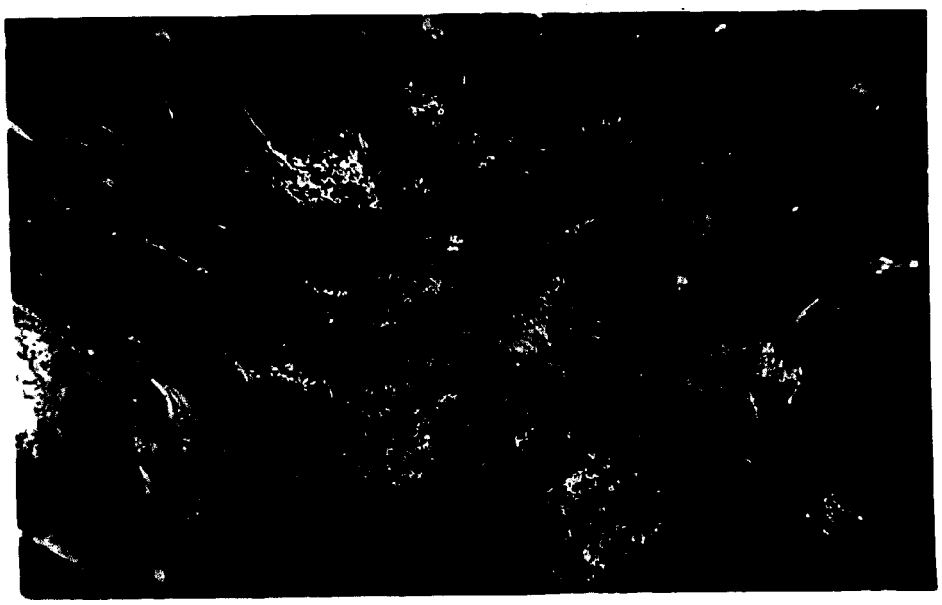


Fig. 45. Dead pikeperch eggs on the spawning grounds at Lake Gogebic, May 12, 1948.

Fig. 46. Dead pikeperch eggs adhering to stones which were removed from the spawning beds at Lake Gogebic, May 12, 1948.

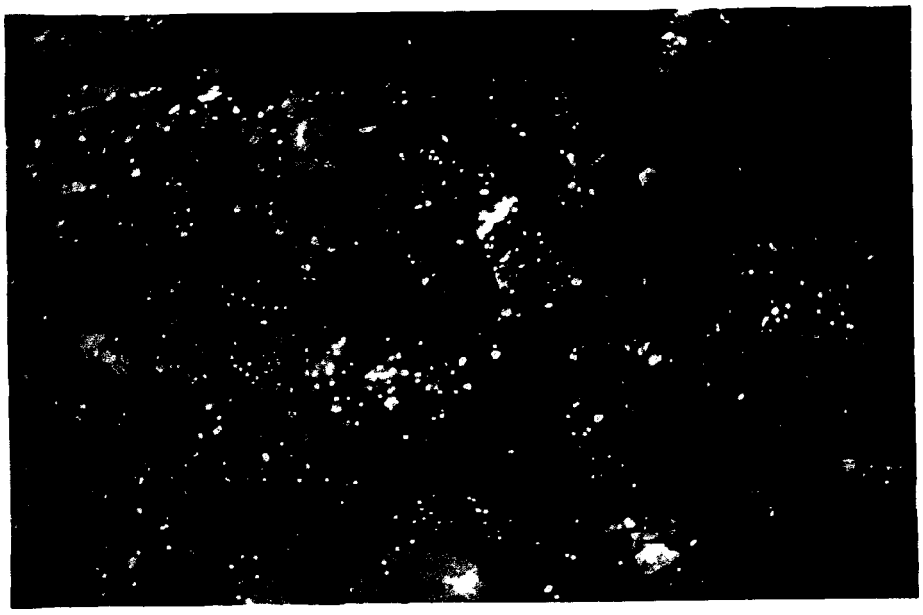


Fig. 47. Fungused pikeperch eggs on the spawning grounds at Lake Gogebic, May 12, 1948 (see text for discussion).

Lake Gogebic, in view of the predominance of males on the spawning beds throughout the 1947 season. For the present the causes underlying the occurrence at Lake Gogebic remain unexplained, and it is merely recorded that in this instance, large groups of eggs, laid at about the same time within a small area suffered a complete or nearly complete mortality.

With regard to the observations of others on pikeperch egg fertility, it may be noted that in hatcheries in the Great Lakes region about 45 percent of yellow pikeperch eggs hatch (Van Oosten, 1937). Fertility percentages given for individual batches of hatchery eggs by various writers range from 10 to 90 percent. Viability in natural waters has not been reported by others. Bean (1903) and Goode (1903) said merely that in a state of nature only a small percentage of the eggs are hatched and that the greater proportion are driven onto the lake shores by storms or are devoured by fish on the spawning beds. Davis (1949) stated that examination of eggs deposited on the spawning grounds revealed that a large percentage of eggs (no further data) had been fertilized.

Observations made at Lake Gogebic indicate that dead eggs are commonly moved and sometimes transported for considerable distances by waves and currents, although windrows of eggs have not been seen. On April 27, 1942, only a few days after spawning is thought to have begun, a severe storm arose while the writer was near the middle of the spawning area, along the east shore. During the storm, a small-meshed scap, 8 inches by 11 inches in size, was held just below the surface of the water, near shore, and the crest of a wave was allowed to wash through it. Inspection revealed that it contained three pikeperch eggs. The procedure was repeated 41 times. On 36 of these, pikeperch eggs were collected, ranging from 1 to 7 in number, and averaging 2.4 per 'dip.' Both translucent (viable?) eggs and opaque

eggs were present, the latter predominating. On May 1, a very slight wave action was sufficient to bring large numbers of pikeperch eggs into suspension. Nearly all of these were dead. It appeared that dead eggs were more readily moved by waves than were viable ones. Large numbers of dead eggs were observed in the northeast end of Six Mile Bay on May 22. Spawning is not believed to have occurred in the immediate vicinity and the presence of wave-washed debris with the eggs suggested the nature of their origin. Only dead eggs were found. That the occurrence of such eggs in this area is not uncommon is suggested by an observation in late May, 1947, when the same condition prevailed.

It is of interest to note that wind in unusual instances acts to destroy small numbers of pikeperch eggs. During nights when there is considerable wind, waves sometimes wash spawning pikeperch over or near the tops of boulders which are exposed during calm weather and between wave crests. Occasionally eggs are washed into contact with these surfaces, apparently at the moment of oviposition, and become firmly attached there. On the night of May 1, 1942, pikeperch were congregated in large numbers near shore. Waves washing onto the shoals moved them sidewise several inches to a foot or more, but they gently coasted with the wave and continued swimming leisurely along in their usual manner. On the following day recently deposited pikeperch eggs were found adhering to portions of rocks which were above the surface of the water. Seventeen eggs were counted on the exposed portion of one such rock, and 27 on another. All adhered strongly to the rock surface. No change in water level had occurred just prior to the observations, and the rocks had not been moved out of position. This occurrence appears not to be common, and was not observed in 1947 or in 1948.

As has been mentioned above (p. 87), few fish are associated with pikeperch on the spawning grounds during the spawning season, and no loss of eggs by predation was observed at Lake Gogebic. Although pikeperch exercise no parental care as such, the proclivity of some males to linger on the spawning beds in Lake Gogebic for a period of many days after the peak of the spawning season probably serves to protect the area during the period of occupancy. It is expected that potential egg predators (e.g., forage fishes) would avoid areas frequented by even a few pikeperch moving along the spawning area. During the day, pikeperch which frequent the shoals at night probably lie in deeper water, just off the beds, so that approach to the shoals is potentially cut off during this period as well. Most if not all of the eggs are hatched by the time the last few males leave the spawning beds at Lake Gogebic.

In other waters, freedom from predators is not always characteristic of conditions prevailing on the spawning beds. Bean (1903) stated that eggs may be devoured by fish on the spawning grounds and added (1912) the observation that a spawning stream at Constantia, New York, was filled with small perch and minnows which fed on pikeperch eggs and fry. He believed that the percentage which escaped these depredations was small. Goode (1903) mentioned the destructive inroads of sturgeon, catfish and suckers upon the pikeperch spawning beds. Cole (1905) advanced the dubious hypothesis that carp might easily affect pikeperch in cases where the eggs are attached to water plants. Cobb (1923) claimed that pikeperch eggs are eaten by suckers at night, although he gave no evidence of this other than the disappearance of accumulations of eggs and the presence of suckers in the area. Adams and Hankinson (1928) referred to an abundance of small fish in Oneida Lake which ate pikeperch eggs.

Pikeperch eggs are not deposited at all under some situations. Eschmeyer (1942) observed that many pikeperch did not spawn in 1940 under conditions which appeared to be favorable. Numerous females examined in Norris Reservoir in June and July were still carrying mature eggs. Derback (1947) reported that stream-migrant pikeperch which encountered cold weather during the spawning season returned to the lake and did not reappear at the spawning grounds in tributary streams. Subsequent fishing in the lake in June yielded some females which were resorbing their eggs.

In summary, soon after spawning begins at Lake Gogebic, four types of eggs are recognizable on the spawning grounds: viable eggs containing embryos; egg shells; opaque white or gray dead eggs; and fungused eggs. Percentages of viability in egg collections made in three lakes during the spawning season ranged from 17 to 72 and averaged 50 for two samples from Lake Gogebic. Waves and currents transport pikeperch eggs for considerable distances. Loss of eggs by predation is believed to be of negligible importance in the economy of Lake Gogebic pikeperch.

Behavior, growth, and food during the first summer of life

The time required for hatching of yellow pikeperch eggs has been observed to be 7 days at 57 degrees F., 18 to 20 days at 48 degrees F., and 28 days at 40 degrees F. (U. S. Commission of Fish and Fisheries, 1903, and Leach, 1927).

Embryos move freely in the egg shell and can be seen moving about for a period of several days before hatching. At the time of hatching the tail and body are freed first and the fish swims about for a time with the head enveloped in the egg membranes. Considerable effort is sometimes required

for the fish to complete its release from the shell. Among eight fish which were collected as eyed eggs at Lake Gogebic and placed in a quart jar for observation, from one to seven minutes was required to effect such escape. After loss of the shell, the fish comes to the surface of the water, becomes quiet, and sinks. It may rest quietly for a time and then repeats this activity. Ryder (1883) reported that the pectoral fin with its supporting rays and the median fin folds are present at the time of hatching, an observation made also by Reighard (1890) and Fish (1932).

The movements of pikeperch immediately after hatching and for a period thereafter are not well known. Cheney (1897) believed that after hatching the brood remains together for the first season if not destroyed, making a solid, compact mass during the first two weeks. Bajkov (1930) said that the fry usually school in comparatively shallow places. Dymond (1926) reported that young pikeperch occur on a sandy bottom, associated with tessellated darters, perch, and young common suckers. Adams and Hankinson (1928) frequently took young pikeperch one to two inches in length, but they were not found in numbers at any one place. Those collected were from shallow water, over clean rocky or sandy bottom, and seemed to belong to a rather definite fish association which contained tessellated darters, zebra darters, cyprinids, and, usually, barred killifish, young perch, and white suckers. Greeley (1929) seined young at numerous localities along lake shores and in the Niagara River, and found them more common in sheltered areas than in exposed places. Raney and Lachner (1942) found young pikeperch in water from a few inches to two feet in depth during the first two weeks in July. By the first week in August it was necessary to seine in weed beds in about four feet of water to take them. Movement toward deeper water continued with the progress of the summer and the fish were taken in from 10

to 12 feet of water during September and October.

At Lake Gogebic, pikeperch were observed hatching on May 21, 1942. On the spawning beds, movements of the fry were difficult to observe because of their very small size. One was observed to spiral up from the bottom, reach the surface film, and then drop down. Extensive search was made in protected areas near shore, but no fry were seen. One was observed about 20 feet from shore, swimming vigorously just below the surface. Four which had hatched in a jar were released at a point about 3 feet from shore, in water 8 inches deep. One headed out toward open water immediately and two swam about in circles for a few moments and then headed outward and were soon lost from view. The fourth settled to the bottom near shore and was lost.

Repeated attempts to collect fry in the open water of the lake and near shore on later dates were unsuccessful.

To further study the habits of pikeperch after hatching, observations were made at Drayton Plains, Michigan, where an estimated 200,000 fry were stocked in a 7.8-acre rearing pond on April 30, 1946. They had hatched on the previous day.

On May 1, thirteen pikeperch fry were collected in the upper 2 feet of water, in the deepest portion of the pond, where water depth ranged from 3.5 to 4 feet. In making the collections, a fine-meshed scap, 14 inches by 14 inches, was pulled through the water at various points and at different depths, and then inspected for the presence of the tiny fry. Although considerable effort was expended in the attempt, no pikeperch were collected along the shoreline or in the shallow half of the pond (about 1 foot in depth), or near the water supply inlet at this end of the pond.

It was observed that pikeperch fry being held in the hatchery for

transport were positively phototropic, a fact long familiar to fish-culturists (Buck, 1911). On May 5, a sealed beam light was placed at a height of about 10 feet above the surface of the deep water of the pond, and directed into it. Fry began entering the illuminated area immediately after dark and as many as 75 at a time were counted during the course of two hours of observation. A light used in a similar manner on May 8 was much less effective in concentrating fry.

In addition to that on May 1, fry collections were made at the pond on May 5, 8, 11, 15, 22, 30, and June 5 and 12. Collections made after May 15 were made with a common sense seine. Sixty pikeperch taken on June 5 averaged 0.8 inch in length.

On May 8 pikeperch fry appeared to be concentrated in water from one to two feet deep, near the shore toward which a steady wind was blowing. Attempts to collect fry near shore on the other dates were either unsuccessful or were markedly less productive than similar efforts in the deepest part of the pond. On May 30, for example, about 50 fry were taken in a single haul through deep water, whereas seine hauls at many points near shore and in the shallow half of the pond yielded not over one pikeperch per haul.

In the light of observations at the hatchery pond, repeated attempts were made to collect pikeperch fry at Lake Gogebic in 1947. On June 2, three fry were collected near the surface, within 20 feet from shore. A spotlight directed at the water from a boat, as well as a submerged light, failed to attract fry when used at various points out in the open water. One fish entered the illuminated area when the light was brought near shore. On June 6, an extensive search along about 50 feet of shoreline where eggs had been abundant earlier, in late May, revealed only two eyed eggs. Hatching appeared to have been pretty well completed. Fine-mesh nets with

diameters of one foot and three feet were towed by a boat equipped with an outboard motor in an attempt to take fry. However, planton (particularly Daphnia) was so abundant that the nets soon became clogged.

On June 8, a collection of fry (not pikeperch) was made in the open water of the lake, with a long-handled dipnet. In this method of collection, the fish were located individually, by sight, from a boat, in perfectly calm weather and bright sunlight, and the net was then plunged down at them. Young of perch, burbot and ciscoes were the only fish taken. Similar collections made in the open water in June of 1941 and of 1947 were found to consist entirely of yellow perch.

The studies at Lake Gogebic and at Drayton Plains hatchery indicate that pikeperch fry do not remain near shore after hatching. Although not substantiated by collections in Lake Gogebic, the suggestion is made that the fry move into the open water of the lake shortly after hatching and lead a pelagic existence until a length of an inch or more is attained. Under the artificial conditions occurring in a holding tank at Drayton Plains, it was observed that the fry sought neither the surface nor the bottom, but remained about 6 to 18 inches below the surface. In the rearing pond, they were taken most frequently in the open water, neither at the surface nor at the bottom. Presumably the tiny translucent fish have a better opportunity to survive under these circumstances than near shore, where small predators (e.g., minnows) are concentrated. Plankton organisms, which constitute the chief food at this stage in life, are readily available in the open water. In this connection Su rber (1929) related that there is no question of the success of plantings of pikeperch fry carried to deep water, but when dumped in still water along shore, they serve merely as a meal for shiners. A pelagic existence and dispersal throughout Lake Gogebic

would also explain their wide distribution, without regard to the location of the spawning beds, when they return to the shoals in late June or early July.

In 1941, pikeperch were first seen in shoal areas on June 25, when two fish, averaging 1.5 inches in length, were taken just south of Six Mile Bay. They were closely associated with perch fry which on this date averaged 1.2 inches in length. Two fish were collected on July 8, and on July 10 a collection of 20 young pikeperch was made. These were found in a small cove, about 200 feet wide at the mouth and extending back from the lake for about 250 feet. This area has a sandy bottom, and was covered with water 2 to 6 inches deep. Several small schools of young perch were observed, each accompanied by one to five pikeperch. These seemed to be participating members of the perch schools, and appeared to be feeding actively with them. They did not come to the surface, as perch sometimes did, but remained close to the bottom. They could be distinguish e d readily from perch by their larger size, lighter color, more translucent bodies, and the absence of cross bands of the perch. When a school fled pursuit, the pikeperch were frequently at or near the head of the group, possibly being faster as a result of their larger size. Each seine haul produced 1 to 4 pikeperch and 10 to 40 perch. No other species was seen.

On this same date, a rather closely grouped school of 14 pikeperch was observed in about 18 inches of water near a dock at the mouth of the Slate River, three miles from the near end of the spawning grounds. There were no perch in the school, although some were near-by. The young pikeperch were moving about in sparse vegetation and remained fairly close together, always reassembling when the school broke into two or three smaller groups for a short time. The school remained within about 25 feet of the spot at

which it was originally seen for a period of several hours. In the same general vicinity there was a school of about 15 to 20 perch, accompanied by 4 pikeperch which showed no disposition to move to the adjacent school of pikeperch. Thus, both pure and mixed schools occurred, at least during early summer. The July 10 collection of pikeperch averaged 2.6 inches in length, whereas 43 perch taken on July 8 and 10 averaged only 1.6 inches.

On August 2, 1941, a haul with a 40-foot seine in about three feet of water, along a sand bar near the mouth of the Slate River, yielded 37 pikeperch associated with young smallmouth bass, perch and suckers, yearling perch, and adult common shiners. The pikeperch averaged 4.1 inches in total length, whereas 34 young perch averaged 2.3 inches in length.

Between October 16 and 21, a collection of 10 young pikeperch was made with a 3/4-inch (bar measure) gill net set in from 4 to 6 feet of water over a sandy bottom with sparse vegetation. Six of the 10 fish had been attacked by larger fish while they were in the net, and 3 adult pikeperch and 3 adult northern pike were caught by the teeth as they attempted to secure the smaller fish (perch and pikeperch). This collection was probably selective for large young, since small specimens were undoubtedly able to pass through the net. The ten fish averaged 6.2 inches in length and 1.1 ounces in weight.

Collections of young pikeperch were made at intervals during the summer of 1947. After repeated futile attempts (June 12, 27, 28; July 2), the first collection was made on July 7, in the identical shallow, sandy cove where young pikeperch were taken in 1941. Twenty were taken. Most of these occurred individually, although several were again seen with schools of perch. One young pikeperch drew my attention because it was swimming upside down. It returned to a normal position from time to time, but was unable to maintain it, turning over onto its back repeatedly, thus causing the fish to

move forward through the water in a spiral. Closer observation revealed the red gills shining through the branchiostegal membranes, suggesting that the mouth was open. The fish was collected and found to be 28 mm. long. In its mouth and throat was a small sucker, 22 mm. in length. Cursory examination of other fish in the collection revealed that some small pikeperch had succeeded in swallowing sucker fry of similar size.

Several additional young pikeperch were taken in the cove on July 8. On July 9, 10 were taken just north of the mouth of the Slate River, over a barren, sandy bottom at depths ranging to four feet. These were associated with yearling pikeperch and with yearling perch.

Thirty-seven young pikeperch taken between July 7 and July 9 averaged 1.2 inches in length; and 27 young perch taken with them averaged 1.0 inches (Fig. 48).

Twenty-five pikeperch collected by L. R. Anderson and A. K. Adams at the same locality on July 25 averaged 2.3 inches in length. Pikeperch were no longer frequenting this barren area on August 8, but 14 (average length 3.3 inches) were collected in a dense bed of submerged pondweeds near-by, in water to three feet in depth, over a sandy bottom. Young pikeperch were taken in the same location from August 18 to 22. Forty-four specimens averaged 3.9 inches in length. A considerable amount of effort was expended in getting this sample of fish, which leads to the observation that young pikeperch have not been collected in large numbers at Lake Gogebic at any time. Compared to young-of-the-year perch, they are scarce in areas where collections have been made. On the basis of such collections alone one might wonder how such a large population of pikeperch is maintained in the lake. Their scarcity may be due in part to the fact that not all young pikeperch frequent the shallow areas, but may occur in much deeper water.

Fig. 48. Living young yellow pikeperch (left) and yellow perch collected at Lake Gogebic, July 7, 1947. Note the lighter color, greater translucency, and absence of vertical bars in the pikeperch. The scale is in mm.

That this is true is shown by the accidental capture of two young pikeperch by entanglement of the canine teeth in large mesh gill nets in August. One of these, 3.3 inches long, was taken near the float line of a 6-foot gill net set about 300 yards from shore, in water 24 feet deep, on August 18. A second, 3.1 inches long, was taken on August 21, near the lead line of a net set in 32 feet of water, also about 300 yards from shore. The stomachs of both contained only Daphnia.

On October 16, 13 pikeperch were collected. The fish were difficult to locate, and only a few were taken at a given location, generally in water as much as four feet in depth, over a sandy bottom. Deeper areas were not sampled.

The growth of pikeperch in Lake Gogebic during the first summer of life in 1941 and in 1947 is summarized in Table 20. It is of interest to note that during 1947 growth was consistently behind the growth observed in 1941. Possibly the late spring of 1947, resulting in delayed hatching, was a factor of significance in this connection. However, growth was probably about the same in 1946 as in 1947, for 21 year-old fish collected on June 20, 1947, before any spring growth had occurred, averaged only 4.8 inches in length, or only 0.1 inch larger than the October 16 collection of young-of-the-year fish. The growing season had probably been virtually completed by late October, so the two figures are comparable. Growth during the first year of life in Lake Gogebic in 1947 is illustrated in Figure 49 by preserved specimens from the various collections. By the end of the first year of life, young-of-the-year can no longer be distinguished with certainty on the basis of length alone because some yearlings are smaller than the largest young fish.

The data presented for growth of young pikeperch compares interestingly with that of Raney and Lachner (1942) from Oneida Lake (Fig. 50). In this

Table 20. The growth of yellow pikeperch during the first summer of life in Lake Gogebic, 1941 and 1947.

Date of collection	Number of specimens	Total length			Average weight, grams	Increment in total length per week (mm.)
		Range	Average, mm.	Average, inches		
1941						
June 25	2	36-40	38	1.5	0.5	...
July 8	2	45-54	50	2.0	1.2	...
July 10	21	56-76	66	2.6	2.5	13.1
August 2	37	91-116	103	4.1	10.0	11.2
Oct. 16-21	10	146-172	157	6.2	32.3	4.8
1947						
July 7-9	37	25-42	31	1.2	0.3	...
July 25	25	46-75	59	2.3	1.9	11.5
August 8	14	65-96	85	3.3	6.0	13.0
August 18-22	44	70-123	99	3.9	9.0	8.2
Sept. 19	1	116	116	4.6	13.9	...
October 16	13	92-176	120	4.7	15.2	2.6

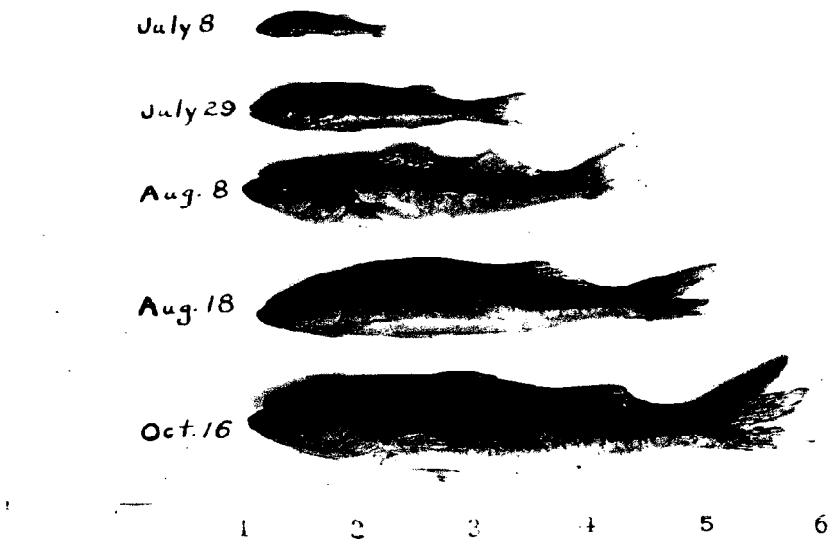
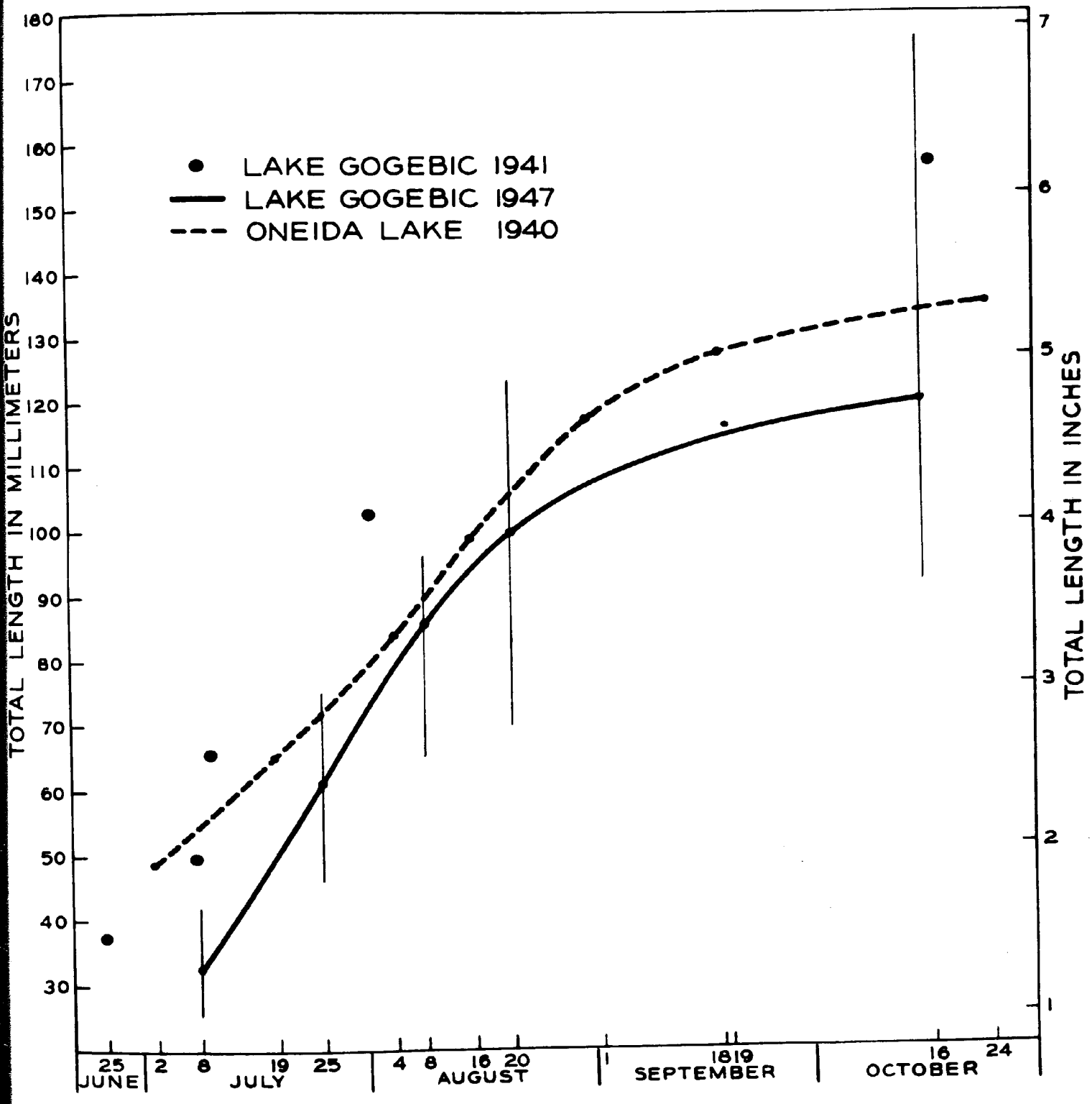


Fig. 49. Growth of young yellow pikeperch in Lake Gogebic in 1947. Specimens represent average sizes in collections made on the dates shown.

Fig. 50. Growth of young yellow pikeperch in Lake Gogebic, 1941 and 1947, and in Oneida Lake, 1940. The curve for Oneida Lake is based on data published by Raney and Lachner (1942).


LAKE GOGEBIC 1941
LAKE GOGEBIC 1947
ONEIDA LAKE 1940
TOTAL LENGTH IN MILLIMETERS
TOTAL LENGTH IN INCHES
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
7
6
5
4
3
2
1
25
JUNE
2
8
19
25
JULY
4
8
16
20
AUGUST
1
18
19
SEPTEMBER
16
24
OCTOBER

water, pikeperch attained an average length of 135 mm. (about 5.3 inches) by October 24, 1940, a size which is smaller than that in Lake Gogebic in 1941, but larger than that for 1947 (and probably also 1946). However, average weekly increment throughout the summer in Lake Gogebic in 1947 was greater than that for Oneida Lake (6.2 and 5.3 mm. respectively). Thirty-seven fish taken from Lake Gogebic on July 7 to 9 averaged only 31 mm. in length, whereas a collection of 104 fish at Oneida Lake on July 2, 1940, averaged 48.2 mm. Average weekly increments were substantially greater at Lake Gogebic than at Oneida Lake during the following several weeks, and by August 20, 44 Gogebic pikeperch averaged 99 mm. in length, and 46 which were collected at Oneida Lake on August 16 averaged the same. From this time until October 24, however, the Oneida Lake fish had a greater average weekly increment than that which accrued to Lake Gogebic pikeperch during about the same period. Comparison of the 1940 year class from Oneida Lake and the 1947 year class in Lake Gogebic shows the rate of growth to be faster in Lake Gogebic, but a longer growing season in Oneida Lake permitted the fish there to realize early and late season advantages, and thus to reach a greater size in the fall.

The early growth of pikeperch has been given less detailed consideration by a number of other workers. Bean (1903) conjectured that the rate of growth must be rapid, and reported that in July, 1888, examples from 4 to 6 inches long were taken, some of which seemed to be young of the year. Forbes (1903) collected a pikeperch in the Illinois River in June, 1870, which was 2 inches long, and another in June, 1878, 2.5 inches long, which were probably young-of-the-year. Adamstone (1922) calculated the growth of yellow pikeperch which were collected in Lake Erie to be 103 mm. in standard length (roughly 4.7 inches total length), based on the study of 25 large

specimens. Deason (1933), also dealing with Lake Erie pikeperch, calculated the average standard length of 1,430 specimens at the end of the first year to be 91 mm. standard length (about 4.1 inches total length). Hart (1928) found that four specimens from Lake Nipigon had attained an average length of 123 mm. (about 5.6 inches total length) at the end of one year. Greeley (1929) noted that four specimens taken on July 26 from the Niagara River were from 1-7/8 to 2-1/8 inches long. Eschmeyer and Jones (1941) studied pikeperch collected from Norris Reservoir in 1938, 1939, and 1940, and calculated total lengths at the end of the first year ranging from 7.5 to 8.6 inches (96 specimens) among the various collections. He also took 14 young fish from sinkholes which averaged 10.5 inches in length, or well over twice that in Lake Gogebic in 1947. Schloemer and Lorch (1942) calculated the average standard length of pikeperch from Trout Lake, Wisconsin, at the end of the first year of life as 114 mm., or 5.3 inches in total length (429 specimens). Average calculated standard lengths at the end of the first year of life among fish from 39 populations in Wisconsin ranged from 86 to 117 mm. These had an unweighted average standard length of 117 mm., or 5.4 inches in total length. Eddy and Carlander (1942) calculated an average standard length of 94 mm. (about 4.3 inches total length) at the end of the first year of life for 6,601 pikeperch from 81 Minnesota lakes and rivers. Carlander (1945) found an average calculated standard length at the end of the first year of life of 143 millimeters (about 6.4 inches, total length) in 2,898 pikeperch from Lake of the Woods.

The length of young pikeperch at Lake Gogebic near the end of the first year of life in 1947 (and 1946) is observed to be less than the calculated or measured lengths in several of the other populations studied, but appears to be greater than that in Lake Erie, 7 of the 39 populations studied by Schloemer

and Lorch, and the fish studied by Eddy and Carlander in Minnesota. The four specimens collected by Greeley in the Niagara River were also smaller than those occurring at Lake Gogebic at about the same time of the year. The probable inaccuracy of the October collections in 1941, as a result of their collection in a gill net which took only the larger fish, prevents comparison with that year. The available data suggest that growth in other waters corresponds more closely with that in Lake Gogebic for 1941 than for 1947 (or for 1946).

The food of young pikeperch has been studied by a number of workers. Among the accounts dealing with food of pikeperch during the first year of life are the following:

Forbes (1880; 1903) examined stomachs of two pikeperch, 2 and 2.5 inches long, from the Illinois River. One contained a small fish and the other a few Entomostraca. Pearse (1921) studied 5 specimens from Lake Geneva, Wisconsin, collected on July 25, which averaged 52 mm. in standard length. These had eaten 30 percent fish, 13 percent chironomid pupae, 52 percent Daphnia, and 3 percent Cyclops. Leptodora also occurred (0.4 percent). Clemens and others (1923) found only fish remains in three young, 53 to 68 millimeters in length, collected at Lake Nipigon, Ontario, between July 20 and August 4. In three fish from the same water, 1-3/8 to 1-7/8 inches long taken July 31, Clemens et al (1924) found mostly micro-crustaceans (Daphnia, Cyclops, Bosmina, and Epischura), a few chironomid larvae and pupae, and the remains of three fish. In Big Sandy Lake, Minnesota, Kidd (1927) found that Entomostraca together with some algae were the chief foods of pikeperch $1\frac{1}{2}$ to 9 inches in length. Gammarus and small fish were found in those over two inches in length. Adams and Hankinson (1928) reported that 6 fish from Oneida Lake, 1 to 2 inches long, contained unidentifiable fish remains, and

that one of these had 9 small fry in its stomach. Sibley (1929) found only fry of Catostomidae in nine specimens ranging from 31 to 54 mm. in standard length collected in New York. Surber (1930) found fish in each of ten specimens ranging from 43 to 75 mm. in length from a slough in the upper Mississippi River. In addition, he found Entomostraca in 9, Daphnia in 2, copepods in 3, and ostracods in 2. Rimsky-Korsakoff (1930) found only fish (yellow perch and Johnny darters) in 32 specimens, 45-70 mm. in standard length, from the Lake Champlain drainage in New York. Bajkov (1930) reported that for the first month fry are plankton feeders (main items: planktonic Crustacea), but shortly after this begin to feed on different insect larvae and small fish. Sibley and Rimsky-Korsakoff (1931) found that six young, 55 to 95 mm. in standard length, from the St. Regis and Salmon Rivers, New York, had eaten only Johnny darters. Nurnberger (1930) examined 54 fish from Big Sandy Lake, Minnesota, ranging from 52 to 380 mm. in standard length, and found, in the stomachs of 28 of these which contained food, 54 fish, 30 insects, and a mass of Potamogeton. Insects were eaten when the fish were 75 mm. in length. Ewers (1933) examined 111 Stizostedion stomachs taken from western Lake Erie between June 27 and September 29, 1929. The fish averaged 59.3 mm. in length, and ranged from 24 to 190 mm. She found 64.6 percent Entomostraca (by volume), 4 percent insects, and 27.3 percent fish. Raney and Lachner (1942) examined 620 stomachs of young taken in Oneida Lake from July 2 to October 24, 1940. These ranged in total length from about 1.3 to nearly 7 inches. Food was present in 495 of the stomachs. In contrast to Ewer's study, just mentioned, fish were by far the most important item of diet in Oneida Lake, equaling 92.9 percent of the total volume, with Johnny darters, pumpkinseeds, and yellow perch contributing heavily to this total. The remaining food was made up of invertebrates,

particularly insects (3.7 percent) and crustaceans (2.7 percent). Smith and Moyle (1945) examined 945 stomachs of pikeperch which ranged from 6.5 to 214 mm. in length, and from 10 to 223 days in age, taken from rearing ponds in Minnesota. The stomachs of 818 contained food. Of these, 13.3 percent contained fish, 38.2 percent copepods, 40.1 percent cladocerans, 60.6 percent insects, 1.8 percent rotifers, 1.1 percent nauplii, and 1.1 percent miscellaneous items.

The results of stomach analyses of young pikeperch collected at Lake Gogebic in 1941 show that fish are a very important item of diet. In this respect they resemble Oneida Lake pikeperch and differ from those in Lake Erie studied by Ewers and those in the hatchery ponds in Minnesota discussed above.

The contents of the stomachs of 55 young pikeperch collected from Lake Gogebic in 1941 are summarized in Table 21. An additional 17 stomachs which were examined were empty. Fish constituted the most important item of diet in all collections except that of October 16 to 21. Five out of six stomachs collected between these dates were crammed with Leptodora. One contained the remains of a fish and two included small mayfly nymphs. For the combined collections, fish constituted about 73 percent of the total food in volume, and occurred in 42 out of 55 (76.4 percent) of the stomachs examined. Insects (chironomid pupae, mayfly nymphs, terrestrial Hemiptera, and unidentified remains) made up 2.4 percent of the total volume and occurred in 12 (21.8 percent) of the stomachs containing food. Cladocera (almost entirely Leptodora) made up the remainder, equaling 24.4 percent of the total volume, but occurring in only 5 (9.1 percent) of the stomachs. Yellow perch were the only fish positively identified in the stomachs, and made up about 58 percent of the total volume of food. They occurred in the

Table 21. Summary of the food of young yellow pikeperch in Lake Gogebic, 1941.

Date	Number of fish	Stomachs containing food	Range in total length, inches	Average length, inches	Number of stomachs containing:			
					Yellow perch	Unidentified fish	Insects	Cladocera
June 24	2	2	1.4 - 1.6	1.5	1	1	...	...
July 8	2	2	1.8 - 2.1	2.0	...	1	1	...
July 10	21	15	2.2 - 3.0	2.6	7	2	9	...
Aug. 2	37	30	3.6 - 4.6	4.1	14	15	1	...
Oct. 16-21	10	6	5.7 - 6.8	6.2	...	1	2	5
Totals	72	55	1.4 - 6.8	3.8	22	20	13	5

collections of June 24, July 10, and August 2, as shown in the table. Unidentified fish (very probably largely perch) occurred in one or more specimens from each collection. Fry of white suckers were not observed in this series of stomachs, but were an item of importance in the diet of small fry collected in early July, 1947, as has been mentioned above. Analyses of food in stomachs of pikeperch collected during that year are incomplete, and are not discussed here.

In summary, yellow pikeperch leave shoreward areas soon after hatching, and probably lead a pelagic existence until they are about an inch or more in length. At Lake Gogebic, they return to the shoals in late June or early July. At this time they may be participating members of perch schools, or may form schools of their own. After early August, pikeperch were usually found in areas sheltered by vegetation or in deep water rather than on the barren sandy shoals which they occupied earlier. In 1946 and in 1947, pikeperch attained lengths of 4.8 and 4.7 inches, respectively, near the end of the first growing season. This is a smaller size than that attained by the species in most outstate waters which have been studied. Food of young pikeperch in Lake Gogebic is composed mostly of fish, particularly yellow perch.

Part II. OBSERVATIONS ON THE LIFE HISTORY OF YELLOW PIKEPERCH IN THE MUSKEGON RIVER WITH SPECIAL REFERENCE TO MIGRATION

Introduction

The Muskegon River is located in the west-central portion of the Lower Peninsula of Michigan. It has its origin in Higgins and Houghton lakes, Roscommon County, and flows in a southwesterly direction for a distance of 227 miles, until it enters Lake Michigan near Muskegon, by way of Muskegon Lake. The drainage basin is long and narrow, with a length of 121 miles, an average width of about 22 miles, and an area of 2,663 square miles (U. S. War Department, 1931). It has a gently rolling topography; has a soil consisting largely of sand and clay; is covered with second-growth timber; and is sparsely populated. Banks of the river valley are from 50 to 150 feet high in many areas, and are much eroded. For its lower 100 miles the river averages from 200 to 250 feet in width and about 5 feet in depth. There is a fall of 559 feet from Houghton Lake to the mouth, or an average of about 2.5 feet per mile. The greatest rate of fall, 4.4 feet per mile, occurs in the 73 miles of stream above the village of Newaygo, which is situated 39 miles upstream from the river mouth. Within the section of greatest fall are located five power dams, owned and operated by Consumers Power Company.

The dam nearest the mouth of the Muskegon is located at Newaygo. It has a head of 17.5 feet and creates an impoundment about four miles long. Croton Dam, 13.4 miles above Newaygo, has a developed head of 40 feet, and backs up water to the foot of Hardy Dam, 6.9 miles upstream. Hardy is the largest of the Muskegon dams. It has a 100-foot head and creates an

impoundment which is nearly a mile wide and over 100 feet in depth, and which reaches upstream for 25 miles, to the foot of Rogers Dam. The latter structure has a head of 40 feet and impounds water for about 8 miles. Big Rapids Dam is 16 feet high, and is located 11.3 miles above Rogers Dam.

The present dams at Newaygo and Big Rapids occupy sites which have been used for power development since the early lumbering days and were built in 1900 and 1925 respectively. The other structures are concrete and earth-fill dams which were constructed in 1900 (Rogers), 1907 (Croton) and 1931 (Hardy). The location of these dams in the Muskegon River is shown in Figure 51.

Each spring large numbers of yellow pikeperch and a few game fish of other species ascend the Muskegon River on their annual spawning migration until they encounter Newaygo Dam, an impassable barrier (Fig. 52). The fish congregate in the section of stream below the obstacle and remain in the vicinity in some numbers for a period of several weeks. Each year for the past 26 years varying numbers (usually thousands) of game fish have been captured below the dam and transferred from this area of seasonal concentration to various points in the stream above and to certain other waters in the drainage. This annual conveyance of fish around the dam is known as the "Newaygo transfer."

Almost since the year of its inception the transfer has been a source of spirited controversy between individuals and groups concerned with the river or its connecting waters above Newaygo Dam and those interested in the fishery below - particularly in Muskegon Lake. The differing points of view led to a study of the problem by the Department of Conservation's Institute for Fisheries Research in 1947 and in 1948. It is in connection with this inquiry that the data here presented were obtained.

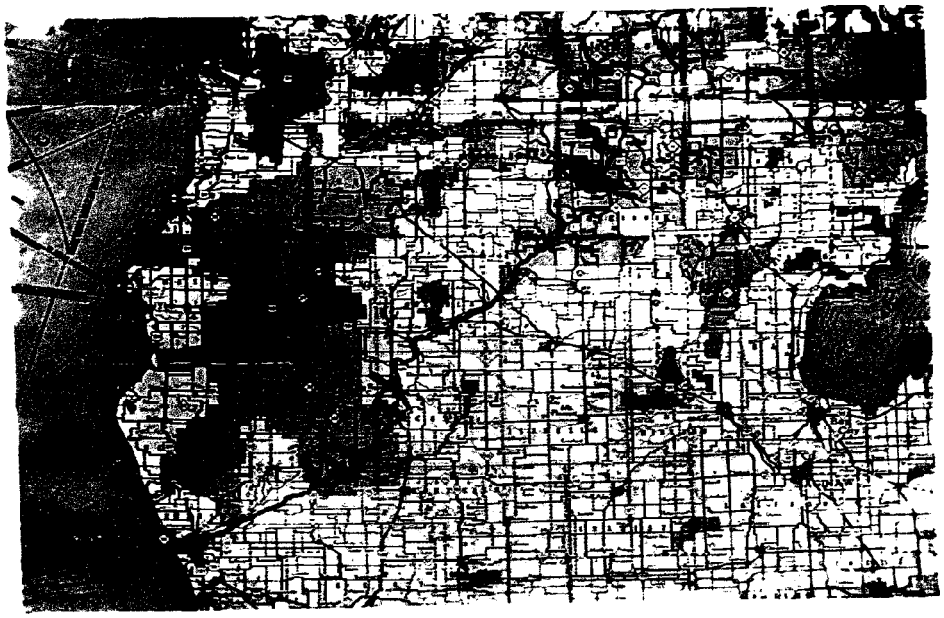


Fig. 51. Map of central Michigan, showing location of power dams on the Muskegon River. In ascending sequence these are Newaygo, Croton, Hardy, Rogers and Big Rapids.

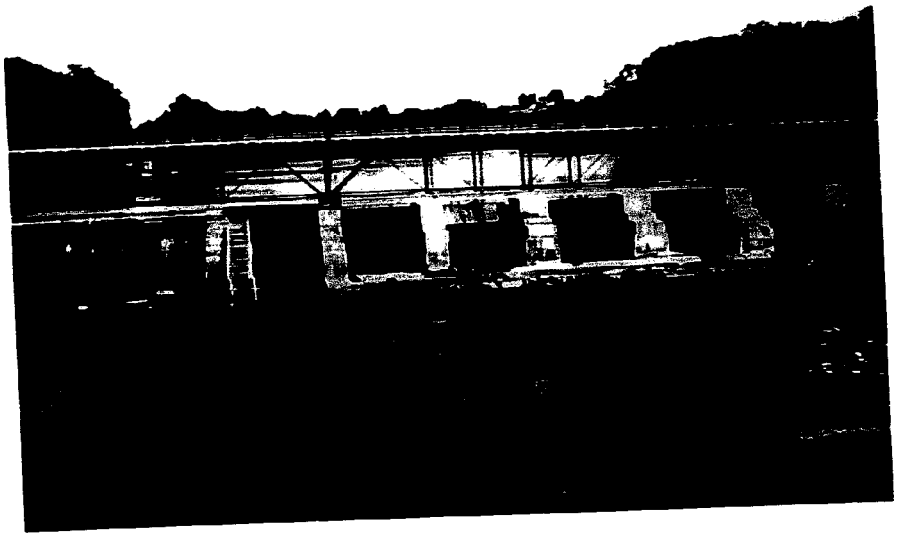


Fig. 52. A view of Newaygo Dam, Muskegon River, during a period of low water, August, 1947.

The Newaygo Transfer

The transfer of game fish around Newaygo Dam was begun in 1923 by a group of sportsmen, with the permission of the Department of Conservation. In 1928 The Department began active supervision of the work and transfer of the fish caught. It has been carried on as an annual function of the Department's Fish Division since that time.

Throughout the history of the Newaygo transfer the capture of fish below the dam has been accomplished by the use of large dipnets operated by winches. Private individuals own and man the nets, and are paid for their services by the Consumers Power Company in proportion to the number of game fish caught by each.

The Muskegon River is about 260 feet wide in the section where dipnetting has been done during recent years (Fig. 53). The gear used (Fig. 54) consists of a steel frame to which a shallow bag of one-inch netting is attached. The frame is supported at each corner by wires of equal length, which extend to a common point above the center of the net. Here they are joined to a rope, which passes through a pulley attached to the outer end of an angling pole which is anchored to the bank. The rope which suspends the net leads to a winch, located near the center of the pole. A wire attached to the upstream side of the net is anchored at a point 10 or 15 feet upstream (Fig. 53, foreground) to prevent the net from being swept downstream as it is lowered into the water. A live box (near the operator's pier in Fig. 54), a long-handled scap net, and a small shelter for use during inclement weather or during slack fishing periods, complete the equipment.

In operation, the net is lowered into the river so that the net frame rests on the bottom. It is left for a period varying from less than a minute

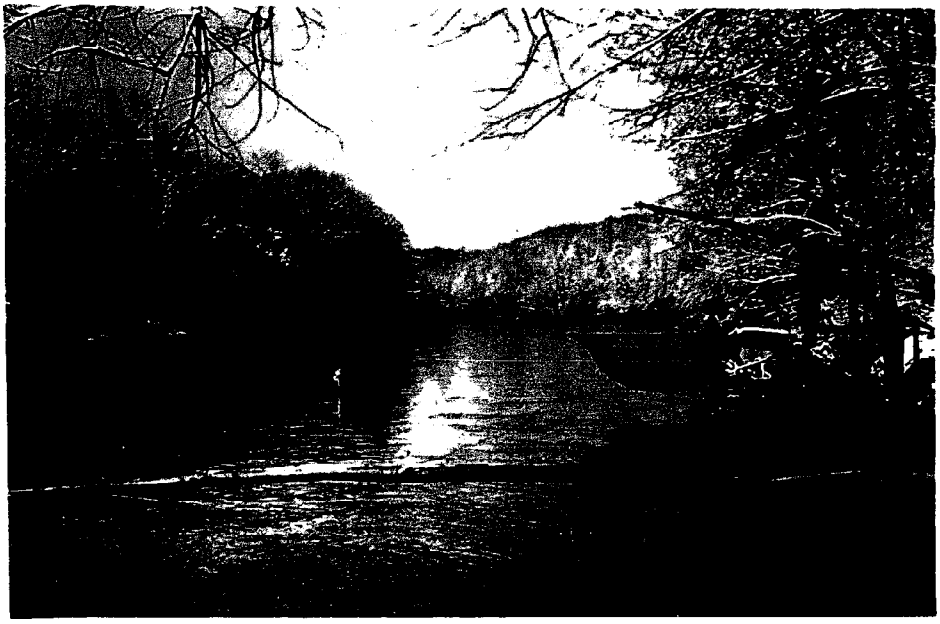


Fig. 53. Downstream view of the Muskegon River at Newaygo. A dipnet is shown at the right center.

Fig. 54. Dipnet used for taking game fish during the Newaygo transfer of 1947. This net is 10.5 feet square.

to much longer, depending upon the inclination of the operator. It is lifted out of the water vertically, at a moderate, steady speed. If fish are taken, a long-handled net is extended into the dipnet, the fish are secured (Fig. 55) and transferred to a live box (Fig. 56). In the transfer, the fish are counted as they are removed from the live box (Fig. 57), and are placed in an aerated tank truck and transported to an upstream area for stocking (Fig. 58).

The numbers of game fish and suckers taken in dipnets during the period from 1928 to 1948 are summarized in Table 22, which is compiled from annual reports submitted by supervisors in charge of the work. The record is probably complete for yellow pikeperch and trout, but totals for other game fish and suckers are incomplete for the earlier years of the transfer.

During the past 21 years, 202,294 game fish, 14,020 white suckers, and 14 sturgeon, Acipenser fulvescens Rafinesque, have been caught. Of the game fish, 195,276 (96.5 percent) were yellow pikeperch and 6,545 (3.2 percent) were trout. The trout were not differentiated by species. Nearly all were rainbow trout, Salmo gairdnerii irideus Gibbons, but a few brook trout, Salvelinus fontinalis fontinalis (Mitchill) and brown trout, Salmo trutta fario Linnaeus, were included. Northern pike, largemouth and smallmouth bass (combined in the records) and yellow perch were represented by much smaller numbers and only during some years of the transfer. Not shown in the table are a few "stone-rollers" (probably hog suckers, Hypentelium nigricans (LeSueur)); three large smelt, Osmerus mordax (Mitchill), reported in 1937; one rock bass caught in 1947, and an occasional sea lamprey, Petromyzon marinus Linnaeus.

Pikeperch completely dominated the game fish catch during each year of the transfer. It has been the aim of supervisors to have the netting period

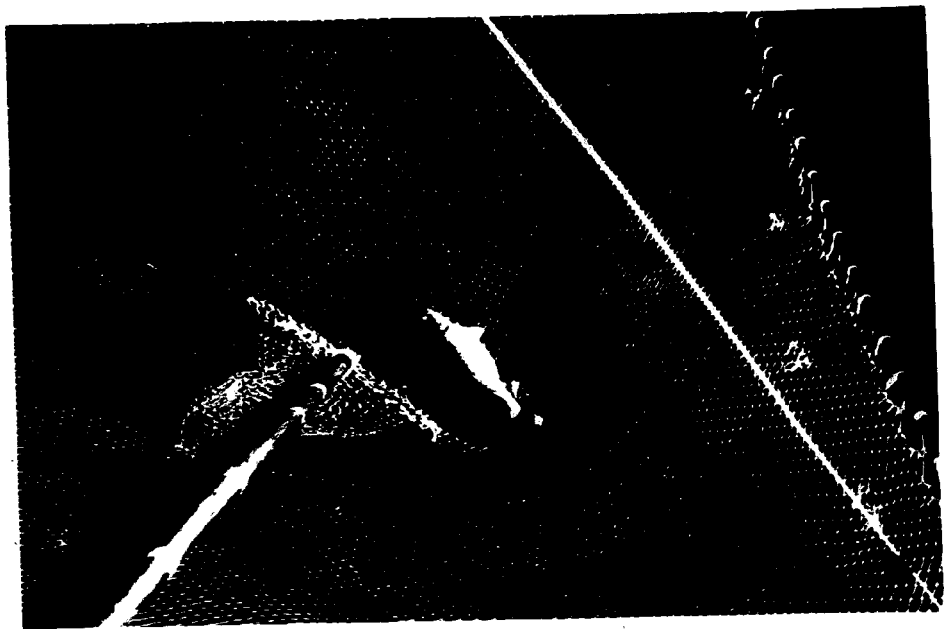


Fig. 55. Removing a yellow pikeperch from a dipnet during the Newaygo transfer of 1947.

Fig. 56. Transferring a large yellow pikeperch from the dipnet to a live box during the 1947 Newaygo transfer.

Fig. 57. Removing pikeperch from live box for transfer to upstream waters during the 1947 Newaygo transfer.

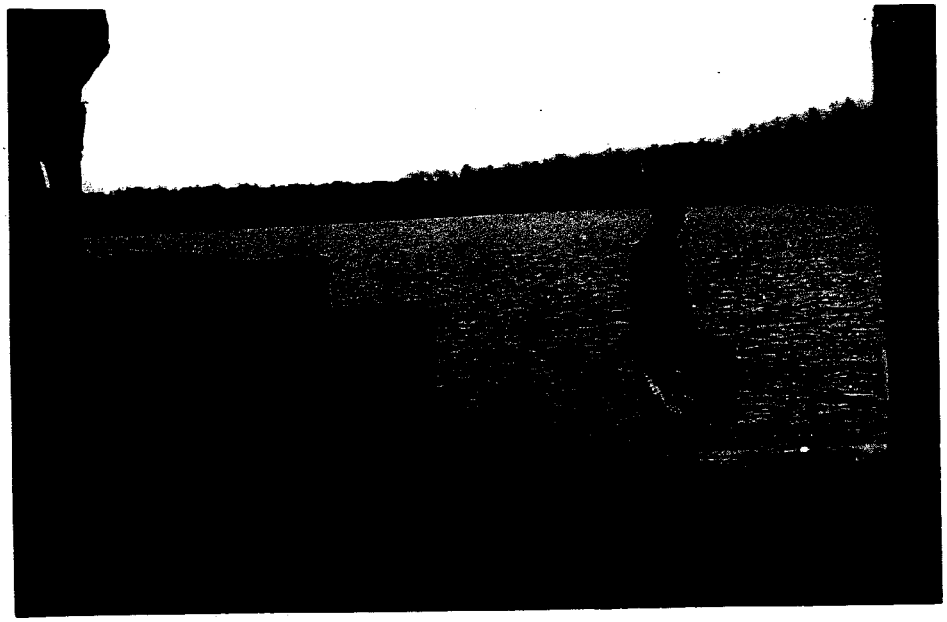


Fig. 58. Pikeperch removed from aerated tank truck and about to be planted in Rogers Pond, Muskegon River impoundment, April, 1947.

Table 22. Summary of numbers and species of fish caught in dipnets in the Muskegon River during the Newaygo transfer, 1928 - 1948.

Year	Yellow pikeperch	Trout*	Northern pike	Bass**	Yellow perch	Sturgeon	White suckers***
1928	469	409	...	...	...	...	...
1929	3,680	1,024	...	...	...	3	...
1930	8,327	1,712	...	...	...	...	...
1931	1,547	291	...	...	...	...	...
1932	3,151	791	...	...	...	2	2,148
1933	43,088	819	...	...	...	3	...
1934	24,284	465	...	...	...	1	...
1935	24,241	230	...	...	...	...	2,226
1936	6,676	69	...	...	...	...	...
1937	6,931	128	13	...	...	3	1,100
1938	7,020	193	5	...	...	...	2,250
1939	6,345	127	27	2	...	...	1,037
1940	2,641	112	94	46	141	...	1,044
1941	12,460	43	31	65	30	...	864
1942	12,469	57	...	...	...	...	419
1943	13,186	32	...	...	...	...	487
1944	3,318	9	10	...	...	...	202
1945	789	10	...	...	...	...	591
1946	4,380	12	1	1	...	...	686
1947	5,540	6	3	...	...	2	263
1948	4,734	6	3	...	...	...	703
Totals	195,276	6,545	187	114	171	14	14,020

*Mostly rainbow trout; occasional brook and brown trout.
**Not identified to species in annual reports.
***Data lacking or incomplete for some years.

include the peak of the pikeperch run, in order to secure maximum numbers of fish with a minimum expenditure of time and expense. Choice of the starting date has been based on weather conditions, stream temperatures, records of previous years, or local opinion. Some years a few nets were operated as test nets prior to the principal netting period, to aid in predicting the probable period of greatest concentration. A tabulation of the catches during consecutive three-day intervals, in terms of percentage of the year's catch, for the various years of the transfer (Table 23) shows that the peak of the run was included in the netting season during most years. In 1936 the peak may have passed before the netting season got underway (only test nets were set during the first three days and none during the following three days). In 1942 netting was probably terminated before the peak was reached and in 1945 the peak may have occurred before netting began. The course of four representative netting periods is shown in Figure 59.

Scheneberger (1939 and 1940) published catch records for nets set during the 1939 and the 1940 pikeperch spawning runs in the Wolf River, Wisconsin. In both years maximum daily catches occurred during the period from April 15 to 17. This is three days earlier than the 1939 peak, but coincides with the 1940 peak in the Muskegon River. Together with dates which he gave for the pikeperch runs in the Wolf River in the years 1934 to 1937, the data indicate a simultaneous occurrence of pikeperch runs in the two streams. His catch records for 1933 in the Fox River below Eureka Dam showed that most fish were taken from April 13 to 15, 1933, or three days ahead of the peak in the Muskegon River for that year.

A tabulation of the dates of netting during the years of the transfer (Table 24) delimits the principal portion of the pikeperch spawning season in the Muskegon River. The dipnetting began as early as March 26 (1933)

Table 25. Yellow pikeperch taken in dipnets below Newaygo Dam in the Muskegon River, summarized by three-day intervals, in terms of percentage of the season's catch.

Year	Days after beginning of netting period											Total Catch
	1-3	4-6	7-9	10-12	13-15	16-18	19-21	22-24	25-27	28-30		
1933	*	*	2	9	12	12	16	24	17	6	2	43,088
1934	2	5	15	14	14	19	13	14	4**	...	...	24,284
1935	4	14	17	23	18	12	8	3	1***	...	...	24,241
1936	2	...	26	24	24	16	8	...	...	...	...	6,676
1937	5	9	17	29	21	12	7	...	...	...	...	6,931
1938	18	22	16	24	15	4	1	*	...	...	...	7,020
1939	7	10	12	16	10	15	19	11	...	...	...	6,345
1940	2	10	14	13	20	19	15	7***	...	...	...	2,641
1942	23	40	37**	...	...	...	...	...	...	...	...	12,469
1943	3	26	40	31	...	...	...	...	...	...	...	13,186
1944	13	17	30	17	14	9**	...	...	...	...	...	3,318
1945	51	20	24	5***	...	...	...	...	...	...	...	789
1946	14	23	25	24	14	...	...	...	...	...	...	4,380
1947	27	29	26	18	...	...	...	...	...	...	...	5,540
1948	22	35	26	13	4	...	...	...	...	...	...	4,743

*Less than one percent of the catch.
**Catch for two days only.
***Catch for one day only.

Fig. 59. Catch of yellow pikeperch in the Muskegon River below Newaygo Dam during four years of the Newaygo transfer.

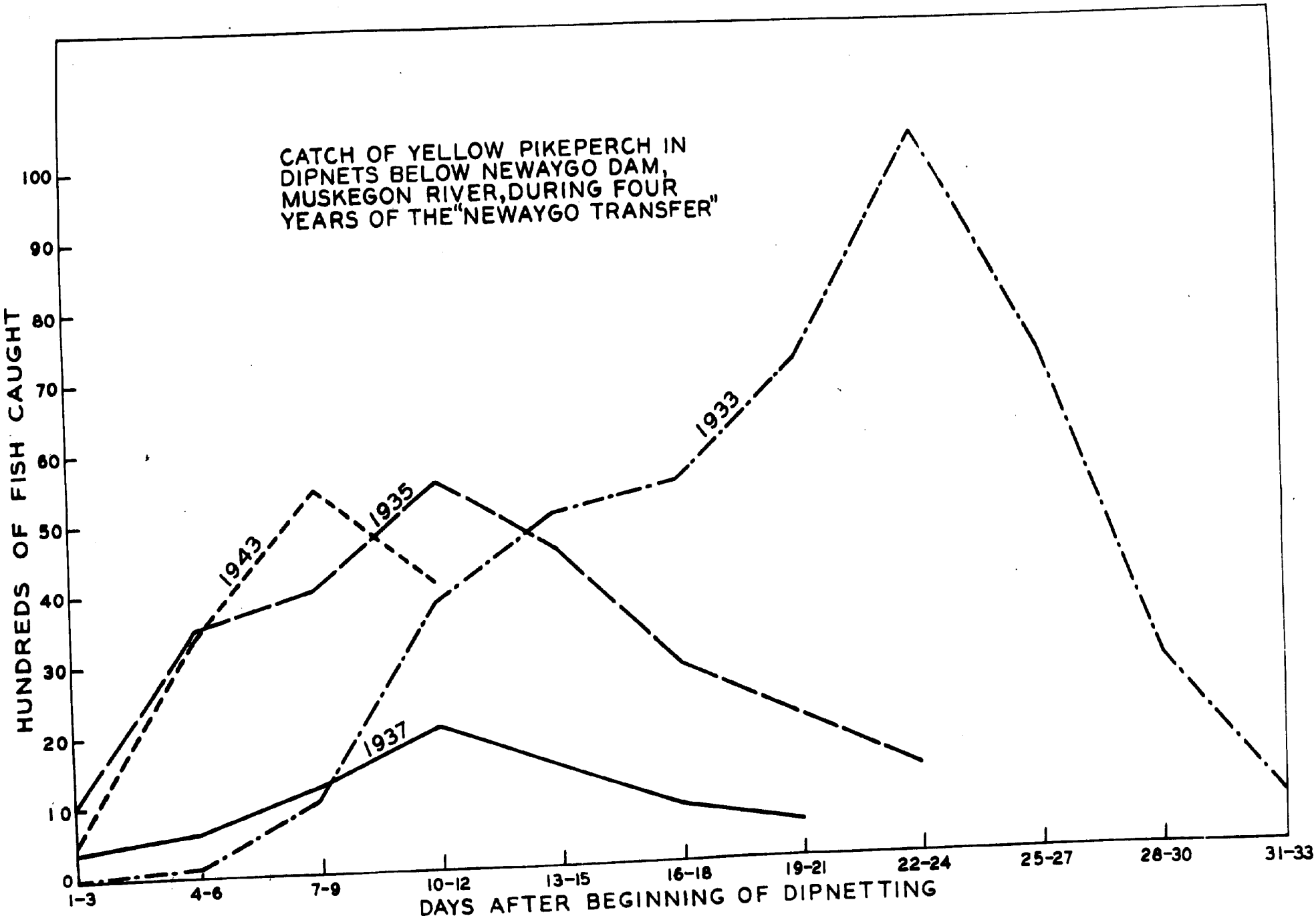

CATCH OF YELLOW PIKEPERCH IN DIPNETS BELOW NEWAYGO DAM, MUSKEGON RIVER, DURING FOUR YEARS OF THE "NEWAYGO TRANSFER"
HUNDREDS OF FISH CAUGHT
0
10
20
30
40
50
60
70
80
90
100
1933
1935
1943
1937
1-3
4-6
7-9
10-12
13-15
16-18
19-21
22-24
25-27
28-30
31-33
DAYS AFTER BEGINNING OF DIPNETTING

Table 24. Duration of dipnetting periods in the Muskegon River below Newaygo Dam.

Year	Netting dates	Dates of largest catch	Days of netting
1933	March 26 - April 27	April 16 - 18	33
1934	April 3 - April 28	19 - 21	26
1935	April 1 - April 25	11 - 13	25
1936	April 14 - April 28	15 - 17	15
1937	April 3 - April 23	12 - 14	21
1938	April 2 - April 24	11 - 13	23
1939	April 2 - April 25	18 - 20	24
1940	April 2 - April 23	15 - 17	22
1942	April 1 - April 8	6 - 8	8
1943	April 5 - April 16	10 - 12	12
1944	April 6 - April 22	12 - 14	17
1945	April 4 - April 13	4 - 6	10
1946	March 29 - April 12	2 - 4	15
1947	April 14 - April 25	16 - 18	12
1948	April 8 - April 22	11 - 13	15

and as late as April 14 (1936, 1947). The operation was terminated by April 8, 1942, but was held over as late as April 28 in 1934 and 1936. The peak three-day period of the run began as early as April 2 (1946) and as late as April 19 (1934). For the 15 years for which there are adequate records, the average period began on April 4, lasted for 18 days, ended on April 21, and reached its peak from April 12 to 14.

The annual catch of pikeperch in dipnets below Newaygo Dam has varied from only 469 in 1928 to 43,088 in 1933 (Table 22). The reasons for the wide range in the number of fish taken from year to year are obscured by the presence of many variables which cannot be evaluated accurately. The length of the netting season during the period ranged from 8 to 33 days. The number of nets in use has varied from 37 in 1933 to only 8 in 1945, and all of the nets were not in use throughout the period of netting; hence, the data cannot be satisfactorily reduced to catch per unit of fishing effort. Ability and interest of the netters has been variable. Length of the netting season and total numbers of fish taken were unrestricted prior to 1936, but since that time there has been a limit of about 10,000 game fish or 15 days of netting. Attempts by supervisors to have the middle of the netting season coincide with the peak of the spawning run have not been equally successful. Prior to about 1944 netting was done throughout the day and night and at any point in the river within about a mile from the dam, whereas in recent years it has been restricted to nights only and to a selected section of stream. Stream flow and water temperatures have varied from year to year. Cobb (1923), MacDonald (1924) and Adams and Hankinson (1928) reported that pikeperch may lay their eggs in lakes if prevented by weather or other causes from entering streams, or fish may spawn anywhere near the mouths of streams where depth and other conditions are satisfactory.

MacDonald added that pikeperch do not enter streams at all during some seasons, or do so only in small numbers. Derback (1947) found that a sudden period of cold weather caused pikeperch to return to the lake after they had entered tributary streams to spawn, and observed that they did not return, but resorbed their eggs.

The catch of yellow pikeperch by commercial fishermen in southern Lake Michigan and out of the port of Muskegon, the take in dipnets below Newaygo Dam, and landings by anglers in the section of the Muskegon River below Newaygo Dam and in Muskegon Lake, are compared in Table 25 and are shown graphically in Figure 60. Correlation among the various catches appears to be present during some years but during others there is little or no relationship between the numbers of fish taken by the various methods and in the different localities. Further discussion, which an examination of the graph provokes, is deemed unwise because of the many variables and uncertainties inherent in the data (as discussed above). No interpretation of the annual variations in the catches at Newaygo Dam is here attempted.

In summary, a total of over 195,000 pikeperch has been caught in dipnets operated in the Muskegon River below Newaygo Dam during the spring spawning migrations of the past 21 years. Annual catches have fluctuated widely about the mean of 9,300. As an average, the netting has continued for an 18-day period (April 4 to 21) and the largest catches have been made from April 12 to 14.

Pikeperch spawning runs of 1947 and 1948

During the 1947 and 1948 spawning runs, the progress of the dipnetting below Newaygo Dam was followed in greater detail than during other years. The handling of large numbers of fish in connection with a tagging study

Table 25. Summary of the catch of pikeperch in southern Lake Michigan*; in Lake Michigan from the port of Muskegon**; in dipnets below Newaygo Dam; and by anglers in the Muskegon River below Newaygo Dam and in Muskegon Lake (combined)***.

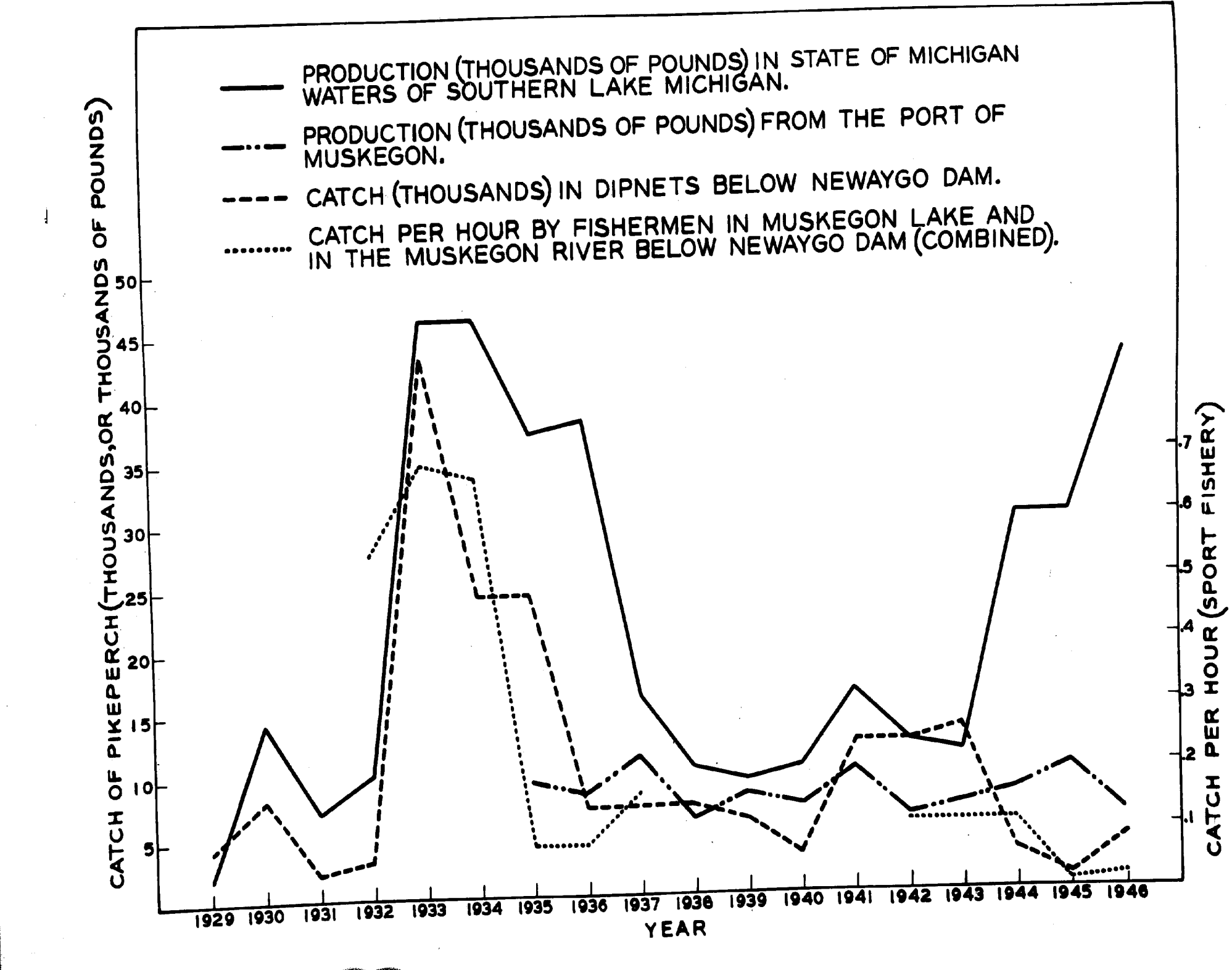
Year	Commercial fishery		Newaygo transfer	Sport fishery		
	Southern Lake Michigan (thousands of pounds)	Port of Muskegon** (thousands of pounds)	(thousands of fish)	Muskegon River below Newaygo Dam and Muskegon Lake (combined)***		
				Hours of fishing censused	Number of pikeperch caught	Catch per hour
1929	2	...	4	...	...	...
1930	14	...	8	...	...	...
1931	7	...	2	...	...	...
1932	10	...	3	29	16	0.55
1933	46	...	43	839	570	0.68
1934	46	...	24	1,650	1,098	0.67
1935	37	9	24	3,732	317	0.08
1936	38	8	7	3,112	253	0.08
1937	16	11	7	326	52	0.16
1938	10	6	7	...	...	...
1939	9	8	6	...	...	...
1940	10	7	3	...	...	...
1941	16	10	12	...	...	...
1942	12	6	12	285	30	0.11
1943	11	7	13	...	...	...
1944	30	8	3	202	22	0.11
1945	30	10	1	490	6	0.01
1946	43	6	4	874	21	0.02

*State of Michigan waters from Arcadia south to the Indiana line. Data from Hile (1936) and by written communication.

**From data compiled by A. B. Cook, Fish Division, Michigan Department of Conservation.

***Compiled by K. G. Fukano, Institute for Fisheries Research.

Fig. 60. Annual production of pikeperch in southern Lake Michigan and from the port of Muskegon (thousands of pounds), catch in dipnets below Newaygo Dam (thousands), and catch per hour by fishermen in the Muskegon River below Newaygo Dam and in Muskegon Lake (combined).


PRODUCTION (THOUSANDS OF POUNDS) IN STATE OF MICHIGAN WATERS OF SOUTHERN LAKE MICHIGAN.
PRODUCTION (THOUSANDS OF POUNDS) FROM THE PORT OF MUSKEGON.
CATCH (THOUSANDS) IN DIPNETS BELOW NEWAYGO DAM.
CATCH PER HOUR BY FISHERMEN IN MUSKEGON LAKE AND IN THE MUSKEGON RIVER BELOW NEWAYGO DAM (COMBINED).
CATCH OF PIKEPERCH (THOUSANDS, OR THOUSANDS OF POUNDS)
CATCH PER HOUR (SPORT FISHERY)
YEAR
1929 1930 1931 1932 1933 1934 1935 1936 1937 1938 1939 1940 1941 1942 1943 1944 1945 1946

provided an opportunity to obtain data which are not available for earlier years.

Water temperatures in the Muskegon River were recorded each day at about 3:00 p.m. and at about 3:00 a.m. by Department personnel supervising the Newaygo transfers of 1947 and 1948. Daily water temperatures were also recorded in 1936 (at noon) and in 1944 (at 10:00 a.m.). The maximum abundance of fish in the netting area, as indicated by the daily catch, occurred at water temperatures of 40 degrees to 42 degrees F. in 1936, 38 degrees F. in 1944, 40 degrees F. in 1947, and 44 degrees F. in 1948 (Table 26). In 1947 there was no clearly defined peak as during most years of the transfer. Spawning was underway and the largest catches for the season were made before the maximum daily water temperature exceeded 40 degrees F. This may have been true also in 1944, although water temperatures possibly exceeded 40 degrees F. during the afternoons of some days during the season. Maximum daily water temperatures ranged from 39 degrees to 42 degrees F. during most of the 1936 season and were fairly constant at 44 degrees F. throughout nearly all of the 1948 netting period. Temperatures taken at about 3:00 a.m. averaged 2.6 degrees F. less than the readings shown in Table 26 in 1947, and 4.4 degrees F. less than the afternoon readings in 1948.

Spawning (as evidenced by the capture of many ripe females) occurred throughout the netting periods of these two years. Since breeding is usually nocturnal, it is presumed that spawning occurred here, but at temperatures below the maxima shown for 1947 and for 1948. Spawning probably began when water temperatures ranged from about 38 degrees to 40 degrees F. (except perhaps in 1948) and reached a peak at between 38 degrees and 44 degrees F. This temperature is lower than that at which the peak of the spawning period occurs at Lake Gogebic (p. 55), and lower than that reported

Table 26. A record of water temperatures in degrees Fahrenheit and daily catch of pikeperch during four netting seasons in the Muskegon River below Newaygo Dam.

Date	1936		1944		1947		1948	
April	Water temperature	Catch	Water temperature	Catch	Water temperature	Catch	Water temperature	Catch
6	...	...	36	195	...	...	...	...
7	...	...	36	105	...	...	45	...
8	34	36	37	138	...	...	43	260
9	35	41	39	110	...	...	44	359
10	38	98	36	222	...	...	44	444
11	...	...	38	243	...	...	44	595
12	...	...	38	347	...	...	44	538
13	39	...	38	324	...	...	44	542
14	41	484	36	311	40	274	44	559
15	41	590	36	182	40	527	44	363
16	41	664	36	190	40	705	44	292
17	42	664	40	190	40	586	46	246
18	42	542	40	273	40	593	46	195
19	42	380	38	196	40	468	47	166
20	42	444	40	7	41	505	45	89
21	40	740	40	157	42	448	45	44
22	41	443	42	128	43	464	...	51
23	41	414	...	...	44	375	...	...
24	43	286	...	...	46	227	...	...
25	43	360	...	...	...	365	...	...
26	46	187	...	...	...	...	...	...
27	45	193	...	...	...	...	...	...
28	...	110	...	...	...	...	...	...
Totals		6,676		3,318		5,540		4,743*

*Total includes nine fish of other species, not identified in the daily catches.

by Cobb (1923), who stated that the best spawning temperature is from 45 degrees to 50 degrees F., and preferably between 46 degrees and 48 degrees F. The data are in substantial agreement with those of Eddy and Surber (1947), who found that the spawning run starts when water temperatures range from 38 degrees to 44 degrees F. Derback (1947) found that spawning occurred at a stream temperature of 43 degrees F.

A tagging experiment carried on in connection with the Newaygo transfer provided an opportunity for measuring and sexing over 1700 pikeperch in 1947 and in 1948.

Among male pikeperch caught in dipnets in 1947, the size group which included fish between 19.0 and 20.9 inches in length composed 37 percent of the males (Table 27). This group was represented by the largest numbers during 8 of the 12 days of netting. Among females, the group measuring from 23.0 to 24.9 inches was dominant throughout most of the period and constituted about 35 percent of the females examined. No significant seasonal trend in size is indicated. The slight day-to-day variations are probably meaningless, since some selectivity occurred in the choice of fish for measurement which slightly favored the representation of large fish on some days. In removing fish from crowded live boxes, it was noted that larger fish were generally caught first. Smaller fish frequently escaped capture until most of the larger fish had been removed, and, on some occasions tagging was interrupted when a live box was only partly emptied. Although having the effect of increasing the number of females over the smaller males in the total (61.2 percent in these samples, as compared to 57.7 percent in a random sample - see below), selectivity favoring the larger size groups may have been exerted. In 1947 males averaged 19.1 inches and the daily averages ranged from 18.6 to 19.7 inches. Females averaged

Table 27. Size frequencies (in terms of percentage of the catch) of yellow pikeperch taken in the Muskegon River below Newaygo Dam, 1947.

Males

Total length, inches	April 14-15	16-17	18-19	20-21	22-23	24-25	Average
13.0-14.9	3.6	5.0	7.4	2.2	7.2	3.5	4.8
15.0-16.9	20.3	17.2	8.4	14.3	12.0	5.9	14.1
17.0-18.9	26.8	27.8	20.0	27.4	21.7	22.4	25.0
19.0-20.9	34.8	36.1	36.8	29.7	41.0	48.2	37.2
21.0-22.9	13.0	12.8	23.2	24.2	14.5	14.1	16.2
23.0-24.9	1.5	0.6	4.2	2.2	2.4	4.7	2.2
25.0-26.9	...	0.5	...	...	1.2	1.2	0.5
No. of fish	138	180	95	91	83	85	672
Average length	18.8	18.8	19.4	19.2	19.1	19.6	19.1

Females

Total length, inches	April 14-15	16-17	18-19	20-21	22-23	24-25	Average
17.0-18.9	...	2.1	1.2	2.0	1.2	1.8	1.3
19.0-20.9	10.9	11.3	5.1	4.5	6.7	11.1	8.0
21.0-22.9	32.1	30.3	27.6	27.9	31.1	27.8	29.5
23.0-24.9	30.4	33.2	35.4	36.4	36.6	38.0	34.7
25.0-26.9	20.6	20.0	24.8	26.0	22.0	16.7	22.1
27.0-28.9	6.0	2.1	5.1	2.6	2.4	4.6	3.9
29.0-30.9	...	1.0	0.8	0.6	...	...	0.5
No. of fish	184	195	254	154	164	108	1,059
Average length	21.8	23.3	23.8	23.6	23.5	23.3	23.3

23.2 inches and the daily mean length varied from 21.0 to 24.0 inches.

In 1948, data similar to those obtained in 1947 were secured (Table 28), but they were divided into two parts, the first covering the principal portion of the run (April 8 to 13) and the second covering the period of decline (April 17 to 22). Males in the size class ranging from 19.0 to 20.9 inches again furnished a larger portion of that sex in the run than any other size group. Between April 9 and April 13 males from 19.0 to 22.9 inches in length dominated, but during the period of decline fish of smaller size were preponderant. A total of 241 males measured from April 8 to 13 averaged 19.4 inches in length, and 242 examined from April 17 to 22 averaged only 18.6 inches. These results are in contrast to the findings in Lake Gogebic in 1947, where large males were dominant in the catches on the spawning beds during the period of decline (p. 8 1).

In the Muskegon River run of 1948, as in 1947, females ranging from 23.0 to 24.9 inches in length were more abundant than other size classes. Like the males, the larger fish (23.0 to 26.9) were strongly represented during the peak of the run, but lost their dominance to smaller fish during the period of decline. The average length of 832 females taken from April 8 to 13 was 23.9 inches; whereas 425 fish sampled from April 17 to 22 had a mean length of 21.9 inches. Thus females, as well as males, were smaller in average size during the period of decline of the run than during its peak.

Females constituted 58 percent of a random sample of 1,298 pikeperch examined during the 1947 netting season (Table 29). The daily catch comprised from 29 to 75 percent females, but no seasonal trend is evident. Females were better represented in 1948 when they made up 72 percent of a season's sample of 1,740 fish, and composed from 54 to 89 percent of the

Table 28. Size frequencies (in terms of percentage of the catch) of yellow pikeperch taken in the Muskegon River below Newaygo Dam, 1948.

Males

Total length, inches	April 8-9	April 10-11	April 12-13	April Average 8-13	April 17-18	April 19-20	April 21-22	April Average 17-22	Grand average
13.0-14.9	1.4	4.7	...	2.1	5.5	2.2	...	3.7	2.9
15.0-16.9	20.2	15.6	13.2	17.8	28.3	24.4	24.0	26.5	22.2
17.0-18.9	21.6	12.5	15.8	18.3	24.4	25.6	24.0	24.8	21.5
19.0-20.9	29.5	40.6	28.9	32.4	25.2	25.6	20.0	24.8	28.6
21.0-22.9	23.0	26.6	39.5	26.5	15.0	17.8	24.0	16.9	21.7
23.0-24.9	4.3	...	2.6	2.9	1.6	4.4	8.0	3.3	3.1
Number of fish	139	64	38	241	127	90	25	242	483
Average length	19.2	19.3	20.1	19.4	18.4	18.8	19.1	18.6	19.0

Females

Total length inches	April 8-9	April 10-11	April 12-13	April Average 8-13	April 17-18	April 19-20	April 21-22	April Average 17-22	Grand average
15.0-16.9	...	0.3	0.4	0.2	0.8	0.9	...	0.7	0.4
17.0-18.9	4.3	3.7	2.2	3.4	14.2	17.2	11.1	14.6	7.2
19.0-20.9	12.5	5.7	10.6	9.0	19.1	27.6	34.9	23.7	14.0
21.0-22.9	19.7	17.7	16.0	17.7	25.6	22.4	33.3	25.9	20.4
23.0-24.9	29.3	34.3	37.2	34.0	21.6	19.8	12.7	19.8	29.2
25.0-26.9	25.5	29.4	27.0	27.6	16.3	7.8	6.4	12.5	22.5
27.0-28.9	8.2	8.3	6.2	7.6	2.4	4.3	...	2.6	5.9
29.0-30.9	0.5	0.6	0.4	0.5	...	...	1.6	0.2	0.4
Number of fish	208	350	274	832	246	116	63	425	1,257
Average length	23.7	24.1	23.8	23.9	22.2	21.6	21.4	21.9	23.2

Table 29. Sex composition of pikeperch taken in dipnets below Newaygo Dam in the Muskegon River.

1947					1948				
Date April	Number	Percentage males	Percentage females	Number of females per 100 males	Date April	Number	Percentage males	Percentage females	Number of females per 100 males
14	153	44.4	55.6	125	8	96	33.3	66.7	200
15	119	42.9	57.1	133	9	251	42.4	57.6	135
16	81	42.0	58.0	138	10	152	23.7	76.3	322
17	252	51.2	48.8	95	11	262	10.7	89.3	836
18	65	49.2	50.8	103	12	196	11.2	88.8	791
19	149	25.5	74.5	292	13	116	13.8	86.2	625
20	46	60.9	39.1	64	17	181	30.9	69.1	223
21	89	50.6	49.4	98	18	192	37.0	63.0	170
22	95	34.7	65.3	188	19	122	41.8	58.2	139
23	84	35.7	64.3	180	20	84	46.4	53.6	115
24	96	42.7	57.3	134	21	41	22.0	78.0	356
25	69	29.0	71.0	245	22	47	34.0	66.0	194
Totals	1,298	42.3	57.7	136	Totals	1,740	27.7	72.3	260

daily catch. Although no daily total showed as many males as females, males were relatively better represented before the peak and during the decline of the run than during the period of maximum numbers (April 11 to 13). At the peak of the run the catch exceeded 500 fish on each of four days. For the three of these for which there are data females constituted 88 percent of the catch. In the period of decline this percentage was 62.

The samples in 1947 and in 1948 were taken within the same section of river, with the same type of gear, and by essentially the same personnel. A difference in the sex ratio of pikeperch during the two years is indicated by the data. This difference is accentuated if only the peak periods of the runs are compared.

In studies of sex ratio on the spawning beds in other waters, males have always outnumbered females. This was true in Oneida Lake, New York, (Adams and Hankinson, 1928); in Wolf River, Minnesota, (Schneberger, 1938, 1939 and 1940); in streams in Minnesota (Eddy and Surber, 1947); in a stream in Manitoba (Derback, 1947); and in Lake Gogebic (p. 62). A predominance of males was also noted in Burt Lake (p. 70), a population which was not believed to be on the spawning grounds. It appears, therefore, that the sex ratio in the Muskegon River in 1947 and 1948 was very unusual. A number of possible explanations may account for it.

The catch may not represent a random sample of the fish present in the river due to selective action of the dipnets. As has been mentioned above, these are lifted from the bottom with a steady upward pull. Since the netting occurs in total darkness, pikeperch are probably less likely to sound for the bottom of the net in their attempts to escape than might be true during daylight hours. Undoubtedly many fish escape the net as it is being lifted. Manifestly females, burdened with a quantity of eggs often equal

to one-fourth of their weight (p. 99) are less active than males, whose reproductive organs probably average less than 5 percent of their weight. The expected result is a selective pressure favoring a high catch of females. Other types of gear were not used in the Muskegon River near the dam in 1947 or in 1948, but a trap net was set from March 28 to April 1 in Muskegon Lake, near the point at which the river enters the lake. Of 22 pikeperch taken, 16 (73 percent) were males. This figure agrees more closely with the findings in other waters.

A second possibility for the unbalanced sex ratio is thatit is truly representative of the migrating population which has been intercepted by the barrier at this locality. This might be explained by some unknown factor, for example, a greater longevity of females, such as was found to exist in Lake of the Woods (Carlander, 1945). The collection from Muskegon Lake mentioned above offers evidence to weaken but not necessarily to refute this explanation. That small sample was taken late in the run, and may not have been representative of the population as a whole.

A third possibility is that the presence of a barrier (Newaygo Dam) affects the sexes differently. Possibly a higher proportion of females remain in the vicinity of the dam, whereas most males return downstream after encountering the barrier.

It is clear that further study is necessary before an explanation for the unbalanced sex ratios can be accepted.

The condition of the ovaries was recorded for 964 pikeperch in 1947 and 1,257 examined in 1948 (Table 30). In 1947, about two-thirds of the females were ripe, 30 percent were green, and 3.5 percent were spent. Green females ranged from 46 percent of the total on April 19 to only 3.5 percent on April 24. Despite minor fluctuations, the number of green females

Table 30. Condition of ovaries of female yellow pikeperch taken in the Muskegon River below Newaygo Dam.

1947					1948				
Date April	Number examined	Percentage Green	Ripe	Spent	Date April	Number examined	Percentage Green	Ripe	Spent
16	94	40.4	56.4	3.2	8	64	71.9	26.6	1.5
17	140	28.5	62.9	8.6	9	144	81.9	13.9	4.2
18	91	30.8	61.5	7.7	10	116	49.1	46.6	4.3
19	202	46.0	52.5	1.5	11	234	49.6	48.3	2.1
20	103	25.2	71.9	2.9	12	174	40.2	58.1	1.7
21	64	31.2	64.1	4.7	13	100	35.0	62.0	3.0
22	98	23.5	75.5	1.0	17	125	48.8	40.8	10.4
23	64	23.5	73.4	3.1	18	121	37.2	51.2	11.6
24	57	3.5	96.5	0.0	19	71	49.3	40.8	9.9
25	51	7.8	92.2	0.0	20	45	46.7	42.2	11.1
					21	32	65.6	28.1	6.3
					22	31	58.1	41.9	0.0
Totals	964	30.0	66.5	3.5	Totals	1,257	51.1	43.8	5.1

decreased and the number of ripe females increased with the progress of the season. Spent females were few in number throughout the period. In 1948, 51 percent of the females taken were green, 44 percent were ripe and the remainder was spent. Green females exceeded ripe females in number early in the netting period, but later no consistent trends with respect to condition of the ovaries were noted. Spent fish again comprised only a small percentage of the catch. This suggests that spent females leave the area promptly after spawning. However, there is the possibility that spent females, because of their greater maneuverability, escape more easily than heavy fish. Early downstream movement is further indicated, however, by a report of angling results at a point in the river immediately upstream from Muskegon Lake. On April 17, 1948, an angler was observed with a spent female pikeperch. He reported that his party had taken 4 on April 12, 17 on the following day, and occasional fish on subsequent dates. All were said to be spent females of large size. On the other hand, two mature females were taken within 3 miles from Newaygo Dam on May 20 and May 24 which had been tagged on April 21 and released below the dam.

Reports by Schneberger (1939 and 1940) also indicated a small percentage of spent females in net catches in the Wolf River, Wisconsin. Of the females taken from March 31 to April 19, 1939, 64 percent were green, 31 percent were ripe, and 5 percent were spent. From April 5 to 21, 1940, these percentages were 42 (green), 46 (ripe), and 12 (spent).

In an attempt to determine the extent of the pikeperch spawning beds in the Muskegon River, eggs were collected at various points in the river below Newaygo Dam on April 23 and 24, 1948, when the spawning season was nearly over. Collections were made with a long-handled net, which consisted of a rigid rectangular frame, 12 inches by 16 inches, made from one-quarter-

inch steel, to which a brass screen, 5 inches deep, was securely attached. In making the collections the boat was pointed upstream, and run with an outboard motor at a speed equal to that of the stream, so that the boat was motionless. The net was forced vertically into the stream and the bottom was agitated with the rigid cross-bar at the bottom of the net frame. Eggs brought into suspension were carried into it by the current, which also served to hold the eggs in the net while it was being lifted. Collections were made near mid-stream.

Eggs of yellow pikeperch were found throughout the section of river extending from Newaygo Dam to a point 16 miles downstream. Although the method of collection was scarcely quantitative, eggs appeared to be about equally abundant for about five miles below the dam. Each "plunge" with the net was successful in taking eggs, with an average yield of about 10 to 15 eggs per attempt. Below this point, eggs were much diminished in number. At some stations (established at about one-half mile intervals in the river) several efforts were required to obtain eggs, and only infrequently were more than six taken in a dip. Diminution in numbers continued to a point 16 miles below the dam, and no eggs were found in a number of collection attempts made in the next mile of stream. The bottom here is sandy with only scattered amounts of gravel of small size and is presumably less suitable for spawning than upstream areas. Examinations were not made between a point 17 miles below Newaygo Dam and the mouth of the river.

It is not known whether or not all fish reach the dam before spawning. If the dams were not present, one may conjecture that many pikeperch would spawn somewhere between a point about 2.5 miles below Newaygo Dam and Rogers Dam, a section of river which has an average drop of 4.6 feet per mile, whereas the lower section of stream, down to Muskegon Lake has a drop of only

about 1.7 feet per mile.* Several writers (Bensley, 1915; Eddy and Surber, 1947; and Derback, 1947) mentioned fast water, riffles, or rapids in their statements concerning pikeperch spawning grounds, and the writer has collected pikeperch eggs in fast water below dams in several streams in Michigan (see below). Cobb (1923) reported that egg-bearing females will not ascend above the first swift water in any numbers, whereas males pass over rapids to a large extent. However, current in the Muskegon River, even in the section of greatest fall, is probably not as swift as that described by Cobb.

Possibly rate of fall is not a factor of great importance in the Muskegon River, however, since apparently many fish spawn in areas downstream from this section of greatest fall, even though a 2.5-mile stretch of it is available to them. Presumably some eggs may be carried or rolled downstream for some distance, but it is unlikely that they would be moved along several miles of the stony bottom before lodging. Conceivably crowding may force a spread of the spawning in the section of stream below the dam. The number of fish present is large. In 1947, the 12 dipnets in use which took 5,540 pikeperch in 12 nights of netting were scattered along 1,078 feet of one bank of the river. When all were set, they covered an area of 1,034 square feet, or 0.37 percent of the river bottom within the upstream and downstream limits of the section of stream within which they were located. Snagging, by means of pulling an unbaited treble gang hook along the bottom was a very productive method of taking fish during the spawning season until 1948, when the section of stream within one-half mile of the dam was closed

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*By interpolation from a profile map (U. S. War Department, 1931)

to fishing during the month of April.

Sections of stream below dams are favored areas for pikeperch spawning. Bensley (1915) reported their preference for streams below waterfalls. In Michigan, viable eggs have been collected in streams immediately below dams not only in the Muskegon River, but also in the Cisco Branch of the Ontonagon River, below Cisco Lake, Gogebic County (May 3, 1947); the West Branch of the Ontonagon River, below Lake Gogebic, Ontonagon County (May 8, 1948); the outlet of Independence Lake, Marquette County (May 2, 1948); and below Alverno Dam in the Black River, Cheboygan County (April 28, 1948).

To summarize, maximum catches (for three-day intervals) of pikeperch in dipnets below Newaygo Dam occurred at water temperatures ranging from 38 degrees to 44 degrees F. during four years of observation. In 1947, male pikeperch averaged 19.1 inches in length; in 1948 this mean was 19.0. The mean length of females was 23.3 inches in 1947 and 23.2 inches in 1948. Females comprised 58 percent of the total fish caught in 1947 and 72 percent of the total in 1948; sex ratios fluctuated widely from day to day during both years. Green, ripe and spent females were present in the catch throughout the netting periods of 1947 and of 1948, but spent fish comprised only a small percentage of the total. Pikeperch eggs were collected throughout the section of river from Newaygo Dam to a point 16 miles downstream, but were concentrated in the area of stream located within 5 miles from the dam.

Movement of tagged yellow pikeperch in the Muskegon River in 1947 and in 1948

The fate of game fish which are transferred to upstream waters during the Newaygo transfer has been a matter for speculation by anglers and interested individuals for many years. During the transfer of 1932 C. J. Hyland tagged 250 game fish which were distributed among four upstream impoundments. In the total were included 172 pikeperch ranging from 10 to 36 inches in length (average, 18.8 inches), 65 rainbow trout with an average length of 24.4 inches, and 13 northern pike with a mean length of 22.9 inches. Number 3 strap tags were used, fastened to the gill covers. Returns were disappointing. Only five recaptures have been reported by anglers. Two of these were of trout and three of pikeperch. Of the latter, one had passed through Big Rapids and Rogers Dams and the other two were caught in the ponds in which they were released (Croton and Hardy).

More extensive tagging programs were undertaken in 1947 and in 1948. During each of these years 1,375 jaw-tagged pikeperch were distributed among the five major upstream impoundments.

Two sizes of tags (Fig.61) were used in the marking of pikeperch in 1947, a No. 3 strap tag, as used at Lake Gogebic (p. 73), and a "Hasco" livestock ear tag, manufactured by the National Band and Tag Company. The No. 3 tag is slightly over 0.5 inch long when in position on the fish, 1/8 inch in width, and has a weight of approximately 0.5 gram. The larger tag (Fig. 62) is slightly over one inch long, 5/16 inch wide, and has an average weight of about 3-1/3 grams. This tag is apparently similar to the one used by Stoudt (1939). The large tags were attached to the lower jaw of 652 large pikeperch, whereas the smaller tags were used on the upper or lower

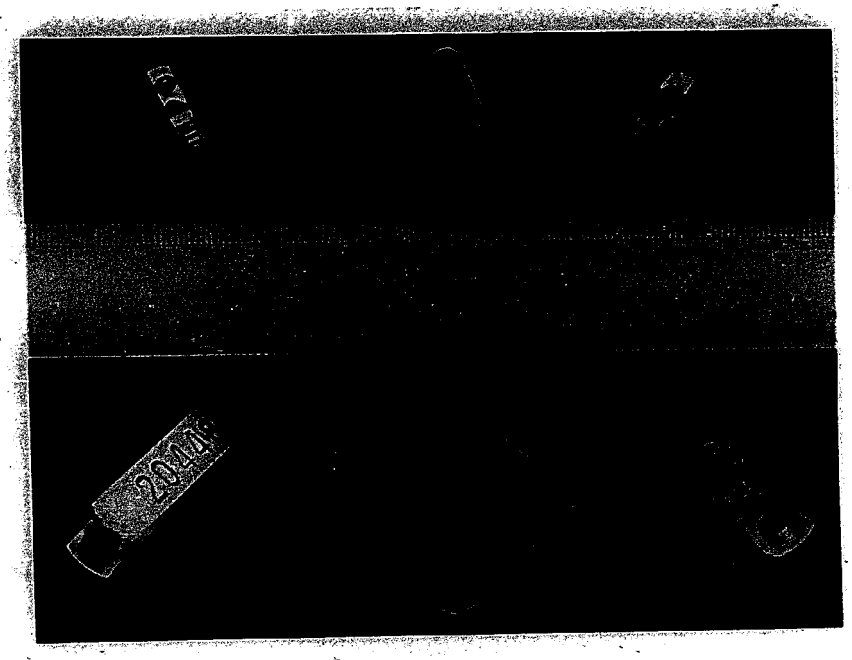


Fig. 61. Two sizes of strap tags used in the marking of yellow pikeperch during the Newaygo transfer of 1947. (Photograph by William Cristanelli).

Fig. 62. A large strap tag in place on the lower jaw of a large pikeperch, Muskegon River, April, 1947.

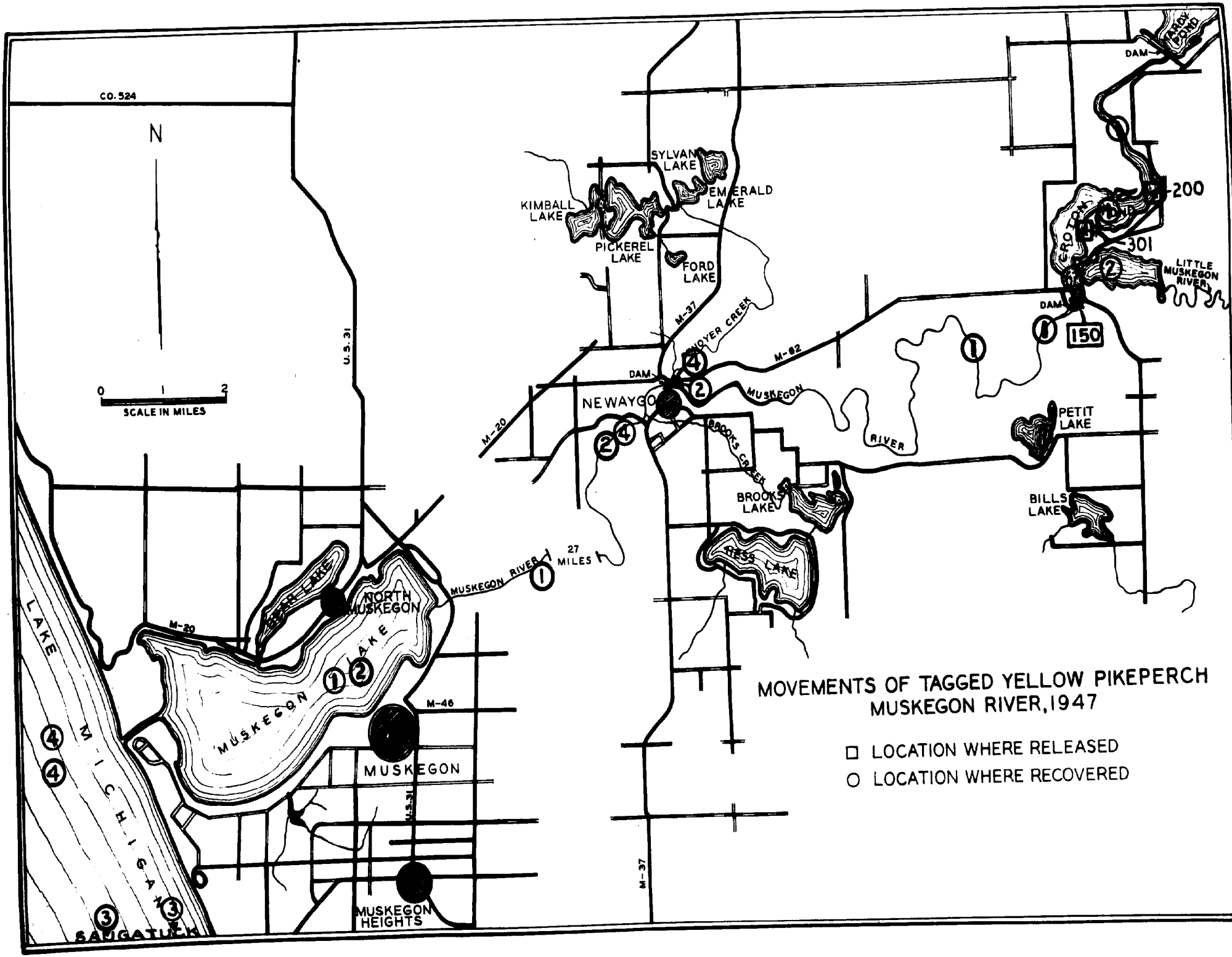
jaw, as at Lake Gogebic (Figs. 28 and 29). In 1948 only the No. 3 tag was used. It was attached to the upper jaw of all fish marked.

Of the 1,375 pikeperch released in the impoundments of the Muskegon River in 1947, 216 (15.7 percent) were recovered by April 15, 1948, and an additional 12 (0.9 percent) were taken between that date and October 15, 1948. The same number of fish released in the same impoundments (but distributed differently) in 1948 yielded a return of 232 (16.9 percent) by October 15, 1948.

Recoveries from 150 tagged pikeperch released just below Croton Dam in 1947 numbered 18 (12 percent) during the first year (Fig. 63). Two fish were recovered in the river above the Newaygo impoundment and 4 were caught in or near the raceway leading to the powerhouse. One was caught by dip-netters below Newaygo Dam during the 1948 transfer and another was taken at the same point by an angler on April 11. These 2 fish had no doubt returned upstream to spawn. Another, probably also on its spawning migration, was taken about 12 miles above Muskegon Lake, on March 27. Two fish were recovered in Muskegon Lake, 4 were caught by commercial fishermen in Lake Michigan near Muskegon, 2 were taken near the mouth of the Kalamazoo River, 93 miles by closest water distance from the place of release, on August 15.

During 1948 there was a return by October 15 of 9.3 percent from 300 fish stocked at a point about 11 miles above Newaygo Dam. Six were recovered at the dam, 5 at various points in the river below the dam, 4 in Muskegon Lake, and 13 in Lake Michigan (Fig. 64). Of the fish reaching the larger lake, 11 were caught within a 2-mile radius of Muskegon (50 to 52 miles from the place of release), 1 was caught near the mouth of the Grand River (62 miles away), and the other was taken in southern Lake Michigan, 2 miles west of the village of Bridgman, after having traveled a minimum of 137

Fig. 63. Locations of release (April, 1947) and of recovery (to April 15, 1948) of tagged yellow pikeperch stocked in the Muskegon River below Croton Dam and in Croton Pond. Numbers inside the rectangles and circles in this and succeeding figures indicate the number of pikeperch released and recovered, respectively, at the locations shown.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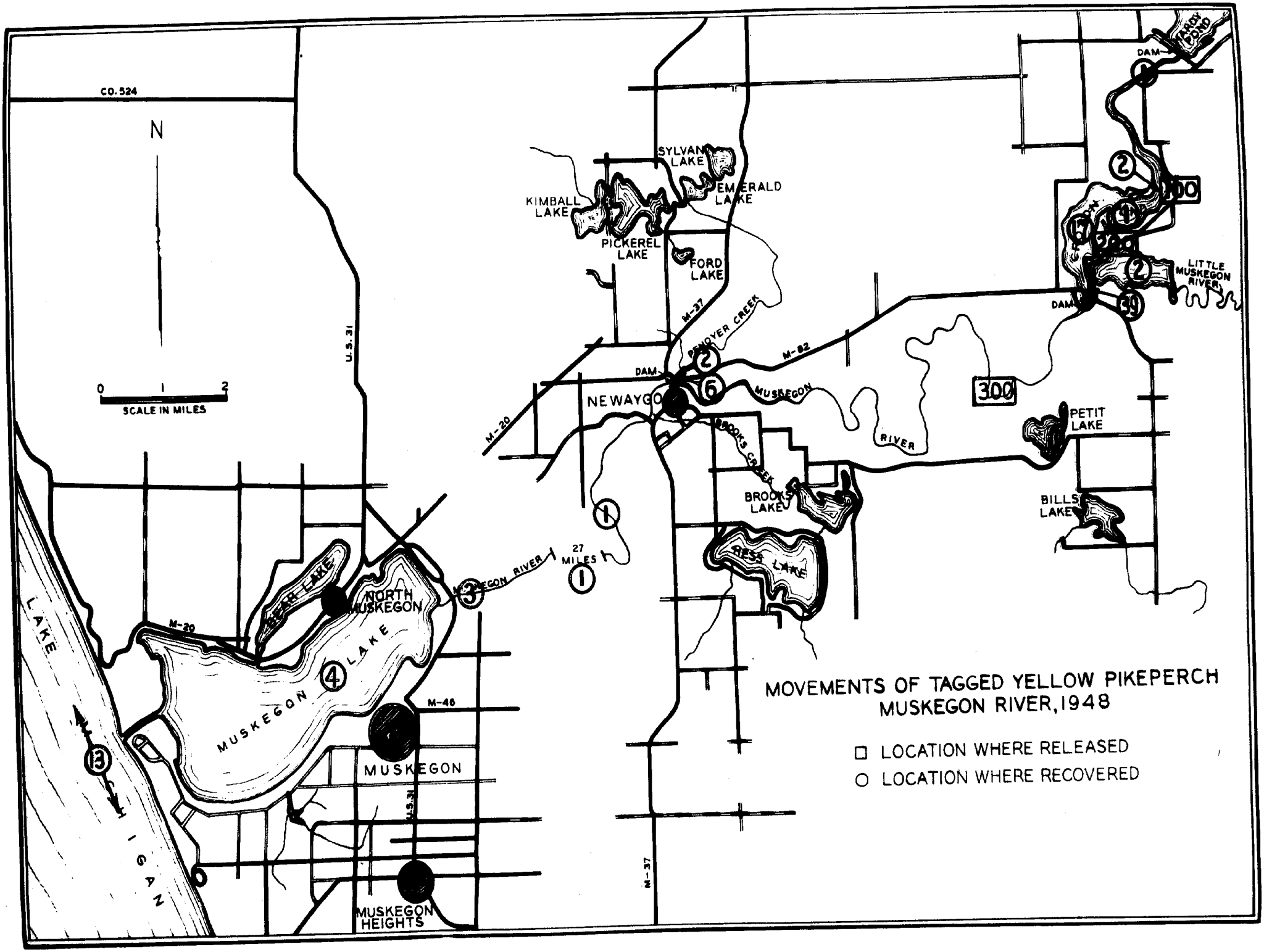
SYLVAN LAKE
KIMBALL LAKE
EMERALD LAKE
PICKEREL LAKE
FORD LAKE
M-37
HOOVER CREEK
M-82
DAM
NEWAYGO
MUSKEGON RIVER
M-20
BROOKS CREEK
BROOKS LAKE
PETIT LAKE
BILLS LAKE
RESS LAKE
TROY POND
DAM
200
301
LITTLE MUSKEGON RIVER
DAM
150
27 MILES
MUSKEGON RIVER
NORTH MUSKEGON
M-20
MUSKEGON LAKE
LAKE MICHIGAN
M-46
MUSKEGON
U.S. 31
MUSKEGON HEIGHTS
M-37
SAUGATUCK
MOVEMENTS OF TAGGED YELLOW PIKEPERCH
MUSKEGON RIVER, 1947
□ LOCATION WHERE RELEASED
○ LOCATION WHERE RECOVERED

Fig. 64. Locations of release (April, 1948) and of recovery (to October 15, 1948) of tagged yellow pikeperch stocked in the Muskegon River below Croton Dam and in Croton Pond.


CO. 524
N
0 1 2
SCALE IN MILES
U.S. 31
SYLVAN LAKE
EMERALD LAKE
KIMBALL LAKE
PICKEREL LAKE
FORD LAKE
M-37
DENYER CREEK
M-82
DAM
NEWAYGO
MUSKEGON RIVER
M-20
BROOKS CREEK
BROOKS LAKE
BESS LAKE
27 MILES
RIVER
300
PETIT LAKE
BILLS LAKE
LITTLE MUSKEGON RIVER
DAM
LAKE
NORTH MUSKEGON
BEAR LAKE
M-20
MUSKEGON LAKE
M-46
MUSKEGON
U.S. 31
MUSKEGON HEIGHTS
M-37
MUSKEGON RIVER
LAKE MICHIGAN
MOVEMENTS OF TAGGED YELLOW PIKEPERCH
MUSKEGON RIVER, 1948
□ LOCATION WHERE RELEASED
○ LOCATION WHERE RECOVERED

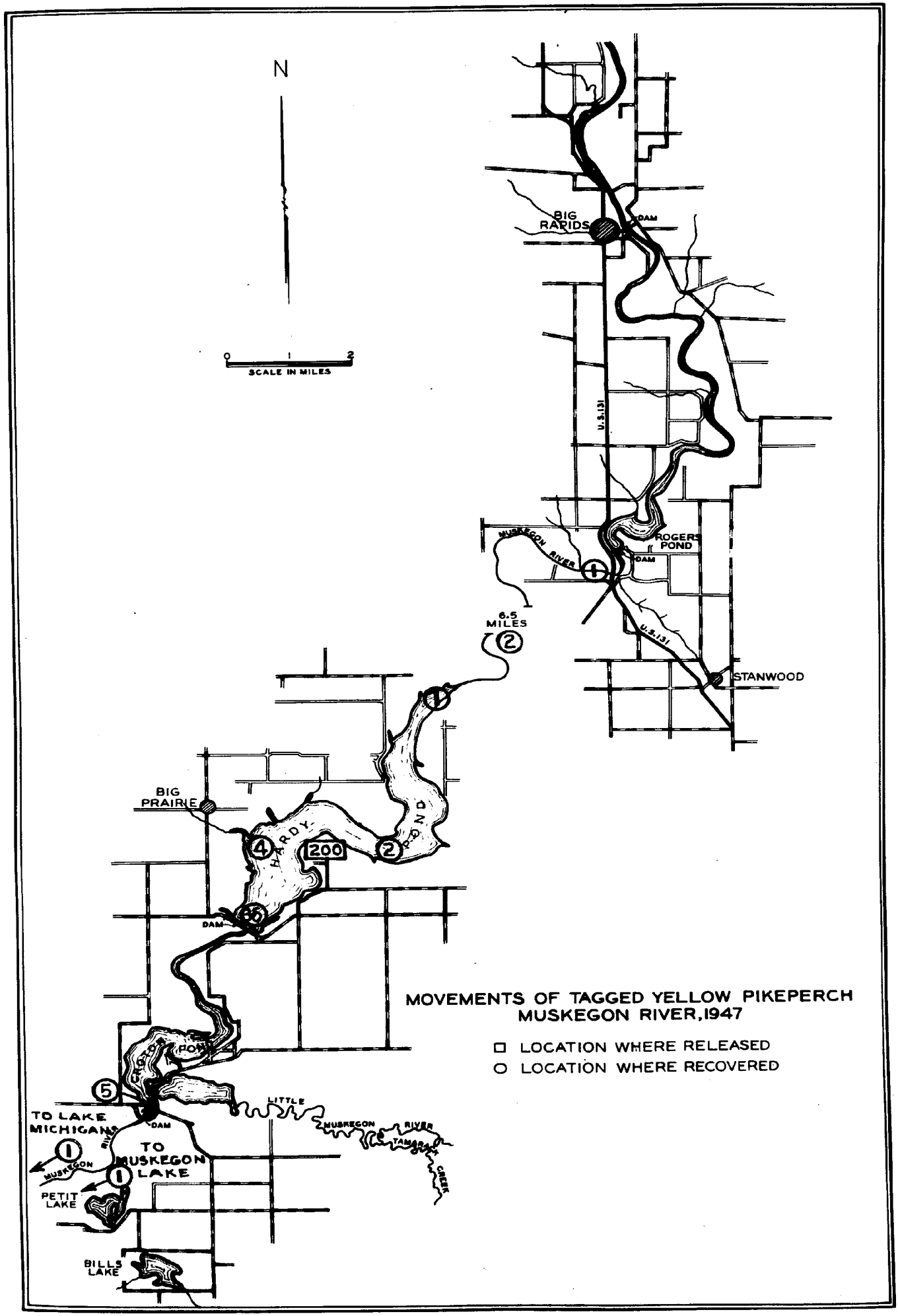
miles in 142 days. This is the greatest distance known to have been traveled by a pikeperch tagged in the Muskegon River.

Sixteen percent of the 501 pikeperch released in Croton Pond in 1947 were recovered during the first year. Of the 80 fish caught, 62 were taken in the pond within 0.5 mile of the dam, and only 3 were taken upstream from the place of release (Fig. 63). Two of these had moved downstream for one mile, and upstream for an equal distance into the impoundment in the Little Muskegon River created by Croton Dam. Of the 14 fish passing downstream through the dam, 2 were caught above Newaygo Dam, 4 were recaptured by dip-netters during the 1948 transfer, 1 was taken in Muskegon Lake, and 7 had reached Lake Michigan. Of the latter, 4 were taken near Muskegon and 3 were caught near the mouth of the Kalamazoo River, about 92 miles from the place of release.

Of 300 fish stocked in Croton Pond in 1948, only two are known to have escaped through or over the dam. These were caught at Newaygo Dam (Fig. 64). Of the 62 caught in the pond, only 3 were caught upstream from the place of release. One was caught just below Hardy Dam, and 2 had gone a short distance up the Little Muskegon River impoundment before they were recaptured. As during 1947, most fish were caught within a relatively short distance from the dam, and 39 were caught at or near the grates protecting the entrance to the power turbines.

Of 200 tagged pikeperch planted in Hardy Pond in 1947, there were 53 returns (26.5 percent) during the first year. Forty-six were caught in Hardy Pond (Fig. 65). Six of these had moved upstream from the place of release, 4 were caught near it, and 36 were taken near the dam, about one mile downstream. Of the remainder, 5 were caught above Croton Dam and 2 negotiated each of the 3 dams downstream from the place of release (Hardy,

Fig. 65. Locations of release (April, 1947) and of recovery (to April 15, 1948) of tagged yellow pikeperch stocked in Hardy Pond.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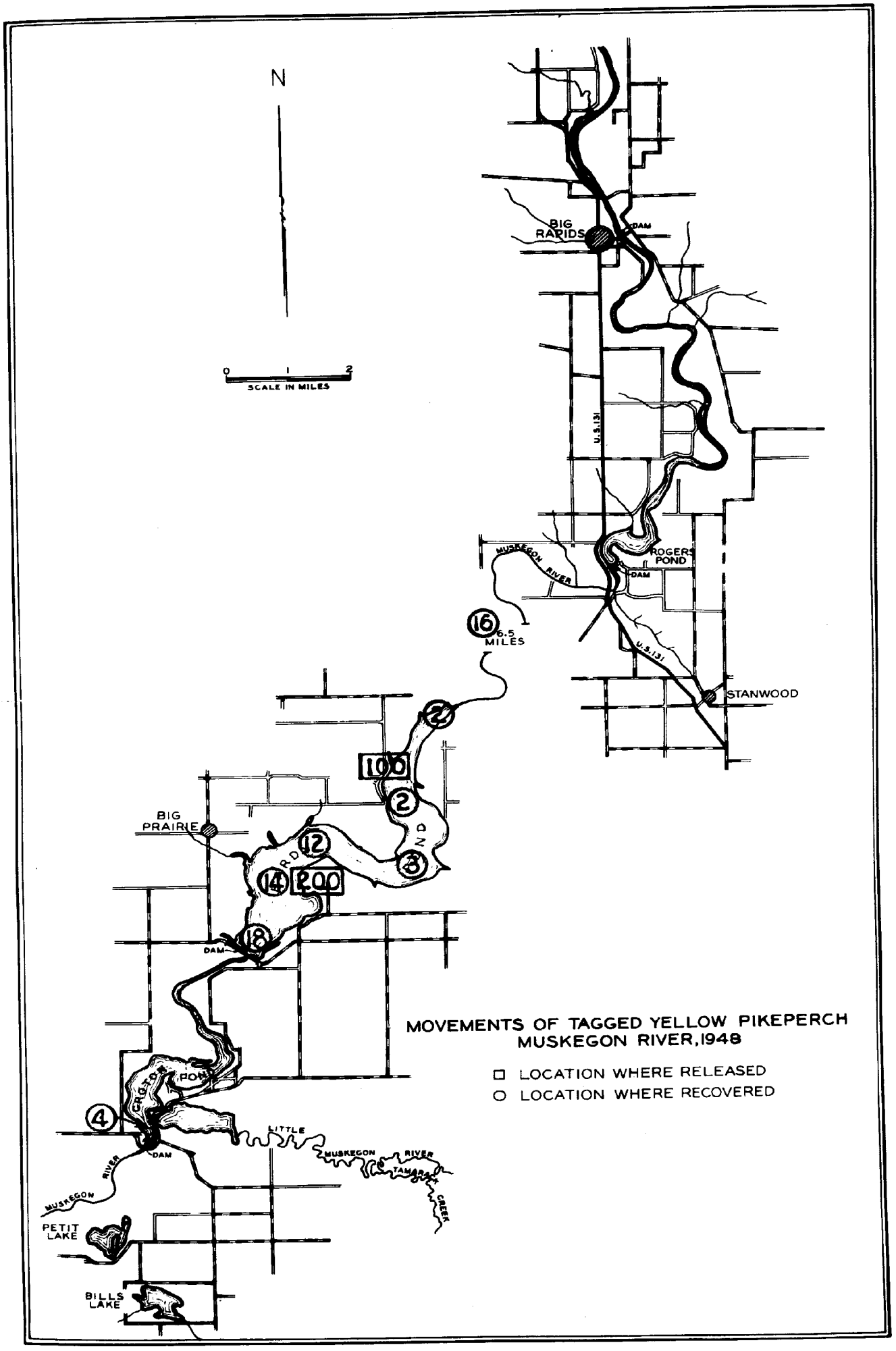
DAM
U.S.131
MUSKEGON RIVER
ROGERS POND
DAM
6.5 MILES
U.S.131
STANWOOD
BIG PRAIRIE
HARDY POND
200
DAM
ROGERS POND
LITTLE MUSKEGON RIVER
TAMARACK CREEK
TO LAKE MICHIGAN
DAM
MUSKEGON RIVER
TO MUSKEGON LAKE
PETIT LAKE
BILLS LAKE
MOVEMENTS OF TAGGED YELLOW PIKEPERCH
MUSKEGON RIVER, 1947
□ LOCATION WHERE RELEASED
○ LOCATION WHERE RECOVERED

Fig. 66. Locations of release (April, 1948) and of recovery (to October 15, 1948) of tagged yellow pikeperch stocked in Hardy Pond.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0 1 2
SCALE IN MILES
BIG RAPIDS
DAM
U.S.131
MUSKEGON RIVER
ROGERS POND
DAM
16
6.5 MILES
U.S.131
STANWOOD
2
100
2
BIG PRAIRIE
3RD
12
3
14
200
18
DAM
GRATON POND
4
LITTLE MUSKEGON RIVER
TAMARACK CREEK
DAM
MUSKEGON RIVER
PETIT LAKE
BILLS LAKE
MOVEMENTS OF TAGGED YELLOW PIKEPERCH
MUSKEGON RIVER, 1948
□ LOCATION WHERE RELEASED
○ LOCATION WHERE RECOVERED

Fig. 67. Locations of release (April, 1947) and of recovery (to April 15, 1948) of tagged yellow pikeperch stocked in Rogers and Big Rapids ponds.

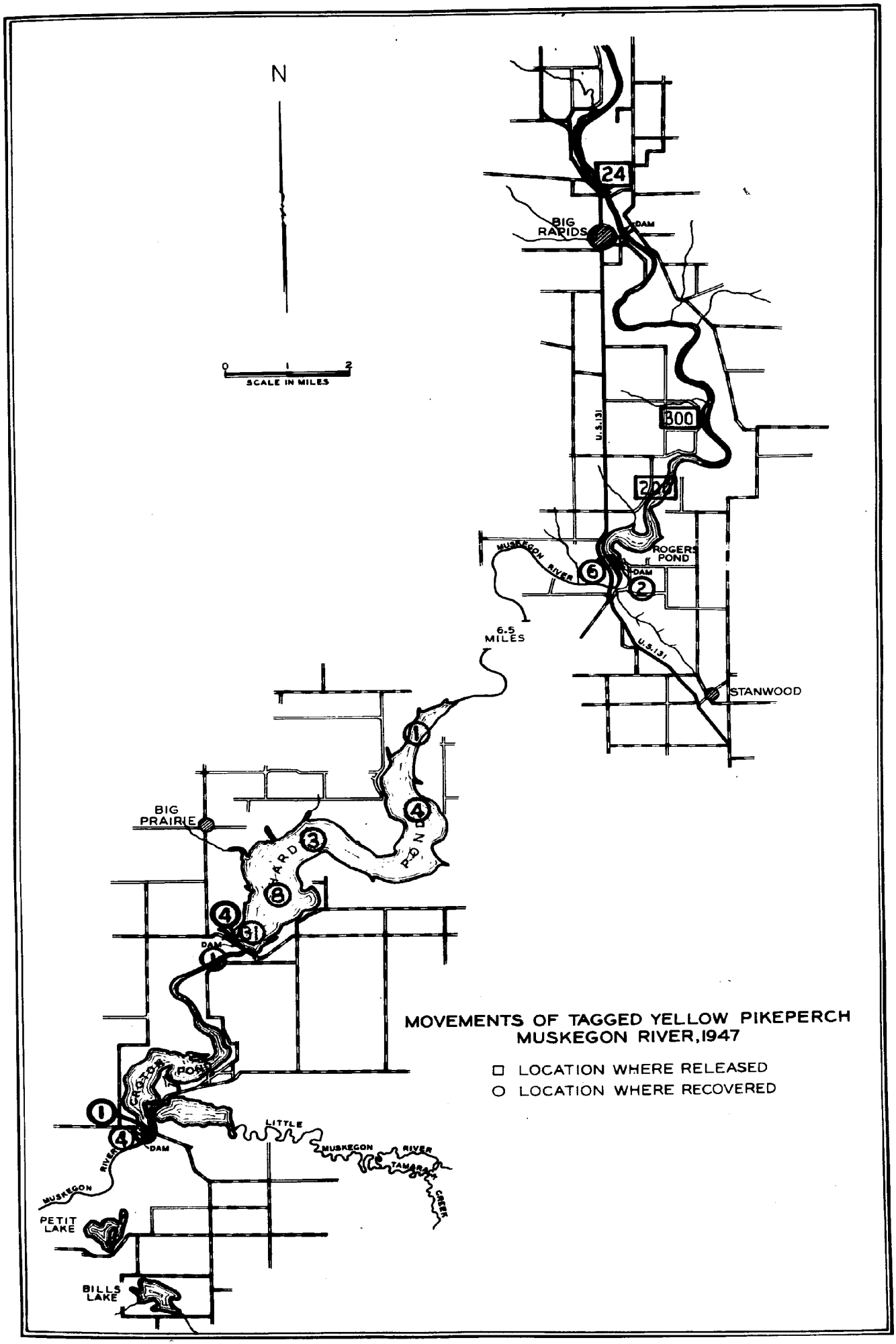

N
0 1 2
SCALE IN MILES
24
BIG RAPIDS
DAM
800
U.S.131
ROGERS POND
DAM
MUSKEGON RIVER
6.5 MILES
STANWOOD
BIG PRAIRIE
DAM
LITTLE MUSKEGON RIVER
TAMARACK CREEK
MUSKEGON RIVER
PETIT LAKE
BILLS LAKE
MOVEMENTS OF TAGGED YELLOW PIKEPERCH
MUSKEGON RIVER, 1947
□ LOCATION WHERE RELEASED
O LOCATION WHERE RECOVERED

Fig. 68. Locations of release (April, 1948) and of recovery (to October 15, 1948) of tagged yellow pikeperch stocked in Rogers and Big Rapids ponds.

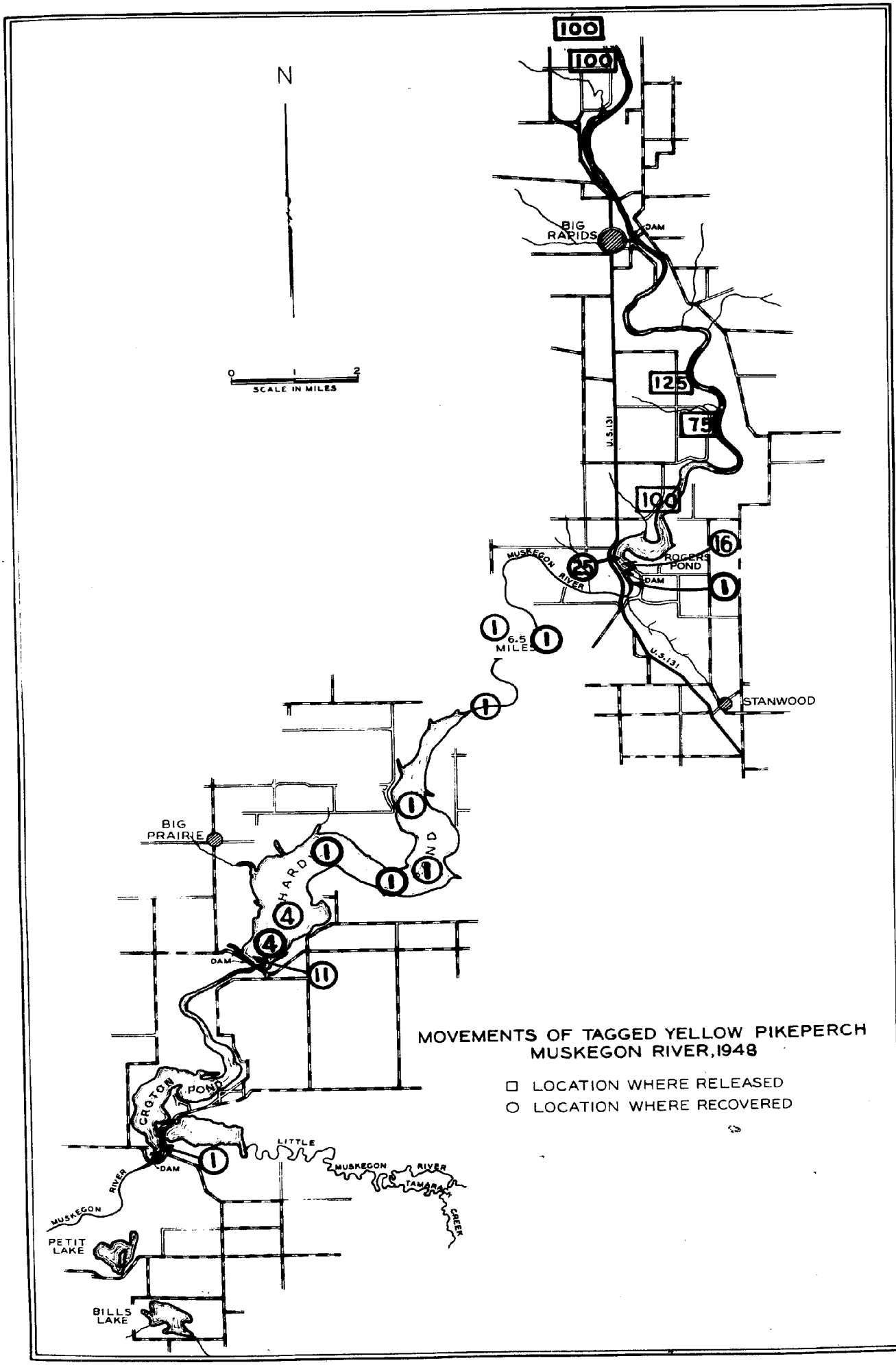

N
0 1 2
SCALE IN MILES
100
100
BIG RAPIDS
DAM
125
75
U.S.131
100
16
MUSKEGON RIVER
25
ROGERS POND
DAM
1
6.5 MILES
1
U.S.131
STANWOOD
1
BIG PRAIRIE
1
HARD POND
1
1
4
4
DAM
11
CROTON POND
1
DAM
LITTLE MUSKEGON RIVER
TAMARACK CREEK
MUSKEGON RIVER
PETIT LAKE
BILLS LAKE
MOVEMENTS OF TAGGED YELLOW PIKEPERCH
MUSKEGON RIVER, 1948
□ LOCATION WHERE RELEASED
○ LOCATION WHERE RECOVERED

Table 31. Summary of recoveries of marked yellow pikeperch, Muskegon River, 1947 and 1948.

Impoundment	April, 1947 - April 15, 1948				April, 1948 - October 15, 1948			
	Number released	Percentage recovered	Percentage of recoveries		Number released	Percentage recovered	Percentage of recoveries	
			Caught in pond in which stocked	Caught elsewhere			Caught in pond in which stocked	Caught elsewhere
Newaygo	150	12.0	33.3	66.7	300	9.3	21.4	78.6
Croton	501	16.0	82.5	17.5	300	21.3	96.9	3.1
Hardy	200	26.5	86.8	13.2	300	23.7	94.4	5.6
Rogers	500	12.0	10.0	90.0	275	13.1	44.4	55.6
Big Rapids	24	20.8	0.0	100.0	200	16.5	0.0	100.0
Totals	1,375	15.7	57.4	42.6	1,375	16.9	65.1	34.9

the recoveries were from the same impoundments in which the fish were released, whereas in 1948 this percentage was 65. The remainder had moved to areas downstream and had passed through one or more power dams.

A summary of the numbers of fish which have been recovered after passing through the various dams is given in Table 32. Results are included for Morley Dam, a 12-foot barrier crossing the Little Muskegon River at a point about 21 miles upstream from Croton Dam. Out of 100 pikeperch stocked in the pond above this structure, 11 were recaptured near the place of release, and 1 was caught just above Croton Dam.

Pikeperch which passed through more than one dam between the time of release and recapture (included in the summary in Table 32) are as follows: 12 passed through Big Rapids and Rogers dams; 1 through Big Rapids, Rogers, and Hardy; 6 through Rogers and Hardy; 2 through Hardy, Croton and Newaygo; and 18 through Croton and Newaygo. Fish tagged in 1947 which were recovered in 1948 are included in the table. They are discussed in further detail below (p. 194).

The data prove that fish of large size are able to negotiate each of the power dams in the main stream of the Muskegon. Carbine and Applegate (1946) reported that three pikeperch tagged at a weir in the Muskegon River, one mile below Houghton Lake, were recovered in the immediate vicinity of (above and below) Big Rapids Dam, a distance of about 130 miles. It is thus apparent that a pikeperch could migrate from Houghton Lake to Lake Michigan, although none is known to have done so.

One is impressed by the inexorable proclivity of the pikeperch introduced into the Muskegon impoundments to move downstream. Of the 448 recoveries during the 18-month study, only 28 were recaptured at a distance of a mile or more above the place of release. In each impoundment, a high

Table 32. Numbers of tagged pikeperch recovered after negotiating dams in the Muskegon River, 1947 and 1948.

Dam passed	Tagged April, 1947		Tagged April, 1948	Totals
	1947*	1948**	1948**	
Newaygo	26	8	22	56
Croton	16	7	2	25
Hardy	13	...	4	17
Rogers	59	1	28	88
Big Rapids	5	...	33	38
Morley	...	...	1	1

*April, 1947, to April 15, 1948
**April 15, 1948, to October 15, 1948

proportion of the fish were taken within a short distance from the dam. In Newaygo, Croton, and Rogers dams, a large proportion of the fish caught each year were taken by dangling baited hooks within a few yards of the grates through which water passes to enter the turbines of the dams. A favorite fishing place at Croton Dam is from the boom which protects the grates from logs and floating debris (Fig. 69). Twenty-five or more persons were seen gathered on the boom on several occasions, fishing in the area below it, and boats were often anchored near-by. A similar boom, also much used by fishermen, is present at Rogers Dam. At Newaygo Dam fishermen concentrate their efforts near the lower end of a narrow raceway leading to the powerhouse. Throughout the impoundments it seems apparent that the fish were striving to complete their normal migration back to Lake Michigan.

The data in Tables 31 and 32 show that the power dams in the Muskegon are either not negotiated with equal ease by fish, or that the degree of compulsion to migrate through them varies. One would expect that Hardy Dam would be the most difficult of the structures to pass successfully. It is not only the highest of the barriers, but no water was spilled during 1947 and 1948, so that fish escaping from the impoundment had to pass through the turbines. Although fish probably pass through the power developing units of the other dams as well, water is sometimes spilled over or through these barriers. It may be pertinent, however, that Hardy Pond is the largest and deepest of the impoundments and that it is only in this reservoir that any appreciable numbers of tagged fish were caught in the areas upstream from the immediate vicinity of the dam (Figs. 65 to 68). Conceivably the better habitat provided in this reservoir is responsible for the relatively few fish moving downstream through the dam. The almost equally small percentage of escapement from Croton Dam is not so easily explained.

Fig. 69. Powerhouse at Croton Dam, Muskegon River, showing boom which protects intake channel, and from which many tagged pikeperch were caught in 1947 and in 1948.

The impoundment ranks second in size and depth among the five impoundments, and thus might be more attractive to pikeperch than the remaining three. However, unusual numbers of fish taken in Croton Pond were caught near the dam, as mentioned above, suggesting that they might be attempting to move through the structure. Furthermore, an interpretation of percentage of escapement based on size and depth of the impoundment does not explain the failure of fish to pass through the 12-foot Morley Dam. Perhaps unrecognized differences in the construction of the various dams, or unappreciated physical or biological conditions, are important factors in determining the amount of escapement from the impoundments.

Of the tagged fish planted in the impoundments in 1947, there were only 12 returns (0.9 percent) between April 15 and October 15, 1948; 9 of these had descended at least to Muskegon Lake. Two which had been stocked in Newaygo Pond were caught in Lake Michigan, 1 near Muskegon and the other near the mouth of the Kalamazoo River. Seven out of 8 recoveries from fish which were stocked in Croton Pond were taken in downstream areas: 1 above Newaygo Dam, 1 at a point 4 miles below the dam (during the 1948 spawning run), 1 in Muskegon Lake, and the remainder in Lake Michigan. Two of the latter were caught near Muskegon, 1 was taken 7 miles north of Muskegon, and another was caught 2 miles upstream from the mouth of the St. Joseph River (on July 10), 132 miles from the place of release. Of fish planted in 1947, 2 were recaptured in Hardy Pond after April 15, 1948: 1 had been stocked in Rogers Pond, the other in Hardy.

The cause for the small return during 1948 from the 1947 tagging is not known. Natural mortality among the large fish transferred to a new environment is probably high. The number of tags lost is not known, but is believed to be small. Smaller fish tagged by a similar method and released

in the Inland Waterway, Emmet and Cheboygan counties, yielded returns which extended over a seven year period (Table 34). The number of fish which are destroyed while attempting to negotiate the structures is also unknown. Reports of mangled fish below the dams, received by the Department of Conservation from time to time, indicate that not all fish are successful in negotiating the structures.

Of 3,000 native pikeperch tagged in 1937 in Lake Winnibigoshish, Minnesota, there was a return of about 13 percent during that year, 5 percent in 1938, 3.5 percent in 1939, and 1 percent in 1940 (Eddy and Surber, 1947). The fish introduced in the Muskegon impoundments showed a higher return during the first year, but present indications are that returns in succeeding years will be very small.

Some indication of the nature of the downstream migration of Muskegon pikeperch was obtained by an analysis of recoveries of fish which were tagged at the time of the 1948 Newaygo transfer and released in the river at the point of tagging, slightly over 0.5 mile below Newaygo Dam (Table 33).

The speed with which pikeperch return to Lake Michigan varies greatly. The first tagged fish recovered in Lake Michigan was taken near Muskegon on May 20, whereas another was caught only 2.5 miles below Newaygo Dam on May 24. Both were ripe females at the time of tagging, on April 17 and April 21, respectively. There were no returns from the river after June 1 (except for one fish which was taken near the mouth in August), suggesting that by this time most fish had left the river and had returned either to Muskegon Lake or to Lake Michigan. Reports indicate good fishing for pikeperch in the river during May, but few adults are taken here in the summer. These data agree with the findings of Eddy and Surber (1947) who reported that the adults stay in the headwaters for from 3 to 6 weeks after spawning and then

Table 33. Recoveries from 292 tagged yellow pikeperch released 0.5 mile below Newaygo Dam, Muskegon River, April 17 to 22, 1948.

Date of capture	Days out	Minimum miles travelled	Miles per day	Place of capture
April 20	2	2	1.0	2.5 miles below Newaygo Dam.
April 24	6	1	0.2	1.5 miles below Newaygo Dam.
May 20	29	2	0.1	2.5 miles below Newaygo Dam.
May 18	31	31	1.0	2 miles above Muskegon Lake.
May 20	33	40	1.2	Lake Michigan, near Muskegon.
May 24	33	1	0.0	2.5 miles below Newaygo Dam.
May 31	39	116	3.0	St. Joseph River, near mouth.
June 1	44	32	0.7	1 mile above Muskegon Lake.
June 12	55	81	1.5	Kalamazoo River, near New Richmond.
June 16	56	76	1.4	Kalamazoo River, near mouth.
June 16	60	40	0.7	Lake Michigan, near Muskegon.
June 24	68	40	0.6	Lake Michigan, near Muskegon.
July 3	77	40	0.5	Lake Michigan, near Muskegon.
July 9	79	34	0.4	Muskegon Lake.
July 7	81	40	0.5	Lake Michigan, near Muskegon.
July 8	81	34	0.4	Muskegon Lake.
July 10	84	34	0.4	Muskegon Lake.
July 12	86	51	0.6	Grand River, near mouth.
July 15	88	51	0.6	Grand River, near mouth.
July 18	91	34	0.4	Muskegon Lake.
July 23	96	76	0.8	Kalamazoo River, near mouth.
August 1	105	46	0.4	Lake Michigan, north of Muskegon.
August 3	107	40	0.4	Lake Michigan, near Muskegon.
August 16	120	114	1.0	St. Joseph River, near mouth.
August 21	126	31	0.3	2 miles above Muskegon Lake.
September 10	145	40	0.3	Lake Michigan, near Muskegon.
September 19	151	40	0.3	Lake Michigan, near Muskegon.
September 19	154	40	0.3	Lake Michigan, near Muskegon.

return to the main body of water.

One fish released below Newaygo Dam was recovered at a point near the mouth of the St. Joseph River on May 31. It had covered a minimum distance of 116 miles within 39 days, for an average rate of travel of 3 miles per day. This is the fastest movement recorded for pikeperch tagged in the Muskegon River.

Of the 28 recoveries (9.6 percent) from the 292 fish released below the dam, 7 were taken in various portions of the river, 4 were caught in Muskegon Lake, 9 were trapped by commercial fishermen within a two-mile radius of Muskegon and the remainder had moved to other areas in Lake Michigan. One had traveled 6 miles north along the shore of the lake, 2 were taken near the mouth of the Grand River (51 miles from the place of release), 3 were caught at or near the mouth of the Kalamazoo River (76 to 81 miles away), and 2 were taken within 2 miles from the mouth of the St. Joseph River, after moving from 114 to 116 miles.

Considering the average of all fish recaptured, the pikeperch released below Newaygo Dam had moved from this point to their point of recapture at the rate of 0.6 mile per day. Five had traveled at the rate of 1 mile per day or more.

Since, as noted above, Newaygo Dam offers relatively little resistance to downstream migration of fish, additional information concerning the speed of migration can be gleaned from a study of recaptures of tagged fish released in this impoundment. In 1947, 10 fish for which both dates and locations of capture are known also moved from the place of release to the place of recapture at an average rate of 0.6 mile per day. (Fish caught during the spring of 1948, which were obviously returning on the upstream migration are not included in this average.) In 1948, 26 fish planted

between Newaygo and Croton Dams moved to their place of recapture at the rate of 0.5 mile per day. Five moved at the rate of 1 mile per day or more.

The average rate of downstream migration of pikeperch in the Muskegon River after the spawning season in 1947 and in 1948 probably exceeded 0.5 mile per day since this is a minimum figure. Many fish were not yet through spawning at the time of tagging, so probably did not begin moving to the place of capture immediately; undoubtedly others were not caught on the date of their arrival at the place of capture. The fact that the peak of the spawning season occurred on April 11 to 14, and that most pikeperch had apparently left the stream by early June, would suggest that the 39-mile trip down the river was made at a rate of about a mile a day or more.

The location of recapture of fish tagged in the Muskegon River reveals that many fish which spawn in this stream probably originate from southern Lake Michigan. After returning to the lake, many frequent the mouths of the Muskegon, Grand, Kalamazoo and St. Joseph Rivers. Some either remain in Muskegon Lake throughout the summer, or range between it and Lake Michigan during this period.

In summary, there was a return during the first year of 15.7 percent from 1,375 tagged pikeperch released in the Muskegon River impoundments in 1947, and an additional return of 0.9 percent by October 15, 1948. The release of the same number of marked fish in 1948 yielded a return of 16.9 percent by October 15. Returns from fish stocked in the various reservoirs ranged from 9.3 percent (Newaygo Pond, 1947) to 26.5 percent (Hardy Pond, 1947). Only 6 percent of all fish recaptured were taken at points upstream from the place of release. Downstream movements were for distances as great as 137 miles and involved the passing of as many as 3 power dams. In 1947, 43 percent of the fish recaptured had passed through one or more of the

structures; in 1948 this percentage was 35. Returns from tagged pikeperch released below Newaygo Dam in 1948 indicated that most fish had left the Muskegon River by early June. Fifty-nine percent of the recoveries from this planting were from Lake Michigan. Most of these were taken near the mouths of the Muskegon, Grand, Kalamazoo and St. Joseph rivers.

Migration of pikeperch in inland lakes

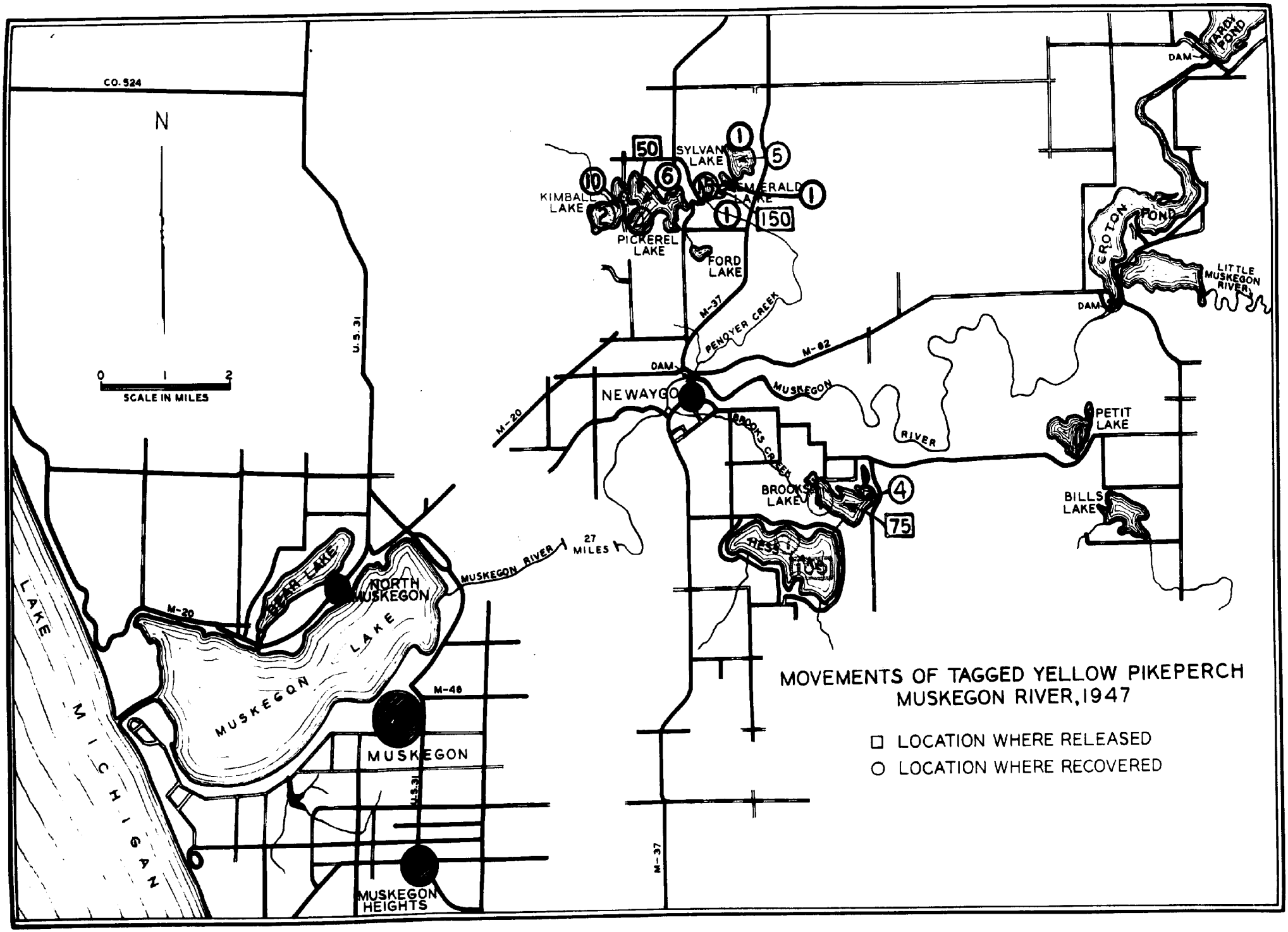
In connection with the 1947 Newaygo transfer, tagged pikeperch were stocked in the north and south Newaygo lakes. The north Newaygo lakes consist of four small (83 to 318 acres), broadly connected, deep (maxima of from 49 to 73 feet) bodies of water with part or nearly all of their bottoms composed of marl. They drain into the Muskegon River via a small stream, Penoyer Creek. The south Newaygo lakes are composed of two shallow bodies of water (26 feet maximum depth), Hess and Brooks lakes. These lakes have areas of 1,125 acres and 293 acres respectively and are in large part choked with vegetation. They are connected and drain into the Muskegon River via a small stream, Brooks Creek.

Of 200 tagged pikeperch released in the north Newaygo lakes in 1947, 45 (22.5 percent) were recovered. The recaptures reveal that the fish moved about freely among the four bodies of water during the course of the season, with some recaptures occurring in each (Fig. 70).

Of 175 pikeperch released in the south Newaygo lakes, only 12 (6.9 percent) were recovered. One traveled from Hess to Brooks Lake, whereas the others were recovered in the same lake in which released (Fig. 70).

No fish is known to have returned to the Muskegon River after being stocked in either the north or south Newaygo lakes.

Fig. 70. Locations of release (April, 1947) and of recovery (to April 15, 1948) of tagged yellow pikeperch stocked in the Newaygo lakes.


CO. 524
N
0 1 2
SCALE IN MILES
U.S. 31
50
SYLVAN LAKE
KIMBALL LAKE
PICKEREL LAKE
FORD LAKE
EMERALD LAKE
150
M-37
PENOYER CREEK
M-82
DAM
NEWAYGO
MUSKEGON RIVER
M-20
BROOKS CREEK
BROOKS LAKE
75
105
PETIT LAKE
BILLS LAKE
HARDY POND
CROTON POND
LITTLE MUSKEGON RIVER
27 MILES
BEAR LAKE
NORTH MUSKEGON
LAKE MICHIGAN
MUSKEGON LAKE
M-48
MUSKEGON
MUSKEGON HEIGHTS
MOVEMENTS OF TAGGED YELLOW PIKEPERCH
MUSKEGON RIVER, 1947
□ LOCATION WHERE RELEASED
○ LOCATION WHERE RECOVERED

In Cheboygan County a dam blocks the Cheboygan River near its mouth and prevents upstream migration of pikeperch from Lake Huron. An operation known as the "Cheboygan transfer," similar to the Newaygo transfer, has been carried on for over 20 years. Fish are caught in trap nets by commercial fishermen, under supervision of the Department of Conservation. They are transferred to the various upstream lakes and their connecting streams which together compose the "Inland Waterway System" (Fig. 71).

In connection with the Cheboygan transfer, 213 pikeperch were tagged in 1931, but only 3 recoveries were obtained. In 1932, a total of 2,154 was tagged and 29 recoveries were secured (Shetter, 1937). Tags used in both studies were attached to the gill covers. It was observed that in general fish dispersed in all directions from all points of release. One fish merely transferred over the dam continued its upstream migration as far as Crooked Lake, whereas another was later recaptured in Lake Huron. One fish transferred to Crooked Lake was recaptured in the nets below Cheboygan Dam before the transfer operation had been completed (Michigan Conservation, 1932). The longest interval between the time of tagging and recovery was 193 days.

In 1942, 568 pikeperch averaging 14.2 inches in total length were jaw-tagged by D. S. Shetter and W. R. Crowe during the Cheboygan transfer, and were distributed among 6 locations in the various parts of the inland waterway. Records of plantings and the recoveries which were made from 1942 to 1948 are shown in Table 34 and in Figure 71. During the period, 59 (10.4 percent) of the fish were recovered by anglers.

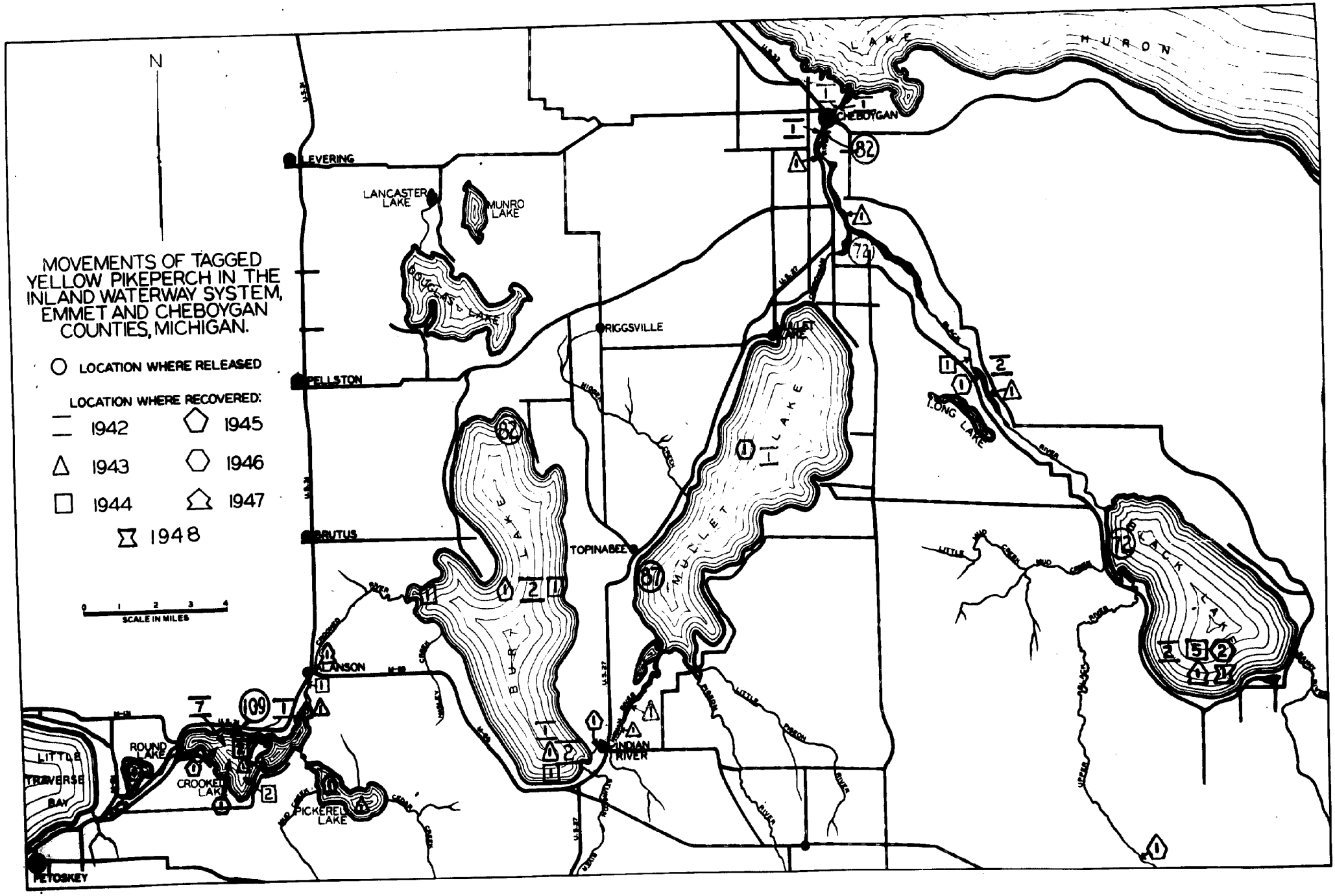
Of 82 pikeperch stocked one-quarter mile above Cheboygan Dam and 72 planted four miles above this barrier, there were only 5 recoveries. Most fish in these plantings probably returned to Lake Huron. Poor recovery of

Table 34. Summary of returns from tagged yellow pikeperch* transferred to the Inland Waterway from the Cheboygan River below Cheboygan Dam in 1942.

Date of release 1942	Number	Average total length, inches	Place of release	Returns 1942	1943	1944	1945	1946	1947	1948	Total recoveries	Percentage recovery	Average time out Years	Days	Average distance travelled, miles
Mar. 31	109	13.0	Crooked Lake	7	1	2	2	1	2	...	15	13.8	2	13	1.5
Apr. 14	82	14.3	Cheboygan River, ¼ mile above Cheboygan Dam	1	1	...	...	...	...	...	2	2.4	...	245	7.5
Apr. 15	72	14.4	Cheboygan River, 4 miles above Cheboygan	2	1	...	...	...	...	...	3	4.2	...	320	7.7
Apr. 16	136	14.4	Black Lake	5	3	5	1	3	1	1	19	14.0	2	104	5.4
Apr. 17	87	14.2	Mullett Lake	1	1	3	2	1	...	...	8	9.2	2	144	7.9
Apr. 21	82	14.7	Burt Lake	5	2	4	...	...	...	...	11	13.4	1	71	10.7
Incomplete data		...	...	...	...	...	1	...	...	...	1	...	...	...	...
Totals	568	14.2		21	8	15	6	5	3	1	59	10.4	1	329	5.8

*One northern pike, 24 inches long, and a 16.3-inch sauger were also tagged and transferred to Black Lake on April 16. The northern pike was caught by an angler, at Black Lake, 26 days after release.

Fig. 71. Locations of release (April, 1942) and of recovery (to October 15, 1948) of tagged yellow pikeperch stocked in the Inland Waterway System, Emmet and Cheboygan counties.


N
MOVEMENTS OF TAGGED YELLOW PIKEPERCH IN THE INLAND WATERWAY SYSTEM, EMMET AND CHEBOYGAN COUNTIES, MICHIGAN.
LOCATION WHERE RELEASED
LOCATION WHERE RECOVERED:
1942
1943
1944
1945
1946
1947
1948
SCALE IN MILES
LAKE HURON
CHEBOYGAN
EVERING
LANCASTER LAKE
MUNRO LAKE
BURT LAKE
RIGGSVILLE
MULLETT LAKE
PELLSTON
BRUTUS
TOPINABEE
LONG LAKE
BLACK LAKE
LITTLE TRAVERSE BAY
ROUND LAKE
CROOKED LAKE
PICKEREL LAKE
INDIAN RIVER
PETOSKEY

tagged fish would be expected in this larger water, since only 4 out of 198 pikeperch of similar size tagged in Saginaw Bay in 1942 were subsequently recovered.

A good share of the remainder of the fish transferred in 1942 apparently remained in the Inland Waterway System and contributed to the fishery for a period of several years. Of 19 recoveries from 72 fish stocked in Black Lake, 11 were caught in the lake, 7 at points downstream, and 1 about 12 miles upstream in the Black River. Of 87 fish released in Mullet Lake, only 1 was recovered in this water, 1 in the Black River, and 6 in or near Burt Lake. Five of 82 fish stocked in Burt Lake were caught there, and 6 moved to upstream waters. Of 109 fish stocked in Crooked Lake, 13 were caught in or near the lake, 1 was taken in Round Lake, and another was recaptured in Pickerel Lake.

The average interval between release and recapture for the 59 fish reported was almost 2 years and the average distance between the place of release and of recapture was 5.8 miles (Table 34).

Tagged pikeperch transferred to the Inland Waterway System did not show the proclivity to return to the lake of their origin which was exhibited by fish planted in the Muskegon River impoundments. Although they had relatively easy access to Lake Huron via broad connecting waters, many of the fish remained in the inland lakes and streams and contributed to the fishery there for a period of seven years.

On April 28 and 29, 1948, 300 native pikeperch were tagged in Burt Lake. By October 15, 19 of these had been recaptured by anglers. Fourteen were taken in Burt Lake, 1 in Pickerel Lake, 1 in the Indian River, and 3 in the Sturgeon River. One of the latter had traveled 8 miles upstream. Returns during future years may verify the indication that the movement of

pikeperch native to Burt Lake is as extensive as that of fish introduced from Lake Huron.

The movements of marked pikeperch in the Muskegon River, the Newaygo lakes, and the Inland Waterway System show that the pikeperch is a wide-ranging species. This has also been demonstrated by other workers. Stoudt (1939) said that pikeperch range extensively and distribute themselves over the entire lake after spawning. Dean (1942) obtained a return of 1.8 percent from 1,248 pikeperch tagged in Lake Erie. Most of these had moved from 16 to 32 miles between the time of release and recapture, and one traveled from South Bass Island, in western Lake Erie, to Irving, New York, a distance of about 200 miles. Eddy and Surber (1947) stated that the pikeperch is a great traveler, and that tagged specimens have been caught within a few months at distances of 70 to 100 miles from the place of tagging.

SUMMARY

1. Lake Gogebic is a large, shallow lake located in the western part of the Upper Peninsula of Michigan. It has soft, brown water which is neutral in reaction, has little aquatic vegetation, and has a stony shoreline.

2. Yellow pikeperch now strongly predominate in a fish population which contains few forage species. Formerly the lake was dominated by smallmouth bass and later by northern pike.

3. The principal spawning grounds of yellow pikeperch in Lake Gogebic extend almost without interruption for a distance of over 10 miles along the leeward east shore of the lake. The bottom in this area is composed of a mixture of gravel, rubble, and boulders, with a substratum of sand and fine gravel.

4. Little-used spawning grounds occur along the north shore of the lake, among submerged rocks forming the riprap for a railroad grade. Some fish probably spawn in the outlet, but none are believed to spawn in inlet streams.

5. Areas with a bottom composed only of sand are rejected by spawning pikeperch in Lake Gogebic and in two other Gogebic County lakes studied.

6. Areas of shoreline in Lake Gogebic with a bottom type similar to that of the principal spawning grounds are not frequented by spawning pikeperch, possibly due to less favorable exposure, resulting in a less cleanly washed bottom. Exposure is not significant in four other lakes examined.

7. Spawning females usually broadcast their eggs at night in water

which is three feet or less in depth, in the company of one or more males. Spawning may be quiet and leisurely or may be accompanied by vigorous milling and splashing about. Rarely, spawning occurs during the day. Male pikeperch congregated on the spawning grounds have a patternless distribution and are nearly motionless or swim slowly about over the shoals.

8. Pikeperch are negatively phototropic, a reaction probably related to the structure of their eyes. This response is believed to account for their nocturnal spawning habits and to explain their avoidance of shallow areas (streams or lake shoals) except at night or during the spawning migration.

9. During years with average weather conditions, small numbers of pikeperch appear on the shoals soon after the ice leaves Lake Gogebic, reach a peak of abundance during about the first week in May when water temperatures range between 45 degrees to 50 degrees F., and then decline in numbers.

10. In 1947, when the break-up of the ice occurred about two weeks later than usual, an estimated 19,000 pikeperch were on the shoals on the night of the date of the break-up. Shoal water temperature was 34 degrees F.

11. Counts on representative samples of shoreline in 1942 and in 1947 indicated a maximum of 22,000 pikeperch (probably mostly males) on the shoals during the peak of the spawning season.

12. In 1942 and in 1947, the decrease in numbers after the peak of the spawning season was reached was more rapid than the increase in numbers up to that maximum, although a few fish remained for two weeks or more after the season's peak.

13. Male pikeperch composed 89 percent of the catch in trap nets set on the spawning grounds at Lake Gogebic from May 8 to May 27, 1947. The percentage of males varied from day to day, the lowest proportion occurring

near the height of the spawning season (May 15), when males comprised 72 percent of the catch. No mature female pikeperch were taken after May 16.

14. In 1947, trap net catches showed that males were the first to arrive on the spawning grounds in numbers and that they remained on the area for a number of days after the females had left.

15. Green, ripe, and spent females were present on the spawning beds throughout the period when females were netted in 1947. Green fish were most numerous early in the season and the highest proportion of ripe females was taken just before the peak of the spawning season.

16. Spawning male pikeperch exhibited no established territoriality, but showed a general movement in both directions along the spawning beds in Lake Gogebic in 1947. Movement was for distances as great as 5 miles and recaptures were at intervals as great as 13 days. Pikeperch dispersed widely in Lake Gogebic following aggregation on the spawning grounds.

17. Adult male pikeperch measured at the spawning grounds at Lake Gogebic in 1947 ranged from 12.2 to 22.1 inches in length and averaged 16.9 inches. Mature females ranged from 15.4 to 28.8 inches and had a mean length of 18.8 inches.

18. Small males left the spawning grounds before the large fish, whereas females taken in the nets averaged larger before May 12 than after that time.

19. Yellow pikeperch comprised 99.8 percent of all fish taken in trap nets on the spawning grounds at Lake Gogebic between May 8 and May 27, 1947.

20. As compared to testes of pikeperch, ovaries are more heavily pigmented (in small fish), more bluntly tapering anteriorly, more transparent, and have more conspicuous transverse venation. The dorsal blood vessel of the testes of mature males is located in a groove, whereas in ovaries it is

at the surface.

21. Developing eggs are visible through the ovary wall of most mature females by mid-August at Lake Gogebic. Residual eggs are also present in some ovaries at this time, although these were not observed in specimens collected in October.

22. By mid-October ovaries and testes are of about equal size and weight, ranging from 3.1 to 7.9 percent and from 3.2 to 5.7 percent, respectively, of the body weight.

23. In Lake Gogebic females, the ovaries averaged 0.7 percent of the body weight in August. Just before spawning, ovaries averaged from 17.3 percent of the body weight (31 fish from Lake Gogebic) to 27.9 percent (5 large fish from Saginaw Bay).

24. In males, the testes averaged 0.2 percent of the body weight in August. In three males collected before and during the spawning season at Lake Gogebic this figure was 3.0 percent.

25. There is a wide variation in egg production among females of similar size. Estimates of egg production made by the weight method showed that in Lake Gogebic fish ranging from 16.0 to 22.7 inches in length yielded an average of 28,503 eggs per pound of fish. For fish of larger size from the Muskegon River and from Saginaw Bay, the averages were 41,188 and 41,667, respectively. Maximum egg production noted was 615,166 in the ovaries of a 31-inch, 13-pound-4-ounce specimen from Saginaw Bay.

26. Residual eggs averaged 0.3 percent of the total estimated egg production in five of six Lake Gogebic pikeperch examined after spawning.

27. Soon after spawning begins at Lake Gogebic there are recognizable on the spawning grounds: viable eggs containing embryos; egg shells; opaque white or gray dead eggs; and fungused eggs.

28. Viability percentages of eggs in collections made in three lakes during the spawning season ranged from 17 to 72 and averaged 50 for two samples from Lake Gogebic. There is wide local variation in percentage of viability of eggs on the spawning grounds; the percentage varies also with progress of the season.

29. Loss of eggs by predation is believed to be of negligible importance in the economy of Lake Gogebic pikeperch.

30. Young pikeperch leave shoreward areas after hatching and probably lead a pelagic existence until they are about an inch or more in length, re-entering the shoals in late June or early July.

31. Young pikeperch may be participating members of schools of yellow perch, or may form schools of their own. After early August they are usually found in areas sheltered by vegetation or in deep water, rather than on the shallow, barren, sandy shoals which they occupy earlier.

32. Pikeperch in Lake Gogebic attained a length of 4.8 and 4.7 inches near the end of the first season of growth in 1946 and in 1947, respectively. This is a smaller size than that attained by the species in most localities investigated.

33. Food of young pikeperch in Lake Gogebic is composed mostly of fish, particularly yellow perch.

34. The Muskegon River is located in west-central Michigan and connects Houghton Lake with Lake Michigan. Power dams ranging from 16 feet to 100 feet in height cross the river at five points between the villages of Newaygo and Big Rapids. Newaygo Dam, the farthest downstream, is 39 miles above the mouth of the river. The others, in ascending sequence, are Croton, Hardy, Rogers, and Big Rapids dams.

35. In the spring large numbers of pikeperch and, to a lesser extent,

other species ascend the Muskegon River on their annual spawning migration and congregate in the section of st ream below Newaygo Dam.

36. Annually, since 1923, a portion of the fish congregated below the dam has been caught in dipnets and transferred to upstream impoundments or to other waters of the Muskegon River drainage. This operation is known as the "Newaygo transfer".

37. More than 195,000 pikeperch have been transferred during the past 21 years. Annual catches have fluctuated from less than 500 to over 40,000 and averaged 9,300 for the period.

38. On the average, the netting season below Newaygo Dam has lasted for 18 days (April 4 to April 21) and the largest catches have been made from April 12 to 14.

39. Maximum catches (for three-day intervals) of pikeperch in dipnets below Newaygo Dam occurred at water temperatures of 36 degrees F. to 44 degrees F. during four years of observation.

40. In 1947, male pikeperch ranged from 13.1 to 26.7 inches in length and averaged 19.1 inches; in 1948 these figures were 14.2, 24.9 and 19.0, respectively. The range in length of females was from 17.7 to 30.7 in 1947, and averaged 23.3 inches. In 1947 the mean length was 23.2 inches, with a range of from 15.8 to 30.4 inches.

41. In 1948, fish of each sex were of larger average size during the peak of the run than during its decline; no such seasonal variation was noted in 1947.

42. Females comprised 58 percent of the catch in 1947 and 72 percent in 1948. The daily percentages fluctuated widely.

43. Green, ripe, and spent females were present in the catch throughout the netting periods of 1947 and of 1948, but spent fish never constituted

a large percentage of the daily total. It is believed that females move downstream soon after spawning.

44. Pikeperch eggs were collected throughout the section of river from Newaygo Dam to a point 16 miles downstream. They were most abundant in the area within five miles from the dam.

45. There was a return during the first year of 15.7 percent from 1,375 tagged pikeperch released in the Muskegon River impoundments in April, 1947, and an additional return of 0.9 percent by October 15, 1948. There was a return of 16.9 percent by October 15 from the same number of fish released in the impoundments in April, 1948.

46. Returns from pikeperch stocked in the various reservoirs ranged from 9.3 percent (Newaygo Pond, 1947) to 26.5 percent (Hardy Pond, 1947).

47. Only 6 percent of all fish recaptured were taken at points upstream from the place of release. Downstream movements were for distances as great as 137 miles and involved the passing of as many as 3 power dams. In 1947, 43 percent of the fish recaptured had passed through one or more of the Muskegon River dams and in 1948 this percentage was 35. Each of the dams was successfully negotiated by some fish. Since no water was spilled at Hardy Dam during the period, this clearly involved movement through the turbines.

48. Returns from 292 pikeperch released below Newaygo Dam in 1948 indicated that most pikeperch had left the Muskegon River by early June. Fifty-nine percent of the recoveries from this planting were taken in Lake Michigan, mostly near the mouths of the Muskegon, Grand, Kalamazoo, and St. Joseph rivers.

49. Planting of tagged fish in the north Newaygo lakes yielded a return of 22.5 percent during the first year following release and revealed

that fish moved freely among the four broadly connected waters. Plantings in the shallow, weed-choked south Newaygo lakes produced a return of only 7 percent; little movement between the two lakes was demonstrated. No fish from either the north or south Newaygo lakes is known to have returned to the Muskegon River. Both groups of lakes are connected with the river by small streams.

50. There were 59 recoveries (10.4 percent), over a span of seven fishing seasons, from 568 marked yellow pikeperch stocked in the various waters of the Inland Waterway System, Emmet and Cheboygan counties, in April, 1942. Extensive movement among the connected waters was shown, but, in contrast to observations in the Muskegon River, no marked proclivity to move downstream toward their place of origin (Lake Huron) was noted.

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