Prepared for Michigan Academy of Science, Arts and Letters

Original: Mich. Acad. Sci., Arts and Letts.
cc: Fish Division
Education-Game
Mr. Carbine
Mr. Applegate
Institute for Fisheries Research
Mr. Hans Peterson

April 10, 1946

REPORT NO. 1038

THE MOVEMENT AND GROWTH OF MARKED NORTHERN PIKE (ESOX LUCIUS, L.) IN HOUGHTON LAKE AND THE MUSKEGON RIVER [1]

by

William F. Carbine and Vernon C. Applegate

INTRODUCTION

This study of the movements of northern pike in Houghton Lake and the Muskegon River (Roscommon County, Michigan) is an outgrowth of an extensive investigation on the life history and habits of this species which was begun in 1937. The first investigations were conducted in fish hatchery ponds. From 1939 on, most of our research was undertaken at Houghton Lake, which is one of the best pike lakes in Michigan. Observations at Houghton Lake were made on the spawning migration of adults, the return to the lake of young and adults from the spawning area, the spawning habits, feeding habits, the growth of young and adults, and their movements. The results of these investigations have already been assembled in part in several published papers (Carbine, 1942, 1944, 1945; Carbine and Shetter, 1946).

Many northern pike were tagged at Houghton Lake and the Muskegon River in connection with the studies on the spawning migration in 1939, 1940 and 1942. At the time of tagging it was believed that recoveries of

---

[1] Contribution from the Institute for Fisheries Research of the Michigan Department of Conservation.

these marked fish would add to the little that is known of the wanderings and dispersion of the northern pike. The fisheries biologist is interested in the movements and distribution of northern pike, especially in heavily fished lakes such as Houghton, and this study may answer some of the following questions: (1) What is the favorite habitat of the northern pike? (2) Is there a possibility that racial segregation or differentiation occurs among the northern pike in a large lake with widely dispersed summer habitats of a suitable character? (3) What places are sought out for breeding by the northern pike that inhabit various parts of Houghton Lake? (4) Do northern pike seek out the same spawning area each year? (5) Do young northern pike exhibit a tendency to return to the parent spawning area? (6) How long will tags remain on fish? (7) Are growth data provided by anglers accurate enough to be useful when obtained on large fish?

Houghton Lake is the largest inland lake in Michigan and has an area of 20,040 acres and a maximum depth of 20 feet (Fig. 1). Seven streams plus many drainage ditches flow into the lake. Each of these, as well as the outlet stream, the Muskegon River, supports a pike run every year. There is also some low, swamp land bordering the lake shore that may be used for spawning, especially during periods of high water level.

Most of our efforts at Houghton Lake were confined to the drainage ditches that flow into the North Bay of Houghton Lake at Peterson's Resort (Fig. 1). These ditches drain the marshes bordering the roads that lead north, south and west from Peterson's. Two-way fish weirs were operated in the ditches in 1939 and 1940 from the time that the northern pike started their upstream migration until the ditches dried up in the summer (Carbine, 1942). In 1942 a weir was operated from the time the pike

started their upstream migration until about one-third of the spawners had returned to the lake. All adult pike taken in the weirs were jaw-tagged at the time of their upstream migration in 1940 and 1942 and at the time of their downstream (return to the lake) migration in 1939.

A two-way fish weir was operated in the Muskegon River from April 7 until June 19, 1939 and from March 31 until July 11, 1940 to determine the extent of the migration of fishes to and from Houghton Lake (Carbine and Shetter, 1946). The weir was located approximately one-eighth of a mile below the Houghton Lake dam (Fig. 1). All northern pike were jaw-tagged at the time of capture and released in the direction they were moving when taken for tagging.

The third major point of tagging operations was at Denton Creek. This creek is an one of the largest streams tributary to, and flowing into, the East Bay of Houghton Lake (Fig. 1). This stream is open each spring to the taking of suckers by spear or by dipnets not exceeding 9 feet square. Dipnetters frequently catch large numbers of northern pike and suckers each spring during the spawning migration of these species. A dam, located approximately two and one-half miles from the mouth of the stream, blocks all upstream migration of fish. At least one dipnet was operated below the pool at the foot of that dam each spring by a Mr. Detmers, owner of the dam. Mr. Detmers had several live-boxes in the stream that he used for holding suckers and arrangements were made whereby he saved all of the northern pike captured in his nets. A total of 81 of these northern pike was tagged by Institute personnel between April 20 and April 24, 1940. After tagging, all pike were released below the dam so that they could spawn and return to Houghton Lake.

All adult northern pike were jaw-tagged according to the procedure described by Shetter (1936). Tags were placed on the mandible, maxillary,

or premaxillary, depending on the size and condition of the fish. The maxillary was used in nearly all cases. The tag was always allowed to remain in the elongate, oval shape it is in after being locked in place around the jaw.

ACKNOWLEDGMENTS

We wish to express our thanks to various members of the Institute staff for assistance rendered during the course of the experiments and for critical reading of the manuscript.

RECAPTURES OF TAGGED NORTHERN PIKE

With the exception of those recaptures made by Institute personnel at spawning areas while engaged in further tagging activities, the recoveries were made exclusively by anglers. All recoveries are tabulated in Table I. It should be noted here that a number of pike were released again after their first, second, or third recapture. Consequently, the totals shown are not in every case initial returns. The grand totals recovered and associated percentage recoveries have been calculated on the basis of initial returns only.

(Insert Table I here.)

The decline in the percentage recaptured of successive tagging operations in the Peterson's ditch and Muskegon River weir experiments is believed to be of no biological significance. It is best attributed to a decline in interest on the part of anglers in the experiments. An intensive creel census was not in operation on Houghton Lake at any time during this study and voluntary reports were the only source of angler data. In the first year of tagging (1939) the experiments were widely advertised

by posters requesting the submission of tag numbers and pertinent data to conservation officers or the Conservation Department. The response in that year was apparently good. Unfortunately, in the succeeding years, advertisement of the experiments was not prosecuted actively with the apparent results in percentage recaptured. A drop in fishing intensity coincident with increased war restrictions and activities may also have contributed to the decline.

Recoveries of the 1939 and 1940 tagging at the Muskegon River weir (60.9 per cent and 38.0 per cent) and the 1939 tagging at Peterson's ditch (29.1 per cent) may be considered excellent. Percentage recoveries of the balance of the tagging activities are not high but are considered adequate for this study. A total of 864 northern pike was tagged in the three years at the three points of tagging. Of these, a total of 230, or 26.6 per cent, were recovered through the end of 1945. This high percentage of recoveries indicates the intensity of the fishery for northern pike in Houghton Lake. The results of our tagging studies and personal observations reflect a high rate of exploitation and an early cropping of the northern pike soon after reaching the legal length of 14 inches. Our data and observations also verify the fact that most northern pike are captured early in the season.

DIRECTION AND SPEED OF MOVEMENT

An analysis of the tag recoveries of these experiments results in data the significances of which are <u>suggestive</u> rather than <u>conclusive</u>. Ideally, more extensive investigations should have been carried out on each major spawning area tributary to the lake and more intensive efforts at recovery of the tagged fish should have been made by trained personnel.

Had these latter points been a reality, the authors would have felt justified in attaching a greater conclusiveness to their interpretation of the data. It is our object, therefore, to present from our data certain suggested patterns of behavior which per se are of use and value to the fisheries biologist and which will provide a guide or a basis for future studies on the movements of this game species.

The minimum, average, and maximum distances traveled by northern pike in their return to the lake following the spawning activities and in their movements during the succeeding months are summarized in Table II. With reference to certain movement patterns discussed later in this paper, it should be observed (Table II) that the pike utilizing the Muskegon River marshes for spawning apparently range farther after returning to the lake than do those aggregations utilizing ditches, streams and marshes bordering the lake shore. On the average, the former will be noted to range about twice as far as the latter (Fig. 2). It should be borne in mind that the distances traveled by the northern pike in Houghton Lake are probably extreme for Michigan lakes. As we have stated previously, Houghton Lake is the largest lake in Michigan (20,040 acres). Suitable summer habitats are widely dispersed and may be an appreciable distance from preferred spawning areas.

(Insert Table II here.)

Extreme distances traveled by the Houghton Lake northern pike are of interest. Reference to Figure 1 reveals that several pike tagged at the Muskegon River weir were recovered in the extreme eastern bay of the lake. This is a minimum distance of nine and one-half miles. Five pike tagged at the same point in 1940 were recovered 11 miles downstream below the Reedsburg dam. The greatest distance traveled was recorded for a pike tagged at the Muskegon River weir in 1939 and recovered in 1940. This

fish was taken by an angler in Big Sandy Bayou, Clare County, 49 miles downstream from its point of tagging.

The speed at which pike travel in moving to and about their spawning grounds was recorded in several instances. Three pike tagged in the downstream trap of the Muskegon River weir in 1940 were soon retaken in a small weir at Peterson's ditch, about 2 miles east of the Muskegon River and one mile west of North Bay. As illustrated in Figure 1, this ditch drains the marshes in the neighborhood of Peterson's (into the lake) and connects Houghton Lake with the river. At its other extremity the ditch drains gently into the river. Midway along the ditch direction of flow is indeterminate during high water levels and the ditch bed is dry during periods of low water. This weir on Peterson's ditch is just 10 miles from the Muskegon River weir. The data on these three pike are as follows:

Tagged at Muskegon River weir			Recovered at weir on Peterson's ditch		Time elapsed
Tag No.	Time	Date (1940)	Time	Date (1940)	Hours
12048	9:45 a.m.	April 13	9:00 p.m.	April 15	59 1/4
12070	10:00 p.m.	April 15	8:00 p.m.	April 16	22
12045	10:00 a.m.	April 13	6:30 a.m.	April 17	92 1/2

Northern pike No. 12070 made the 10-mile journey from the Muskegon River weir to the weir on the ditch in 22 hours, for an average speed of about 0.5 miles per hour. This fish probably traveled faster than that as it may have wandered through many oxbows and other tributaries before finding the river entrance of the ditch. There is some indication here that northern pike may travel considerable distances in search of suitable spawning grounds.

The total of 230 initial recaptures plus three of the repeat recoveries (total 233) are now considered in relation to the number of days between tagging and recapture (Table II). The number of days out varied from 1 1/2 to 1,729 days. Of these 233 recaptures, 141 (60.5 per cent) were taken the same year they were tagged; 70 fish (30.0 per cent) the first year after tagging; 15 fish (6.4 per cent) the second year after tagging; 6 fish (2.6 per cent) in the third year after tagging; and one fish (0.4 per cent) in the fifth year after tagging. The length in time that tags are retained in good condition by the northern pike is obvious from the preceding data. Seven pike were out over 1,000 days (range, 1,039 - 1,175 days; average, 1,077 days) between tagging and recovery. All had retained their tags in good condition. One of these pike is a specimen which had a total period out of 1,729 days. However, at the end of 1,074 days it was recaptured and the original tag replaced by a larger one as it was noted that the original tag was compressing the maxillary. This pike had grown exactly 254 millimeters (10 inches) between tagging and recapture 1,074 days later. It appears that the tags used ("medium size," 36 millimeters, strap length) were satisfactory in their application to this species of fish.

There is a significant difference of between 35 and 40 days in the average number of days out between tagging and recovery of the northern pike tagged at the weir at Peterson's in 1942 and those tagged at the same point in 1939 and 1940 (Table II). This difference in the minimum number of days out is even more pronounced. This apparent divergence in the number of days between tagging and recovery is due to the fact that in 1942 the spawning migration of northern pike started and ended much earlier than in the other years. In 1942 all fish but one had been tagged between 40 and 52 days before the opening of the fishing season, whereas in the earlier years some fish were still being tagged after the season opened.

MOVEMENTS OF MARKED NORTHERN PIKE

A word should be said in advance as to the preferred summer habitat of the northern pike in Houghton Lake. A number of our premises are based on the utilization by the pike of more or less localized summer haunts. Observations on the preferred habitat of northern pike are scattered through the literature (Bensley, 1915; Reighard, 1915; Kendall, 1917; Adams and Hankinson, 1928). They are generally agreed, with but one exception (Dymond, 1926), that the northern pike prefer the weedy bottoms of bays, estuaries, and sheals as a spring and summer habitat in lake environments. Dymond reported that in Lake Nipigon the pike resort to deep water, 60 to 100 feet, in summer. Our observations are similar in character to the majority opinion. As we have stated previously, our recaptures were made almost exclusively by anglers. These fishermen are unquestionably directed to the best pike fishing grounds by the local resort guides and by the consequent concentration of anglers at any given spot. As a result, virtually all our recoveries came from certain localized areas in the lake. In each instance these areas are the off-shore weedbeds. We must conclude, then, that these weedbeds constitute the local spring and summer habitat of the preponderance of the northern pike in Houghton Lake.

There are at least 15 of these weedbeds in Houghton Lake of a size that warrants popular naming by the local residents; i.e., South Shore Weedbed, Little Round Weedbed, etc. They vary in size from several acres to approximately 1,000 acres and are present as shoal areas with depths of from one to seven feet. Vegetation is both submergent and emergent in combination, or as submergent only. Dominant types are wild rice (Zizania), bulrush (Scirpus), and pondweeds (Potamogeton). Elsewhere, in deeper water, vegetation is sparse or absent.

How resident are the pike in a given weedbed or the weedbeds of a limited area? Kendall (1917) quoting Smitt (1892)[1] writes, "When the pike has chosen its station for the season, it restricts its wanderings to the immediate neighborhood, leading a solitary life and never being seen in company except during spawning." Hessle (1934), with the majority of his recaptures of marked northern pike within 12 months of tagging, found that most of his recoveries were within one kilometer (5/8 of a mile) of the point of tagging. Fishermen and the fisheries biologists do not wholly agree in this, the former being of the opinion that pike are continual wanderers, moving restlessly from place to place in a lake. The anglers' observations may very well be true for small lakes with more or less uniform habitat conditions. For a large lake with dispersed summer "ranges" of a suitable character our data contribute evidence towards the sedentary nature of certain aggregations of the pike during the summer months. Our conclusions as to spring and summer movement within a weedbed or from weedbed to weedbed in a limited area are arrived at, in part, by inference, since our data on the movements of the pike contribute primarily to knowledge of the spawning migration.

From a cursory inspection of the chart of plotted tag returns (Fig. 1) it appears that a number of northern pike in Houghton Lake were returning each year to the same area to spawn. A thorough inspection of the data available is summarized as follows:

Peterson's Ditch Tagging Experiments (1939, 1940, 1942).--In 1939, 378 northern pike were tagged at Peterson's ditch. Of these, 72 were recaptured in 1939, one of which was released again, leaving a theoretical

---

[1] Smitt, F. A. 1892. A History of Scandinavian Fishes, Vol. II. The Pike, 997 - 1010. Stockholm, 1892.

balance of 307 tagged pike in the lake from this experiment. Of these, a total of 35 tagged pike were recovered in 1940. Of this latter group, 22 were recovered over a period of 15 days (April 9 - 23) at Peterson's ditch as they were making spawning runs again in the ditch. No observations were made at this location in 1941. During operations at the ditch in 1942, three pike of the aforementioned 22 recaptures were recovered a second time, again making their spawning run in the same ditch. In the same year a fourth specimen that had been tagged when making the run in 1939 was recovered under the same circumstances. In 1944 a pike was recovered in Muddy Bay that had been tagged in 1939 and recovered in 1940 and 1942, on each of the latter dates when making its spawning run in Peterson's ditch.

In 1940 a total of 118 pike were tagged at Peterson's ditch. Ten of these were recovered in 1940 and 3 in 1941, all in the lake proper. (There were no observations at Peterson's ditch in 1941.) This leaves a theoretical balance of 105 tagged pike from this experiment in the lake at the end of 1941. Failure to submit recoveries on the part of anglers and a natural mortality would probably reduce this number considerably. Six of the remaining tagged pike of the 1940 experiment were recovered in 1942. Five of these were taken when they again returned to Peterson's ditch to spawn.

Of the 130 northern pike tagged at Peterson's ditch in 1942, only 6 recoveries after the year of tagging (5 in 1943 and 1 in 1945) have been made to date. All of these were recovered somewhere in the lake during the summer months. No observations or attempts to recover tagged pike at the spawning areas were made after 1942.

In the course of observations at Peterson's ditch in 1939 and 1940 on the spawning habits of the northern pike, the dorsal fins of a number of newly-hatched young-of-the-year were clipped. A total of 1,651 was fin-clipped in 1939, and 386 in 1940, as the young pike migrated from the ditch to the lake. Unfortunately, the same fin was clipped in both

years so we cannot distinguish between the year classes. However, during operations at the ditch in 1940, seven fin-clipped yearlings entered the ditch, presumably to participate in the spawning activities. These yearlings averaged 372.1 millimeters in total length and ranged from 338 millimeters to 398 millimeters in length. During operations at the same point in 1942, thirty-six fin-clipped pike were recovered without any or with only partial fin regeneration. These individuals ranged from 401 to 660 millimeters in total length and were apparently returnees from both the 1939 and the 1940 markings. In addition to this number, 55 pike with apparently completely regenerated dorsals, but bearing evidences of fin-clipping (abnormal appearance of fin rays and fin outline), were recovered. These latter fish are necessarily considered questionable.

Denton Creek Tagging Experiment (1940).--Eighty-one northern pike were tagged in Denton Creek (extreme eastern side of Houghton Lake) in 1940 as they moved up that creek to spawn. Four of these were recaptured in 1940, leaving a theoretical balance of 77 Denton Creek tagged pike in the lake at the end of 1940. No observations were made on the creek in 1941, but a Mr. Detmers of that neighborhood recaptured between 10 and 12 tagged pike during the spawning run while seining for minnows and dipnetting for suckers in the creek. These were said to have been released again by him after recording the tag numbers. As often happens, this record was lost by him and therefore the report can be useful only as corroborating evidence.

Ten valid recaptures of these Denton Creek fish were reported in 1941. Of these, nine were recovered in the lake during the summer months and one was taken at Denton Creek during the spawning run by Mr. Detmers. This would leave a theoretical minimum balance of 67 tagged pike. Three recoveries of Denton Creek tagged pike were made during 1942. Two of these were recaptured in Denton Creek as they migrated upstream to spawn.

Muskegon River Tagging Experiments (1939, 1940).--Twenty-three northern pike were tagged at the Muskegon River weir in 1939. Seven of these were recaptured in 1939, leaving a theoretical balance of 16 Muskegon River weir tagged pike in the lake. Of these 16 fish, four recaptures were made in 1940 as follows: two were recovered during the operation of the weir in that year when they were again migrating down the Muskegon River to spawn; one was recovered in the lake during the summer fishing season; and another was recaptured 49 miles down the Muskegon River from the point of tagging.

The 1940 tagging at the weir is not considered here as there were no operations at the weir in 1941. Furthermore, it was apparent that those tagged 1940 migrants that traveled downstream beyond the newly completed Reedsburg Dam (11 miles from the lake) could not return to the lake. Five of the 13 anglers' recoveries of the 1940 tagging at the weir were taken below the dam in 1941.

Analysis of places of recapture in relation to points of tagging in all years shows little or no evidence of "straying"; i.e., pike tagged at the Muskegon River weir and at Denton Creek were not recovered during the spawning season on any but the spawning areas where they had been tagged. Recaptures of pike tagged in 1939 at Peterson's ditch during the spawning season revealed only three instances of "straying"; one was recovered April 20, 1940, in the South Heights ditch (see Fig. 1), another at the Muskegon River weir, April 18, 1940, and the third entered Peterson's ditch from the Muskegon River on April 16, 1940.

We cannot conclude from these data that all or nearly all of the northern pike in Houghton Lake are returning to the same or relatively close to the same spawning area each year. The proportion of tagged

recoveries on the spawning grounds to the total number tagged is emperically low. Yet we must consider that many anglers' recaptures are not turned in and that poachers are taking tagged as well as untagged pike on the spawning grounds (evidences of this are in the authors' files). In those years when observations were made on the spawning grounds, it is significant that the proportion of recoveries on the spawning grounds to the total recoveries for that year is high. Upon examining the data again with these considerations in mind, we may tentatively conclude that an appreciable number of northern pike are using the same spawning grounds in successive years. Furthermore, for those pike spawned in Peterson's ditch there is evidence that some yearling northern pike are returning to their parent spawning area, presumably to participate in the spawning act.

The foregoing discussion lends evidence to certain other movement patterns suggested by the data. Are the northern pike in Houghton Lake occupying more or less well-defined local summer habitats, utilizing annually a suitable, conveniently located spawning area--and returning after each spawning run to these same local summer haunts? A summary was prepared (Table III) to ascertain to what extent this was so.

(Insert Table III here.)

Analyses of the recaptures of the Peterson's ditch tagging (1939, 1940, 1942) indicate that, excluding the recoveries made on the spawning grounds, most of the recoveries were made on the weedbeds of Muddy Bay and North Bay. These beds are 0.5 to 2.75 miles from the spawning area. This condition obtains not only in the year of tagging but in successive years after each tagging experiment. Recoveries of the three years' tagging are combined in the following table (Table IV). Totals shown are

exclusive of the recaptures made on the spawning grounds and two recaptures of doubtful location.

(Insert Table IV here.)

It should be noted (Table III) that with but one exception the balance of recoveries are from areas within 5.5 miles of Peterson's ditch. This is of doubtful significance as there are suitable spawning grounds nearer in each instance to the locality of recapture than Peterson's ditch (Fig. 1). However, it does appear significant that the majority of tagged pike of the three years' tagging operations were recovered in the weedbeds of two nearby bays--not only in the year of tagging but in successive years after each tagging experiment. It is possible that the tagged pike wandered indiscriminantly about the lake before being retaken in Muddy and North bays one or two or four years after tagging. However, the data presented herein suggests that this is unlikely.

A similar pattern of movement is evident among the pike tagged at Denton Creek (Fig. 1 and Table III). Although total recaptures from this experiment are inadequate for any detailed analysis, it should be noted, however, that of the 14 recoveries made other than on the spawning grounds, eleven were taken in East Bay. These recaptures occurred in the year of tagging, one year after tagging and two years after tagging.

From our examination of these two widely separated tagging experiments we have arrived at several tentative conclusions: (1) These data suggest that certain patterns of movement are exhibited by those aggregations of northern pike utilizing the spawning areas under observation. This pattern takes the following form: occupation of more or less well defined local summer habitats (i.e., weedbeds of North Bay and Muddy Bay or the weedbeds of East Bay); utilization annually of suitable, conveniently located spawning areas; and return after each spawning run to the

same aforementioned local summer haunts. (2) That deviations from this pattern are present but in numbers insufficient to invalidate the movements suggested above.

That these data show evidences of racial segregation is doubtful at the present time. It is apparent that those pike spawning in the Peterson's ditch area are returning for the most part to the nearby weedbeds of North Bay and Muddy Bay each year. And the same condition obtains for the Denton Creek spawners and East Bay. There is little evidence of any admixture between the two aggregations of northern pike. None-the-less this is best interpreted in the light of availability and convenience. Pike spawned in Peterson's ditch are going to find suitable summer haunts upon their entrance into the lake initially in the weedbeds of North and Muddy bays. Only a small proportion appear to wander farther in search of suitable summer ranges. In contradistinction to popular views, they apparently become resident in these, the nearest and most available summer habitats. Again it is proximity and convenience that most probably directs them back to their parent spawning areas. A similar interpretation may be made of the Denton Creek spawners with reference to their incidence in the weedbeds of East Bay.

The pattern of movement tentatively suggested for the northern pike spawning in Peterson's ditch and Denton Creek apparently does not obtain for those spawning migrants tagged at the Muskegon River weir (1939, 1940). These pike were tagged as they were migrating down the Muskegon River to spawn in the abundant marshes along its shores. Analysis of the recaptures of this tagging experiment shows initially that those pike utilizing the Muskegon River marshes for spawning are decidedly more far-ranging in spring and summer habits. Examination of Figures 1 and 2 indicates that recoveries were made, over a period of years, from all parts of the lake

and the river. It was also noted at the time of tagging that the Muskegon River migrants were larger pike than those observed in spawning areas elsewhere around the lake. The original tagging records were examined and average total lengths by sexes, singly and combined, for all experiments were computed. These are presented in Table V, together with the sex ratio data.

(Insert Table V here.)

Statistically the Muskegon River migrants appear larger and consequently morphologically distinct from the other two aggregations studied. That this is a racial distinction does not seem likely. The apparent differences in average length could be attributed to a variable sex ratio on the various spawning areas observed. A sexual dimorphism has been noted for the northern pike insofar as the females appear to grow faster in a given period than do the males (Carbine, 1942). From an examination of the sex ratio data (Table V) it does not seem likely that this sexual dimorphism is the causal factor. A maximum change in the proportion of larger females to smaller males in, for instance, the 1940 tagging experiments, of 9.1 per cent could not account entirely for a gross difference of 104 to 178 millimeters in average total length. Another possible causal factor, assuming in this instance that we are dealing with a more or less distinct aggregation of pike, is a differential growth rate. The growth potential of the northern pike under varying conditions has been shown by Carbine (1945). Perhaps these pike, being more restless and far-ranging in habit, are feeding better and growing faster. However, in attributing it to this factor alone we are obliged to assume that this accelerated growth is a trait of race rather than the result of chance or accident or of wider foraging habits among the larger and older fish.

It is distinctly possible that the age composition of the sample of Muskegon River migrants differed from that of the other samples studied. Although the sedentary nature of the younger pike has been observed by numerous writers, it has also been noted that the older and larger pike may be more restless and shifting in their movements. We are dealing with a sample in this instance which is observedly larger than the others. It has also displayed a tendency to wander over the entire lake and considerable distances down the Muskegon River. Consequently we are inclined to favor the latter explanation, bearing in mind that an apparent differential growth rate resulting from more extensive foraging on the part of individual older fish may be a contributing factor.

In conclusion, several points should be brought out which may favor the possible existence of races of pike in Houghton Lake. Racial differentiation is usually expressed in terms of morphological distinctions or in differences in growth or rates of development (Mayr, 1942). However, racial distinction can also be expressed in terms of habits or behavior. Differentiation arising from the latter may result ultimately in distinctions of a morphological or developmental nature. We mean to imply from this that apparently different patterns of behavior exhibited by the various aggregations of pike studied from Houghton Lake may be an indication of racial distinction. These habits were expressed in the Peterson's ditch and Denton Creek aggregations by spawning in inlet waters and relatively restricted foraging. On the other hand, the habits of the Muskegon River aggregation were characterized by spawning in outlet waters and far more extensive foraging. This latter habit, combined with the known growth potential of the species, may have resulted in the apparent size distinction between this group and those from Peterson's ditch and Denton Creek.

It is our opinion that the majority of the pike in Houghton Lake fall in a category with, and exhibit a movement pattern similar to, that described for the Peterson's ditch and Denton Creek material. We have a positive measure of the number of Muskegon River migrants in our weir operations in several years. This number is small in relation to the observed numbers making active use of the marshes and streams about the lake shore.

GROWTH OF TAGGED NORTHERN PIKE IN HOUGHTON LAKE AND THE MUSKEGON RIVER

The length of the fish at the time of capture was not always given by the anglers reporting tagged northern pike. Whenever a recovery was received for which certain pertinent information was not reported, a self-addressed, stamped postal card was sent to the person requesting this information. Despite this effort on our part, only 45 per cent of the anglers reported the length of their catch. A great many of the lengths were obviously in error. A total of 50 per cent of the fish that were reported recaptured the same year in which they had been tagged presented a "negative growth" between the time of tagging and recapture, 43 per cent exhibited a positive growth and 7 per cent exhibited no growth at all.

The "negative growth" of these fish varied from 0.5 millimeters (0.02 inches) in 16 days to 125 millimeters (4.9 inches) in 55 days, while the increment for those fish showing a positive growth varied from 0.5 millimeters (0.02 inches) in 16 days to 342 millimeters (13.5 inches) in 37 days. All of the fish captured by anglers later than the same year of tagging showed a positive growth except for three fish which exhibited a "negative growth" of 3, 5 and 8 millimeters in 424, 384, and 415 days.

Obviously, the growth of those fish recaptured by anglers cannot be considered in this study.

It was not until the growth data had been compiled that the writers realized that this material could not be used. We therefore propose the following reasons for the inutility of these data: (1) All Institute measurements of total length were made by squeezing the lobes of the caudal fin together. It is apparent that this length would be greater than if the lobes of the caudal fin were left in a normal position. It is possible that some anglers are not attempting to obtain the greatest length possible. (2) Many anglers carry a short ruler in their tackle boxes and it is entirely possible that they could make a slight mistake when measuring a large fish with a six-inch ruler. (3) Some anglers evidently estimate the length of a fish. (4) Institute staff members could have made a mistake in recording the length of the fish at the time of tagging. (5) Some anglers undoubtedly use a "fisherman's rule" or else they are subject to exaggeration or underestimation. In defense of the anglers it may be said that not all fishermen are prone to exaggerate the size of their catch.

For growth data it was therefore necessary to use only those tagged fish that were recaptured in weirs and measured by Institute personnel. A total of 34 northern pike, captured in weirs and tagged in 1939 and 1940, were recovered in weirs in 1940 and 1942 (Table VI). Of these, 26 fish were recovered in 1940, and 8 fish in 1942. Only two of the recaptures were fish that were tagged and recovered in the Muskegon River weir. Three of the fish that had been tagged at Peterson's in 1939 were recaptured there again in 1940 and in 1942. The growth increment of the northern pike recaptured one year after tagging ranged from 6 to 157 millimeters (0.2 - 6.2 inches). Those fish out two years after tagging grew

between 18 and 174 millimeters (0.7 - 6.9 inches) and the growth of the fish that had been out for three years ranged from 62 to 254 millimeters (2.4 - 10.0 inches) (Table VI). These ranges in growth increment are given irrespective of the arbitrary size groups, established by the writers, with their implied differences in age. With the small number of fish available for growth determinations it is impossible to present even a tentative population growth analysis. However, it does appear that the growth rate of the fish that were large at the time of tagging did not differ greatly from those that were small. In other words, some of the larger pike apparently possess a growth potential as great as the smaller ones. This phenomenon has already been shown for the northern pike by Carbine (1945). Our data also indicate that the female pike grew at a faster rate than the male pike--1 year after tagging males had increased an average of 37 millimeters (1.5 inches), and females 87 millimeters (3.4 inches); 2 years after tagging males had grown an average of 34 millimeters (1.3 inches), and females 108 millimeters (4.2 inches); 3 years after tagging males grew an average of 107 millimeters (4.2 inches), and females 168 millimeters (6.6 inches).

(Insert Table VI here.)

Several recaptures are of sufficient interest to mention here. Northern pike No. 4460 was tagged at Peterson's on April 26, 1939 (length 549 millimeters or 21.6 inches) and recovered at the same place in 1940 (length 645 millimeters or 25.4 inches) and again at the same place in 1942 (length 803 millimeters or 31.6 inches). This fish was recovered a third time by an angler, in Muddy Bay, on January 18, 1944, at which time it measured 914 millimeters or 36.0 inches in length. This fish grew a total of 366 millimeters or 14.4 inches in the 1,729 days between tagging and final

recovery. Northern pike No. 32703 was tagged at Peterson's on April 1, 1942 (length 511 millimeters or 20.1 inches). This fish, when recovered by an angler on June 18, 1945, was 813 millimeters or 32.0 inches in length. Very accurate measurements were taken to verify this length. In the 1,175 days between tagging and recapture this fish had grown 302 millimeters or 11.9 inches.

INSTITUTE FOR FISHERIES RESEARCH

by W. F. Carbine and V. C. Applegate

Report approved by A. S. Hazzard

Report typed by E. F. Livingston

LITERATURE CITED

Adams, C. C. and Hankinson, T. L. 1928. The Ecology and Economics of Oneida Lake Fish. Roosevelt Wild Life Annals, 1, Nos. 3 and 4, Roosevelt Wildlife Forest Exp. Sta., N.Y. State Col. For., Syracuse Univ., 235-548.

Bensley, B. A. 1915. The Fishes of Georgian Bay. Contributions to Canadian Biology, Suppl. 47th Ann. Rep., Dept. Marine and Fisheries, Fisheries Branch, 1-51.

Carbine, W. F. 1942. Observations on the Life History of the Northern Pike, Esox lucius L., in Houghton Lake, Michigan. Trans. Amer. Fish. Soc., 71 (1941), 149-164.

Carbine, William F. 1944. Egg Production of the Northern Pike, Esox lucius L., and the Percentage Survival of Eggs and Young on the Spawning Grounds. Pap. Mich. Acad. Sci., Arts and Letters, 29 (1943), 123-137.

Carbine, William F. 1945. Growth Potential of the Northern Pike (Esox lucius). Pap. Mich. Acad. Sci., Arts and Letters, 30 (1944), 205-220.

Carbine, William F. and Shetter, David S. 1946. Examples of the Use of Two-way Fish Weirs in Michigan. Trans. Amer. Fish. Soc., (in press).

Dymond, J. R. 1926. The Fishes of Lake Nipigon. Univ. of Toronto Studies, Biol. Series No. 27, Pub. Ontario Fisheries Research Lab., 27, 1-108.

Hessle, C. 1934. Märkningsförsök med Gädda, I. Östergötlands Skärgård Åren 1928 Och 1930. (Mitteilungen der Austalt für Binnenfischerei bei Drottningholm, Stockholm) Stockholm, 1934.

Kendall, William C. 1917. The Pikes: their Geographical Distribution, Habits, Culture, and Commercial Importance. U. S. Bureau Fisheries, append. to Rep. for 1917, Doc. 853, 1-45.

Mayr, Ernst. 1942. Systematics and the Origin of Species. Columbia University Press, New York, 1942. 1-334 pp.

Reighard, Jacob E. 1915. An Ecological Reconnaissance of the Fishes of Douglas Lake, Cheboygan County, Michigan, in Midsummer. U. S. Bureau Fisheries Bull., 33, 215-249.

Shetter, David S. 1936. The Jaw-tag Method of Marking Fish. Pap. Mich. Acad. Sci., Arts and Letters, 21 (1935): 651-653.

TABLE I

NUMBER OF NORTHERN PIKE TAGGED AND PERCENTAGE RECOVERED[1]

Year	Number tagged	Recovered 1939	Percentage	Recovered 1940	Percentage	Recovered 1941	Percentage	Recovered 1942	Percentage	Recovered 1943	Percentage
									Muskegon River Weir		
1939	23	7	30.4	4 (2)	17.4	3	13.0	...	...	...	...
1940	134	.....		36 (3)	26.9	13	9.7	1	0.7	1	0.7
									Houghton Lake - Peterson's Ditch[2]		
1939	378	72 (1)	19.0	(2) 37 (25)	9.8	2	0.5	(3) 4 (4)	1.3	...	...
1940	118	.....		10	8.5	3	2.5	(1) 7 (4)	5.9	...	...
1942	130	.....						13	10.0	5	3.8
									Houghton Lake - Denton Creek		
1940	81	.....		4	4.9	10	12.3	3 (2)	3.7	...	...
	864										

[1] In parenthesis above each figure representing number of tag recoveries in a given year is the number of recoveries of
in parenthesis below the tag recovery figure is the number of recoveries of that year which were released again after

[2] Includes one fish tagged at Evergreen Point in 1939 and recovery of same in 1940.

Recovered 1944	Percentage	Recovered 1945	Percentage	Total initial recoveries	Percentage total initial recovery	Total recoveries
...	...	...	...	14	60.9	14
...	...	...	...	51	38.0	51
(1) 1	0.3	...	...	110	29.1	116
...	...	...	...	19	16.1	20
...	...	1	0.8	19	14.6	19
...	...	...	...	17	21.0	17
				230	26.6	237

that year that were repeat recoveries of that or a preceding year; recording pertinent data.

TABLE II

SUMMARY OF DAYS OUT AND DISTANCE TRAVELED
BY TAGGED NORTHERN PIKE

Year of recovery	Total recovery	Days out[1] Minimum	Days out[1] Average	Days out[1] Maximum	Distance traveled (miles) Minimum	Distance traveled (miles) Average	Distance traveled (miles) Maximum
Peterson's Ditch Tagging							
1939 Tagging --							
1939	72	1.5	25.5	144	0.2	2.6	8.25
1940	35*	279	361.9	463	1.0	3.5**	5.0
1941	2	756	775.0	794	...	4.25	...
1942	4	1054	1062.5	1070	...	...	...
1943	None						
1944	1	...	1729	...	...	?	...
1940 Tagging --							
1940	10	7	31.6	44	1.0	2.8	5.0
1941	3	415	433.7	444	2.75	2.9	5.5
1942	6*	657	709.3	764	1.0	2.25**	3.5
1942 Tagging --							
1942	13	50	66.5	94	1.0	2.3	3.5
1943	5	427	467.6	508	1.0	1.6	2.75
1944	None						
1945	1	...	1175	...	...	5.0	...
Denton Creek Tagging							
1940 Tagging --							
1940	4	28	81.0	193	3.0	3.75	6.0
1941	10	268	398.7	519	1.0	4.0	7.25
1942	3	680	702.3	715	...	3.0*	...
Muskegon River Tagging							
1939 Tagging --							
1939	7	22	45.1	66	2.75	6.0	8.5
1940	4	281	363.0	432	...	8.5*	...
1941	3	764	784.3	797	6.0	7.5	9.0
1940 Tagging --							
1940	35	2	50.4	144	1.0	5.2	10.0
1941	13	384	425.7	454	5.5	8.9	11.0
1942	1	...	799	...	...	2.0	...
1943	1	...	1039	...	...	7.5	...

* Does not include two repeats in same season.

** Based on 8 recoveries.

* Does not include one repeat of same season.

** Based on two recoveries.

* Based on one recovery.

[1] For the purposes of this study, days out (time between tagging and recapture) have not been computed on the basis of 24 consecutive hours equals one day. For example, a pike tagged on April 15 and recovered on April 16 with a total time increment out of 22 hours was considered "out" two days, i.e., April 15 and April 16.

TABLE III

SUMMARY OF RECAPTURES OF TAGGED NORTHERN PIKE

BY PLACE OF TAGGING AND PLACE OF RECAPTURE

Number tagged, date and place of tagging and date and place of recovery	Distance from point of tagging in miles	Number recovered	Percentage recovery of total recovery in given year	Days out		
				Minimum	Average	Maximum
1939 Tagging, Peterson's Ditch						
Number tagged - 378						
Recaptured in 1939						
Muddy Bay	2.75	32	44.4	42 hrs.	21.3	144
North Bay	0.5 - 1.5	25	34.7	31.5 hrs.	21.8	62
Weedbed off Houghton Heights	3.5	6	8.3	8	60.0	123
North Shore Weedbed	2.75	1	1.4	...	39	...
South Shore Weedbed	5.5 - 6.0	5	6.9	12	21.4	41
Middle Grounds	5.0	2	2.7	10	36.5	63
East Bay	8.0 - 9.0	1	1.4	...	26	...
Recaptured in 1940						
Muddy Bay	2.75	1	2.8	...	389	...
North Bay	0.5 - 1.5	4	11.1	359	395.75	422
South Shore Weedbed	5.5 - 6.0	2	5.6	279	337.5	396
Middle Grounds	5.0	3	8.3	397	420.0	463
Peterson's Ditch	0.0	22	61.1	332	351.6	375
Muskegon River Weir	3.5	1	2.8	...	358	...
South Heights Ditch	4.5	1	2.8	...	352	...
Locality Unknown	...	2	5.6	?	?	?
Recaptured in 1941						
Muddy Bay	2.75	1	..	...	794	...
Middle Grounds	5.0	1	..	...	756	...
Recaptured in 1942						
Peterson's Ditch	0.0	4	..	1054	1062.5	1070
Recaptured in 1944						
Muddy Bay	2.75	1	..	...	1729	...
1940 Tagging, Peterson's Ditch						
Number tagged - 118						
Recaptured in 1940						
Muddy Bay	2.75	4	..	7	24.75	36
North Bay	0.5 - 1.5	4	..	30	33.0	37
Middle Grounds	5.0	2	..	41	42.5	44

Recaptured in 1941						
Muddy Bay	2.75	2	..	442	443.0	444
South Shore Weedbed	5.5	1	..	...	415	...
Recaptured in 1942						
Muddy Bay	2.75	1	..	...	836	...
North Bay	0.5 - 1.5	1	..	...	657	...
Peterson's Ditch	0.0	5	..	682	719.8	764
1942 Tagging, Peterson's Ditch Number tagged - 130						
Recaptured in 1942						
Muddy Bay	2.75	5	..	55	60.2	66
North Bay	0.5 - 1.5	7	..	58	73.4	94
Muskegon River	2.5	1	..	...	50	...
Recaptured in 1943						
Muddy Bay	2.75	1	..	...	473	...
North Bay	0.5 - 1.5	4	..	427	466.25	508
Recaptured in 1945						
Middle Grounds	5.0	1	..	...	1175	...
1940 Tagging, Denton Creek Number tagged - 81						
Recaptured in 1940						
East Bay	3.0	3*	..	28	43.7	64
Middle Grounds	6.0	1	..	...	193	...
Recaptured in 1941						
East Bay	3.0	7	..	268	399.7	519
Middle Grounds	6.0	2	..	400	413.5	427
Denton Creek	0.0	1	..	...	362	...
Recaptured in 1942						
East Bay	3.0	1	..	...	680	...
Denton Creek	0.0	2	..	712	713.5	715

* One of these recaptured the same season at Peterson's Ditch and released again.

** This fish recovered in 1940 and 1942 at Peterson's Ditch when returning there to spawn.

TABLE IV

TOTAL RECOVERIES (EXCLUSIVE OF THOSE ON THE SPAWNING GROUNDS) AND RECAPTURES MADE IN NORTH BAY AND MUDDY BAY OF NORTHERN PIKE TAGGED AT PETERSON'S DITCH

Time increment before recapture	Total number of recaptures	Number recovered in Muddy Bay and North Bay
Recaptures in year of tagging	95	77
Recaptures one year after tagging	20	12
Recaptures two years after tagging	4	3
Recaptures four years after tagging	1	0
Recaptures five years after tagging	1	1
	121	93

TABLE V

AVERAGE LENGTHS AND NUMBERS AND PERCENTAGE OF BOTH SEXES

OF NORTHERN PIKE AT TIME OF TAGGING

Year of tagging	Total number sexed	Average total length Males	Females	Number males	Percentage males	Number females	Percentage females	Average total length males and females
			Peterson's Ditch					
1939	378	538.5	596.9	247	65.3	131	34.7	542.4
1940	118	503.2	588.5	68	57.6	50	42.4	539.4
1942	130	519.5	566.3	70	53.8	60	46.2	540.7
			Muskegon River Weir					
1939	(Inadequate sex data)							683.8
1940	130	597.5	659.3	63	48.5	67	51.5	629.3
			Denton Creek					
1940	81	463.4	439.3	42	51.9	39	48.1	451.8

TABLE VI

VARIATION IN GROWTH OF INDIVIDUAL NORTHERN PIKE RECOVERED, MEASURED, AND RELEASED AGAIN BY INSTITUTE PERSONNEL

Tag number and sex	Date tagged	Total days out	Number of years out (approximate)	Total length at tagging (millimeters)	Total length at capture (millimeters)	Growth increment (millimeters)	Size group at time of tagging (millimeters)	Variation in growth increment (millimeters)	Average increment (millimeters)
♂ 4297	5/7/39	346	1	337	418	81			
♂ 4266	5/9/39	341	1	372	459	87	300 - 399	55 - 87	74.3
♂ 4280	5/21/39	332	1	384	439	55			
♂ 4582	4/30/39	346	1	413	473	60	400 - 499	39 - 60	49.5
♂ 4473	4/26/39	351	1	470	509	39			
♂ 4515	4/27/39	355	1	510	555	45			
♂ 4333	5/2/39	345	1	510	528	18			
♂ 4370	5/5/39	352	1	515	566	51			
♂ 4419	4/26/39	356	1	526	619	93			
♂ 4475	4/26/39	356	1	532	558	26			
♂ 4453	4/26/39	355	1	536	570	34	500 - 599	6 - 157	51.2
♀ 4514	4/27/39	357	1	547	704	157			
♀ 4460	5/1/39	352	1	549	644	95			
♂ 4380	5/5/39	342	1	560	566	6			
♂ 4251	5/7/39	375	1	561	588	27			
♂ 4557	4/29/39	348	1	563	570	7			
♂ 4492	4/27/39	355	1	563	600	37			
♀ 4306	5/1/39	358	1	585	655	70			
♂ 4495	4/27/39	358	1	604	620	16			
♂ 4500	4/27/39	350	1	604	637	33			
♂ 4595	5/1/39	353	1	605	620	15	600 - 699	6 - 33	18.3
♂ 4524	4/27/39	363	1	614	624	10			
♂ 4315	5/2/39	352	1	628	634	6			
♂ 4367	5/5/39	348	1	648	678	30			
♀ 4119	4/30/39	351	1	750	795	45	700 - 799	45	45
♀ 4112	4/28/39	388	1	810	880	70	800 - 899	70	70
♀ 12325	5/14/40	682	2	357	531	174	300 - 399	174	174
♂ 12270	4/16/40	712	2	499	550	51	400 - 499	51	51
♂ 12316	4/22/40	715	2	542	560	18	500 - 599	18 - 142	80
♀ 12278	4/17/40	726	2	577	719	142			
♂ ⚜ 4266	5/9/39	1054	3	372	525	153	300 - 399	153	153
♀ ⚜ 4460	5/1/39	1070	3	549	803	254	500 - 599	254	254
♂ ⚜ 4367	5/5/39	1056	3	648	710	62	600 - 699	62 - 82	72
♀ ⚜ 4485	4/27/39	1070	3	683	765	82			

⚜ Repeat recoveries.

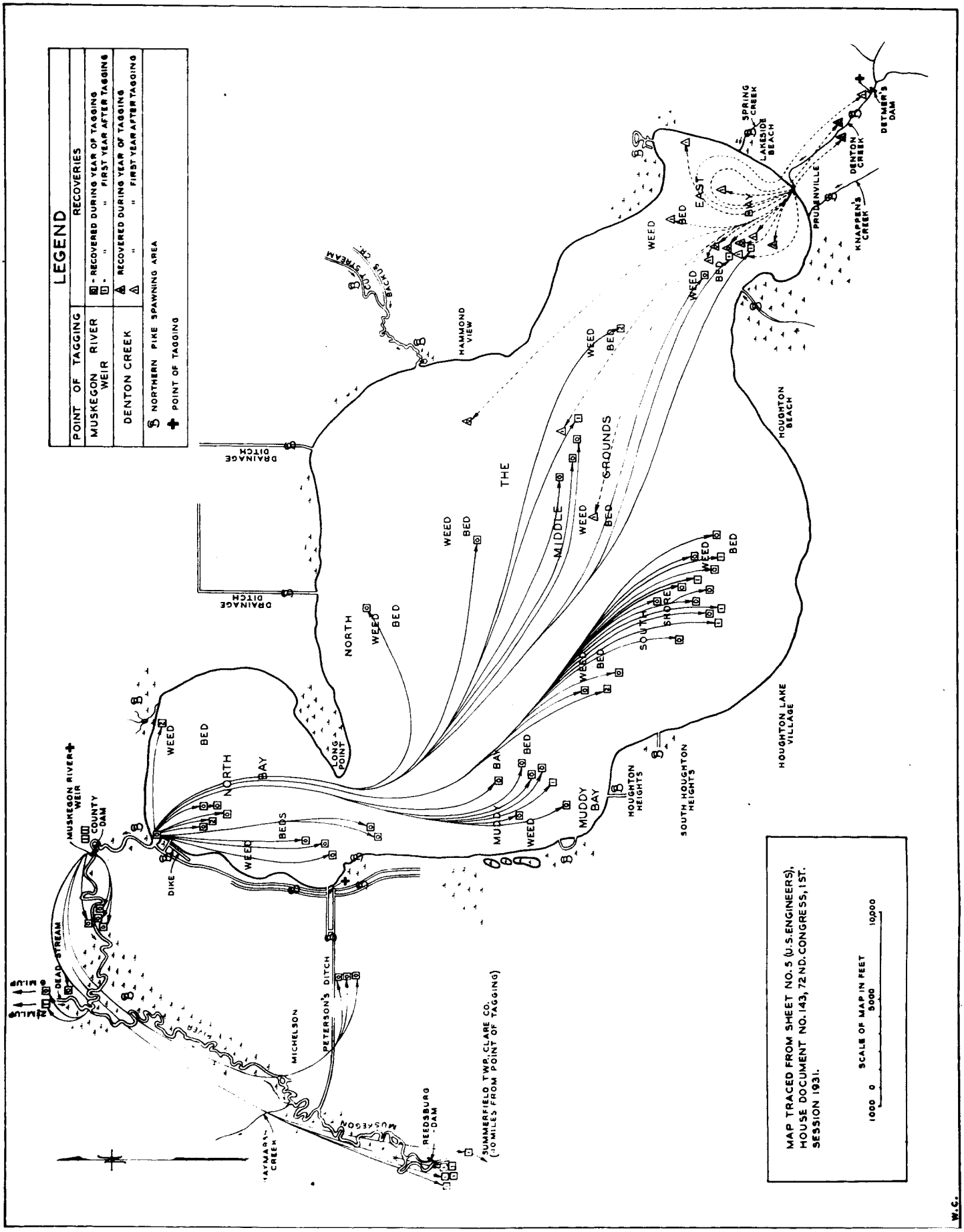

Figure 2. - Map of Houghton Lake and the Muskegon River showing the dispersion of the Muskegon River and Denton Creek spawners after the termination of the spawning season.