Prepared for
Am. Fish. Soc.

Original: Fish Division
cc: Education-Game
Mr. Carbine

October 13, 1941

Note:
first report attached - 2 which
H. L. Peterson received a copy

REVISION OF REPORT NO. 687

OBSERVATIONS ON THE LIFE HISTORY OF THE NORTHERN PIKE, ESOX LUCIUS L., AT HOUGHTON LAKE, MICHIGAN [1]

[1] Contribution from the Michigan Institute for Fisheries Research

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Abstract

Male northern pike made up 65 per cent of the 378 adults taken in the upstream weir of the ditches tributary to the North Bay of Houghton Lake in April, 1939. They averaged 21.2 inches, total length, while the females averaged 23.5 inches. In 1940, 58 per cent of the 118 adults were males. These fish averaged 19.8 inches in total length as compared with 23.2 inches for the females. Most of the spawners appeared in the weir between 6:00 p.m. and 9:00 a.m. The average number of days that the adult northern pike spent in the ditches in 1939 was 18 1/4 days (range 6 to 50 days). In 1940 the average number of days spent in the ditches was 23.9 days (range 4 to 90 days).

The numbers of young northern pike (aside from an insignificant few that were preserved) that passed through the downstream weir from the spawning grounds to Houghton Lake were: 1939 - 7,239; 1940 - 1,495. The

average length of the young increased at a rate of at least 1.8 millimeters per day during the 82 days after the first hatch was observed in 1939, and at least 1.3 millimeters per day during the first 85 days after the first hatch was observed in 1940.

Introduction

The lack of a satisfactory explanation for the abrupt increases or decreases in the abundance of the northern pike in some Michigan lakes has brought out strongly the need for more detailed information on the life history and growth rate of this species. The nature and extent of the fluctuations in the catch of northern pike at Houghton Lake, Roscommon County, Michigan have been brought out by creel-census records taken by conservation officers since 1928. These records show that the quality of fishing for northern pike declined steadily from 1928 to 1931 and was improved during the years 1932 to 1934, with a peak in 1933. In 1935 the abundance of northern pike again waned. When fishing was poor for northern pike, the abundance of pan fish increased. Although Houghton Lake has always had a reputation as one of the best northern pike lakes in Michigan, the decline in the abundance of the species in recent years has resulted in numerous complaints by fishermen and resort owners. Previous surveys and examinations revealed that Houghton Lake offered excellent possibilities for studies on the life history of the northern pike. Consequently, the present investigation was started at Houghton Lake in the early spring of 1939 and was continued through that summer and the spring and summer of 1940.

Observations were made on the spawning migration, spawning habits, return of adults and young to the lake, feeding habits and growth of young

and adults, and the migration (other than the spawning migration) of the northern pike). Only the data obtained on the spawning run and return migration of adults and the production and growth of young northern pike are presented in this paper.

Marsh land adjacent to the shores of Houghton Lake is gradually being reclaimed. Although this practise has increased the number and price of lake lots, it has also decreased the extent of northern pike spawning grounds. This decrease of available spawning territory, together with low water and other unfavorable spawning conditions, is probably responsible, in part at least, for the decrease in the northern pike population. This study was undertaken, therefore, on the marshes to determine the spawning requirements of the pike, and the extent and character of the spawning grounds still available.

Houghton Lake, one of the most important resort lakes in Michigan, is located in the upper half of the Lower Peninsula. The area of the lake is 20,044 acres, and the maximum depth is 20 feet. Its fame as a popular tourist lake is illustrated by the fact that approximately 100 resorts (hotels, boat liveries, and tourist camps), and at least a thousand private cottages and summer homes are to be found along its shores.

Description of the spawning area

Seven streams and many drainage ditches flow into Houghton Lake. Each stream or ditch, and the outlet (Muskegon River) as well, supports a northern pike run almost every year. Fairly extensive low, swamp land bordering on the lake shore also may be used for spawning, especially during periods of high lake level. The present investigation was confined mainly to the drainage ditches that flow into the North Bay of Houghton Lake at Peterson's Resort (Fig. 1). These dredged ditches provide drainage for the marshes

Fig. 1. Map of Peterson's drainage ditch system (diagrammatic)

bordering the roads that lead north, south, and west from Peterson's. Of the seven ditches shown on the map, only the first four were under observation. The culvert that connects Ditches I and V was plugged to prevent the movement of northern pike into the area under observation. The four ditches have a total length of 2 1/4 miles, a maximum depth of 3 feet, and a width varying from 6 to 15 feet. The bottom is composed of sand and decaying vegetation. The color of the water varies from light to dark brown. Marsh grass (Calamagrostis canadensis), which is the dominant plant in the ditches, also grows with willows along the ditch banks. At periods of high water, many marsh areas of varying sizes that border on the ditches are flooded. These areas are often used by spawning northern pike, although most of the spawning takes place in the ditches themselves. Most of the ditches dry up completely in late summer.

Description of fish weirs

Weirs used to capture young and adult northern pike were installed in Ditch I, approximately 75 feet from the lake (Fig. 1). The maximum depth at this location was 15 inches and the width was 7 feet. The upstream and downstream weirs used to take the adult fish each consisted of three wings. The wings were constructed of plaster lath 4 feet long and 5-foot lengths of 1- by 2-inch slats driven into the bottom, 1 inch apart. A barrier of similar construction placed perpendicular to the ditch banks 15 feet from the apex of the V formed by the other two wings completed the "pot" in which the fish were impounded. The apex of the V headed into the current to catch fish going upstream; the form of the weir was reversed when the fish began to move downstream.

All northern pike fingerlings that migrated from the ditches to Houghton Lake were captured in a V-shaped weir whose wings were made by placing window screen (12 meshes to the inch) over wooden frames. These screens were buried securely in the bottom of the ditch and in the bank, with the apex pointed downstream. A home-made minnow trap of window screen (12 meshes to the inch) was placed in the opening at the apex of the V. This trap was soldered to a piece of sheet metal which fitted tightly in grooves, one in each wing, so that it could be removed by sliding upwards.

Condition of ditches and lake at time of spawning run

Houghton Lake had an extremely high water level and was covered with 18 inches of ice during the last week of March, 1939. At this time the water in the ditches was completely frozen over (usually to the bottom). By April 2 the ice and snow in these ditches had begun to melt, and on this date all of the ice had disappeared in Ditch I near the point at which it empties into the lake. The warmer water that entered the lake from the ditches opened a hole in the ice of the lake near the shore and also melted the ice offshore so that in the shoal area an open space existed between the bottom of the lake and the surface of the ice. This open space permitted the passage of northern pike from the deeper water of the lake into the ditches. The first run of northern pike (estimated at 50 fish) entered the ditch on the night of April 2, before a weir could be installed. Considerable difficulty was experienced in the construction of the weir, because of the frozen banks and ditch bottom. However, it was completed on April 3. The upstream run of northern pike continued until April 25. The ditches were either partially or completely

frozen over until April 15. The ice did not disappear completely from Houghton Lake until April 23.

In 1940 Houghton Lake was extremely low, although at the time of the earliest observation on March 16, the water level of the marshes and ditches was higher than in 1939, due to the ice in the culverts and ditches. The water over the broad shoal that extends out in Houghton Lake from the mouth of the ditch was frozen to the bottom. By April 5, approximately 100 feet of the ditch nearest the lake was open, and there was a good flow of water into the lake. The weir was installed on this date. On April 9, a hole about 70 feet in diameter had been opened in the ice of the lake at the mouth of the ditch, and the first northern pike entered the weir on this day. The spawning run continued until April 23. The ditches were almost completely covered with ice until April 15 in the 1940 season. The size of the open spot in the ice cover of the lake at the mouth of the ditch increased almost every day. Occasionally, however, a thin film of ice formed over this opening at night, but this ice did not interfere with the passage of fish and usually broke up during the following day. The general break-up of the ice in Houghton Lake started on April 21 but the ice did not melt completely until April 24.

Observations on the spawning runs of 1939 and 1940

Measurements and determinations of sex were made for all northern pike on their upstream migration in 1939. At the same time each fish of the 1939 run was marked by fin-clipping. This marking involved a different combination of fins each day (20 different combinations were used; consequently the fish that were taken on the last four days were all given the same mark). As was mentioned in the preceding section, the

northern pike that ran upstream on the first night in 1939 (April 2) were not recorded. Jaw tags were affixed to the adults at the time of the downstream migration in 1939 and to the upstream migrants in 1940.

Time and length of the spawning run. The spawning run of northern pike covered a period of 24 days in 1939 (April 2-April 25). Spawners ran up the ditches over a period of 15 days in 1940 (April 9-April 23). McNamara (1937) made observations on the northern pike run at Chemung Lake, Livingston County, Michigan, over a period of four years, but he did not make specific statements to the dates of the run in any one year. He stated merely that the time of the migration was from late February till the middle of April.

Total number of spawners. A total of 378 northern pike were taken in the weir in 1939 as compared with 118 in 1940.[2] Possible explanations

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[2] These 118 fish taken in 1940 did not, however, make up all the northern pike that spawned in Ditches I-IV, since 28 additional fish trapped in a weir in Ditch V were transported to Ditches I-IV. The northern pike captured in Ditch V had ascended from the Muskegon River.

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for the smaller run in 1940 are: northern pike may have been prevented from moving between the lake bottom and the surface ice because of the low lake level in 1940; the lake may have contained fewer adult northern pike in 1940; or the northern pike may have spawned elsewhere. Some evidence for this latter explanation was found in the fact that the run of northern pike at the weir on the Muskegon River was larger in 1940 than in 1939.

Daily number of migrants. The total daily run of northern pike in 1939 and 1940 is presented in Table 1. In 1939, the largest number of spawners taken in any one day was 53 on April 4. The number of migrants exceeded 25 on only 5 days. The majority of the 1940 spawners entered the weir during the 4-day period, April 14 to 17, with just occasional stragglers entering before and after these dates (Table 1). No correlation could be found between the temperature of the water in the ditches and the number of fish that ascended.

Table 1. The daily run of northern pike spawners in Peterson's Ditch, April 1939 and 1940

Day of month	Number of males	Number of females	Total number
1939			
2	...	...	1/ 50
3	11	4	15
4	32	21	53
5	2	2	4
6	10	16	26
7	6	1	7
8	4	4	8
9	3	3	6
10	1	8	9
11	3	8	11
12	2	3	5
13	12	4	16
14	6	6	12
15	6	3	9
16	22	9	31
17	6	3	9
18	7	9	16
19	11	0	11
20	20	7	27
21	17	12	29
22	20	6	26
23	22	2	24
24	11	0	11
25	13	0	13
Total	247	131	2/ 378
1940			
9	3	...	3
10	6	1	7
11	2	...	2
12	1	1	2
13	2	1	3
14	8	5	13
15	12	12	24
16	13	11	24
17	9	6	15
18	1	3	4
19	...	4	4
20	1	3	4
21	1	1	2
22	7	2	9
23	2	...	2
Total	68	50	118

1/ Estimated to have entered ditch on first night of the run.

2/ Does not include the 50 fish that ran upstream on first night.

Hourly variation in the number of migrants. The hourly variation and the average hourly number of adult northern pike that entered Peterson's ditches to spawn in 1939 and 1940 is summarized in Table 2. The largest number of fish entered the weir in the 3-hour period between 9:00 p.m. and midnight. The next largest number ran between midnight and 9:00 a.m., and some early-morning lifts indicated that most of these fish entered the trap before 3:00 a.m. Ninety-five per cent of the migrants, during this 2-year period, were taken between 6:00 p.m. and 9:00 a.m. Only occasional stragglers entered the weir during the daylight hours.

Table 2. Hourly variation in the number of adult northern pike entering Peterson's ditch to spawn in 1939 and 1940 (Average number per hour indicated in parenthesis)

Year	Total number of spawners	Number captured in time period					
		12 M - 9 a.m.[1]	9 a.m.- 12 N	12 N - 3 p.m.	3 p.m.- 6 p.m.	6 p.m.- 9 p.m.	9 p.m.- 12 M
1939	378	118 (0.57)	1 (0.01)	8 (0.12)	9 (0.13)	85 (1.23)	157 (2.27)
1940	118	34 (0.25)	1 (0.02)	1 (0.02)	5 (0.11)	38 (0.85)	39 (0.87)
Total	496	152 (0.44)	2 (0.02)	9 (0.08)	14 (0.12)	123 (1.08)	196 (1.72)

[1] Apparently most of the fish taken within this period migrated before 3:00 a.m. (see text).

Size of spawning-run fish. The mean size of all of the northern pike spawners that were taken in 1939 and 1940 was 21.8 inches. The average for the 1,767 northern pike taken during the creel census of the winter of 1936-1937 was 21.2 inches (Eschmeyer, 1937).[3] These figures indicate

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[3] Eschmeyer, R. W. 1937. Houghton Lake creel census, winter of 1936-1937. Unpublished report of the Institute for Fisheries Research, No. 417, May 10, 1937.

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that the run of spawners in Peterson's ditch was composed of average-sized fish.

No correlation was observed between the average size of either the males or the females and the time of entry into the spawning area. McNamara (1937) said that the average size of males and females increased as the spawning season progressed, but failed to mention whether or not his statement was based on actual measurements. The total lengths of the female northern pike taken in 1939 varied from 19.1 to 37.5 inches in total length, and averaged 23.5 inches. The lengths of the males varied from 12.3 to 26.6 inches, with an average of 21.2 inches.

Again in 1940 there was no significant difference in the size of males or females at the beginning and end of the spawning migration. The average total length of the female northern pike was 23.2 inches with a range of 15.1 to 35.9 inches, while that of the males was 19.8 inches, with a range of 12.1 to 26.8 inches. The average total length of the females was about the same in 1939 and 1940, while that of the males was 1.4 inches less in 1940 than in 1939.

Sex ratio. Both males and females were taken on the first two days of the 1939 run (Table 1), but the males predominated. Fish of both

sexes entered the upstream weir each day of the 1939 run except on April 19 and on the last two days when only males were taken (Table 1). Males comprised 65 per cent of the total run in 1939. The sex ratio was 188 males per 100 females. Of the 131 females that entered the ditches to spawn, 23 were preserved for further study. Consequently, the ratio of fish that were allowed to spawn was 229 males to 100 females. With certain minor exceptions the relative abundance of the males tended to increase as the 1939 spawning run progressed.

In 1940, the males seemed to predominate at the start of the run; during the first five days, 14 males were taken in the weir as compared with 3 females. Females were relatively more abundant during the later days of the run. Males made up 58 per cent of the entire run of northern pike in 1940 (136 males per 100 females). In addition to the fish captured in the weir in Ditch I, 28 northern pike, 13 males and 15 females, were taken in a weir in Ditch V (see note 2) and placed in the area under observation. With these additional fish, the total number of spawners was 146. Eighty-one of these were males and 65 were females (125 males per 100 females). Although observations indicate that sometimes only one male spawns with a female, the majority of the females observed spawning were accompanied by two males, and a few by more than two.

Observations made at Houghton Lake do not agree with these of McNamara (1937). He stated that males run upstream first and the females follow later. He did not give any detailed information, however, or give evidence that all fish running upstream were examined.

State of gonads. Our records indicate that the first northern pike to run upstream were ripe to the extent that milt and eggs dropped from most of the fish as they were picked up. In 1939 all of the males taken in the upstream weir were ripe, as were 90.1 per cent of the females. In 1940, 91.2 per cent of the males and 86 per cent of the females were ripe. It appears, therefore, that the maturation of sperm and eggs of northern pike takes place before the fish begin the spawning migration.

Seven fish taken in the weirs in 1940 had clipped dorsal fins, which indicated that they were young that hatched in the ditches in 1939. The average total length of these seven yearling fin-clipped northern pike was 14.6 inches. Four of the fish were ripe males (13.3-15.0 inches, total length), and one was a gravid female (15.7 inches). One male (14.5 inches) was either green or immature, and the sex was not determined for the remaining fish (15.1 inches). Some northern pike, therefore, may be mature at the end of the first year of life. It was not determined whether the eggs and sperm of these fish were viable.

Return of adults to the lake. A period of 40 days elapsed in 1939 between the time that the first northern pike was taken in the downstream weir on April 21 and the last one had left the ditches on May 30. The majority of the 364 fish, or 93 per cent, returned to the lake between April 25 and May 7. A wide variation was found in the number of days spent in the ditches by the spawning fish. The average[4] number of days

[4] This average is based on only 313 of the 364 downstream migrants because 51 of these 364 fish were either not fin-clipped on their way upstream (the 50 fish that ran upstream the first night were not marked), and my assistant failed to record the marks on some of the downstream migrants during June.

spent in the ditches was 18 1/4 days (range 6 to 50 days). A total of 29 fish died in the ditches. Since two of these had each eaten one marked adult northern pike, it is possible to account for a total of 31 dead northern pike. A number of the northern pike had apparently jumped out of the water onto the ditch banks. Others may have died from the strain of spawning, or from injuries sustained during the spawning act, or during the handling at the weirs. All but about 10 of the northern pike estimated to have gone upstream[5] were accounted for. These 10 fish may have been

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[5] This number includes the 50 northern pike that were estimated to have entered the ditches on the first night of the run, plus 60 fish that were taken for samples, found dead, and those (6 fish) that escaped before being tagged and the 358 fish that were tagged.

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eaten by other fish, birds, turtles, or may have died and escaped notice. It is also possible that poachers may have taken some of them.

A period of 88 days elapsed in 1940 from the time that the first northern pike was taken in the downstream weir on its return to Houghton Lake, April 24, until the last one had left the ditches on July 20. Fifty-one per cent of the northern pike returned to the lake during the last seven days of April, 35 per cent returned in May, 13 per cent in June and 1 per cent in July. The fish on which these percentages were based included the 28 northern pike captured in Ditch V (see note 2). As in 1939, the time the spawners spent in the ditches varied widely. In 1940 the shortest number of days spent in the ditches by any one northern pike was 4 days (April 23-26), the longest period was 90 days (April 22 to July 20), and the average was 23.9 days. Sixteen dead fish were found in the ditches in 1940. Of the number of fish known to have been in the ditches, all but

43 returned or were accounted for in some way. Poachers were known to have been active in 1940 and part of the loss can no doubt be traced to them.

Seven small northern pike taken in the downstream trap in 1940 on their return to the lake had not been tagged. These fish were all small enough to have passed between the slats of the weir. One of these fish had a clipped dorsal fin, which indicated that it was one of the young northern pike of the 1939 hatch at this place.

Growth of young northern pike

Collections of the young northern pike used for growth determinations were taken in the ditches by seines, minnow traps and dip nets and from the weir. Collections were made every day, when possible. At times, however, samples could not be obtained by any of the methods listed above. Since accurate measurements were difficult to make on small, live northern pike, many of them, particularly in the earlier collections, were preserved and measured later in the laboratory. The weekly average lengths of the combined samples from the ditch and from the weir have been employed to estimate the early growth of the northern pike (Tables 3 and 4).

Certain conditions that tended to make the sampling of young northern pike selective as to the size of the fish throw doubt on the reliability of successive average lengths as precise measures of growth. During the earlier part of the sampling period the continual addition of newly-hatched fish reduced the average differences to less than the probable growth of individual fish. Samples taken from the ditch were affected most severely by this source of error. The average lengths of the earlier collections from the weir, on the other hand, may have been somewhat high

Table 3. The weekly average size of young northern pike in Peterson's ditches, 1939

Date	Number of samples	Number in samples	Total length in millimeters			Increase of average	Average daily increase	Average daily increase by months
			Minimum	Maximum	Average			
May 6	1	32	11	17	13.8	[1]...	...	...
May 7-13	7	173	12	30	19.4	5.6	[2] 1.2	1.5
May 14-20	6	79	17	42	28.5	9.1	1.3	(May)
May 21-27	4	68	21	77	44.2	15.7	2.2	26 days
May 28-June 3	4	141	36	114	57.6	13.4	1.9	...
June 4-10	5	92	37	129	105.5	47.9	6.8	3.3
June 11-17	1	4	89	129	106.7	1.2	0.2	(June)
June 18-24	4	52	54	178	127.4	20.0	2.9	30 days
June 25-July 1	2	14	122	215	154.8	27.4	3.9	...
July 2-8	7	225	54	213	166.2	11.4	1.6	0.4
July 9-15	7	190	94	229	162.7	-3.5	-0.5	(July)
July 16-22	5	101	98	219	167.6	4.9	0.7	23 days
July 23	1	16	107	191	160.4	[1] -7.2	[2] -1.6	...
Total	54	1,187	...	...	...	...	...	...

[1] Less than a week

[2] Four and one-half days

Table 4. The weekly average size of young northern pike in Peterson's ditches, 1940

Date	Number of samples	Number in samples	Total length in millimeters			Increase of average	Average daily increase	Average daily increase by months
			Minimum	Maximum	Average			
May 4	1	14	8.5	12	10.1	[1]...	...	...
May 5-11	3	35	10.0	16	13.3	3.2	[2] 0.7	0.6
May 12-18	2	52	17.0	22	19.1	5.8	0.8	(May)
May 19-25	3	53	17.0	31	23.1	4.0	0.6	28 days
May 26-June 1	2	15	22.0	32	27.3	4.2	0.6	...
June 2-8	4	70	28.0	52	39.3	12.0	1.7	2.1
June 9-15	3	139	37.0	85	50.9	11.6	1.7	(June)
June 16-22	5	52	41.0	100	63.0	12.1	1.7	30 days
June 23-29	5	6	64.0	134	88.0	25.0	3.4	...
June 30-July 6	6	36	48.0	126	102.8	14.8	2.1	...
July 7-13	7	17	92.0	136	111.5	8.7	1.2	1.3
July 14-20	5	56	78.0	177	114.8	3.3	0.5	(July)
July 21-27	3	15	97.0	166	124.1	9.3	1.3	27 days
August 22-24	2	3	190.0	227	208.7	[2] 84.6	[4] 2.8	...
Total	51	563	...	...	...	...	...	...

[1] Less than a week

[2] Two days - August 22 and 24

[3] Four and one-half days

[4] Thirty and one-half days

because of the tendency of young northern pike to move downstream only after the attainment of a certain minimum size. Very few fish less than 20 millimeters long were taken in the weirs at periods when smaller fish were extremely abundant in the ditches. Cannibalism also tended to increase the average length of samples from the weir since the smaller fish, deprived of their natural protective cover and confined in close quarters, frequently were eaten by the larger individuals in the trap. The average lengths of samples from both the ditches and the weir may have been too small in the latter part of the sampling period because of the earlier migration of the individuals with the more precocious growth.[6] Data were not available for the evaluation of the amount of error introduced by these sources of selection. Fortunately, some of the sources tended to compensate each other. Nevertheless, it is believed that the estimates of growth provided by the data of Tables 3 and 4 should be considered minimal.

[6] The relationship between size and time of migration was not clear-cut. Although few fish migrated at a length of less than 20 millimeters, large numbers remained in the ditches until they had become much larger. Once all the young northern pike had passed the length of 20 millimeters, little correlation could be observed between length and the tendency to move downstream.

The weekly average sizes of the young northern pike taken in the ditches during 1939 are recorded in Table 3. The weekly average sizes fluctuate a great deal, probably because of inadequate samples, therefore discussion is based mainly on the average daily increase in size.

Measurements were made on 1,187 young northern pike. Advanced fry, probably representing successive hatches, appeared in the daily collections from the ditches as late as May 13. Others possibly may have hatched after this date, but none were taken in any of our samples. During May the average size of young northern pike increased on the average of 1.5 millimeters per day. The increases were irregular in June, but averaged 3.3 millimeters per day. Growth appears to have declined in July, the increase in size averaged just 0.4 millimeters per day. Certain of the irregularities in the data are no doubt traceable to the small numbers of fish in the samples. A great divergence existed between the minimum and the maximum lengths of young northern pike throughout the period of sampling. With few exceptions (when the samples were small), the minimum and maximum sizes of young fish increased from week to week.

In 1939 the average size of the young northern pike taken in the ditches and in the weir increased at the rate of 1.8 millimeters per day during the 82 days between the estimated time of first [7] hatching on May 3,

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[7] The first fry observed on May 5 were estimated to have hatched about 2 days earlier.

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until the ditches dried up on July 23.

The maximum length attained by any young northern pike in the ditches during the 1939 total season was 9 inches. This fish was taken on July 10 and was probably not more than 69 days old. Its daily average rate of growth may be estimated therefore as 3.2 millimeters.

The average daily increase in the size of young northern pike during May, 1940, (28 days) was 0.6 millimeters per day (Table 4). This average was 2.1 millimeters per day during June and 1.3 millimeters per day in July.

Cool and cloudy weather with frequent rains may account in part for the slow growth during May. The average size of young northern pike increased at the rate of 1.3 millimeters per day during the 85 days from the time of hatching on May 4, until July 27, the last day on which an adequate sample was taken. Only three northern pike fingerlings were taken after July 27; one of them was caught on August 22 and the other two on August 24. The largest northern pike fingerling taken from the ditches in 1940 was caught on August 22, and had a total length of 8.9 inches.

Fifty young northern pike were taken with a seine on June 17 in Ditch VII (see Fig. 1) which was not under observation in 1940. The average total length of these fish was 100.7 millimeters; the length varied from 69 to 139 millimeters. They averaged just 33 millimeters larger than young taken on the same date in the ditches that were under observation (Ditches I-IV). One possible explanation for this excellent growth is that Ditch V usually contains water the year around and may therefore have a better food supply. The fact that minnows migrate up this ditch from the Muskegon River is particularly important. This more or less permanent stock of forage fish was supplemented in May 1940 by several thousand minnows 2 to 4 inches in length that escaped from the tanks of a commercial minnow dealer.

One hundred eight-five northern pike with an average total length of 20.0 millimeters were taken from Ditches I-IV and placed in an experimental minnow pond at the Drayton Plains Hatchery on May 11, 1939. This pond was stocked liberally with minnows of all sizes. On October 19, when this pond was drained, 10 northern pike were removed. The total length of these fish ranged from 11.25 inches to 14.25 inches, and averaged 12.54 inches. Their average daily growth was 1.85 millimeters during the 161 days they spent in the pond.

The remarkably rapid growth made by the young northern pike is approached by only one other fresh-water fish, the northern long-nosed gar (Lepisosteus osseus) (Hubbs, 1921).

Migration of young northern pike

All of the young northern pike that migrated from Peterson's ditches in 1939 and 1940 were taken in a weir, measured and then were released in Houghton Lake. More young fish moved downstream from the marshes to the lake on clear, bright days than on cloudy days. It was observed that the young pike drifted along, either head or tail first or across the current, just beneath the surface of the water.

The first free-swimming fry were observed on the afternoon of May 5, 1939. These young northern pike were all advanced fry with remnants of the yolk sac attached. The young fish were found just below the surface of the water and when frightened darted into the weeds or dropped to the bottom. Young northern pike appeared to be much more active, and remained nearer the surface of the water on bright, sunny days than on cloudy days.

The first northern pike fingerlings moved into Houghton Lake from the ditches on May 12, 1939, approximately 10 days after hatching (see note 7). At this time their average total length was 19 millimeters. Of the total number of fish that were taken in the weir in the 1939 season, 85.4 per cent migrated during the last 20 days of May, 8.6 per cent in June and 6.0 per cent in July (Table 5).

The first newly-hatched fry in 1940 were found on May 4, each hanging to plants by a thread from the adhesive organ. The first free-swimming fry were observed on May 7. During the next few weeks many fry and

Table 5. The number of young northern pike migrating from Peterson's ditches into Houghton Lake in 1939 and 1940, by monthly periods

Month	1939		1940	
	Number taken	Percentage of total	Number taken	Percentage of total
May	[1] 6,184	85.4	[2] 372	24.9
June	621	8.6	999	66.8
July	434	6.0	121	8.1
August	...	...	3	0.2
Total	7,239	100.00	1,495	100.0

[1] May 12-31 (20 days)

[2] May 25-31 (7 days)

fingerlings were observed, and they appeared to be as numerous as in 1939, when many more adults spawned in this area.

In 1940 the first young northern pike were taken in the downstream weir on May 25, just 22 days after the first fry were observed in the ditches. This interval of time is in contrast with 1939, when the first young northern pike moved down 10 days after hatching. At the time of the first 1940 migration (May 25), the total length of the fish averaged 23 millimeters. In the 1940 season, 24.9 per cent of the total run of fish entered the lake in the last 7 days in May (May 25-31). The majority (66.8 per cent) entered the lake in June, 8.1 per cent in July and 2 per cent (3 fish) in August. Altogether 90.9 per cent of the total run migrated to the lake during the first 26 days of the run (May 25 to June 19).

It appears that the run of young northern pike was delayed about 12 days longer in 1940 than in 1939. The only explanation that we can offer for this delay is that there were more cloudy and cold days during May in 1940 than in May of 1939. In the 1940 season, only 24.9 per cent of the total run of fish entered the lake from the ditches during May (7 days), compared to the 85.4 per cent that moved into the lake during the last 20 days in May, 1939.

Total number of young northern pike migrating to the lake

Altogether, 7,239 young northern pike returned to the lake in 1939 (Table 5). This number[8] represents the total production resulting from

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[8] The number of migrating young no doubt would have been higher had not samples been taken from the ditches for the study of growth.

the spawning of 108 females and 247 males.

During the 1940 season, 1,495 young northern pike moved to Houghton Lake from the marshes (Table 5). These fish represent the total production resulting from the spawning efforts of 65 females and 81 males (see note 8). It is not believed that the smaller number of spawners in 1940 accounted for the low production as compared with 1939, since the examination of the ditches shortly after hatching indicated young northern pike to be as abundant in 1940 as at the corresponding period of the preceding year.

The greater abundance of minnows and small perch in the ditches in 1940 doubtless contribute to the lower production in that year. In 1939, minnows and small perch (2 to 4 inches long) started to run up the ditches at about the time the northern pike fry were hatching. These minnows and perch were allowed to enter the ditch for only one day. Samples of these fish were taken at intervals and preserved for a later stomach analysis. Cursory examination of a few of the perch revealed that some of them had eaten small northern pike. Perch and minnows were not prevented from running upstream in 1940 because it was decided that to block off the run would upset natural conditions. Samples of the perch and minnows were collected and preserved throughout the summer but as yet their stomachs have not been examined. However, there is little doubt that the perch were partially responsible for the reduced production of northern pike in the ditches in 1940.

Acknowledgments

The writer wishes to express his thanks to Mr. Harold Bowditch, Conservation Officer Tom White, and Mr. Philip Woodworth for their valuable assistance in the collection of data; to Dr. A. S. Hazzard and various

members of the staff of the Institute for Fisheries Research for their guidance and assistance; and to Mr. H. L. Peterson, District Supervisor of Fisheries Operations, and Mr. John Peterson for the use of facilities and equipment during the course of this investigation. I am indebted to Doctors A. S. Hazzard, Ralph Hile and C. J. D. Brown for a critical reading of the manuscript and for suggestions in presentation of data.

Summary

1. An investigation was begun on the spawning activities and the early life history of the northern pike in the marshes and drainage ditches flowing into the North Bay of Houghton Lake in the spring of 1939 and was continued through that summer and the spring and summer of 1940.

2. All migrating northern pike young and adults were captured in weirs.

3. Northern pike spawners usually ascend the ditches in the early spring as soon as the flow of water from the ditches opens a hole between the ice cover of the lake and the lake bottom.

4. In 1939, the spawning migration covered a period of 24 days (April 2 to April 25). In 1940 the fish entered the spawning grounds over a period of 15 days (April 9 to April 23).

5. A total of 428 northern pike entered the ditches in 1939 as compared with 118 in 1940. The sex ratio was 188 males per 100 females in 1939 and 136 males per 100 females in 1940.

6. The average size of neither the males nor the females varied according to the time of entry into the spawning run. The average total length of female northern pike in 1939 was 23.5 inches while the males averaged 21.2 inches. In 1940 the female northern pike averaged 23.2

inches total length, and the males averaged 19.8 inches.

7. No correlation could be found between the temperature of the water in the ditches and the number of fish that ascended.

8. Ninety-five per cent of the adult northern pike entered the spawning area between 6:00 p.m. and 9:00 a.m. The largest number of fish entered the weir in the 3-hour period between 9:00 p.m. and midnight. Only occasional stragglers entered during the daytime.

9. The relative abundance of the males tended to increase as the 1939 spawning run progressed. The change of the sex ratio was without definite trend in 1940 although the females were somewhat more abundant toward the middle of the spawning run than at the beginning.

10. Observations indicated that the maturation of sperm and eggs of northern pike takes place before the fish begin the spawning migration.

11. Seven yearling northern pike that had been fin-clipped at Peterson's ditches in 1939 were captured in the upstream weir in 1940.

12. The average daily increase in the size of young northern pike in 1939 was 1.8 millimeters per day during the 82 days after hatching. In 1940 the daily increase averaged 1.3 millimeters per day during the 85 days after hatching.

13. In 1939 a total of 7,239 young northern pike returned to the lake from the ditches. In 1940 only 1,495 young reached the lake.

14. In 1939 and 1940 small minnows and perch started to run up the ditches at about the time the northern pike fry were hatching. Cursory examination of a few of the perch revealed that a few of them had eaten small northern pike. The greater abundance of minnows and perch in the ditches in 1940 doubtless contributed to the lower production in that year.

15. The first northern pike fingerlings moved into Houghton Lake from the ditches on May 12, 1939, approximately 10 days after hatching. In 1940, the first fry were taken in the downstream weir on May 25, just 22 days after hatching. This apparent delay of 12 days in the 1940 run was probably due to the colder weather in May of 1940 than in May of 1939.

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(These references have been checked against the original sources.)

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