ASPECTS OF THE LIFE HISTORY AND ECOLOGY OF THE SPOTTAIL SHINER, *NOTROPIS HUDSONIUS* (CLINTON)

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by

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Introduction

The aim of this project was to obtain as much information as possible on the life history and ecology of the spottail shiner, *Notropis hudsonius* (Clinton). For the purpose of this study, a life history approach is interpreted to be directed toward following the changes in form and behaviour that take place during the lifetime of typical individuals of the species in the population being studied. Ecology is considered to be concerned with the relationship of the population to its environment. These relationships may be different for the various age groups found within the population. The relationship of each age group to the others within the population, to other populations within the biotic community, and to the physical environment determine its ecology. The timing of these stages is primarily the concern of a life history study. It may involve merely a change of form, such as a fish becoming fully scaled, or a change in behaviour, such as may be associated with the loss of the yolk sac. The latter case would also have ecological implications. In this study, both the stage of the life history and its ecological aspects were studied as fully as possible.

The time available for the investigation did not allow more than one population to be studied with sufficient intensity to yield information of value. Therefore, an intensive study of a single population was undertaken rather than a more diffuse study including several populations. Observations on other populations were used as compsrisons, however. Although a synecological approach was not intended, it was thought necessary to make similar but less detailed observations on the other populations of closely associated species in the lake, in order to determine their ecological relationships to N. hudsonius.

The ubiquity of this species can be seen from its distribution, as given by Hubbs and Lagler (1949): Mississippi River and its main tributaries, from Kansas, Iowa and Illinois, northward, through the Red River of the north and as far as the Saskatchewan system, Lake Athabaska and the James Bay region; Lake Superior and some of its tributaries; also the Hudson and probably the Susquehanna River systems. Trautman (1957) states that the northern limit of range is somewhat indefinite.

Eddy (1957) gives the distribution of N. hudsonius as: North Dakota and adjacent Manitoba, to the Hudson River, south to Virginia, Illinois and Iowa. Filyk (1955), in an unpublished report on the distribution of minnows and other small fish in northern Saskatchewan, reports N. hudsonius from all twelve of the lakes examined. Filyk's study extended from Jackfish and Murray Lakes, which were the most southerly (53°N. lat.), and included Waskesieu, Lac des Iles, Waterhen, Ile à la Cross, Big Peter Pond, Little Peter Pond, Churchill, Frobisher, Cree and Reindeer Lakes. The last two were the most northerly, being about 57°N. lat. The data from Filyk's study has shown that the spottail shiner was the most abundant minnow taken in seine hauls in all but two of the lakes. In these lakes (Big Peter Pond and Lac des Iles), *N. athernoides* is essentially a northern species, confined to northern Ohio, Indiana and Illinois, and abundant in the northern states, east of the Dakotas. *N. hudsonius* was also found in Wollaston Lake, Lake Athabaska and Great Slave Lake, by Rawson and in the Mackenzie River at Fort Good Hope, by Wynne-Edwards (1952).

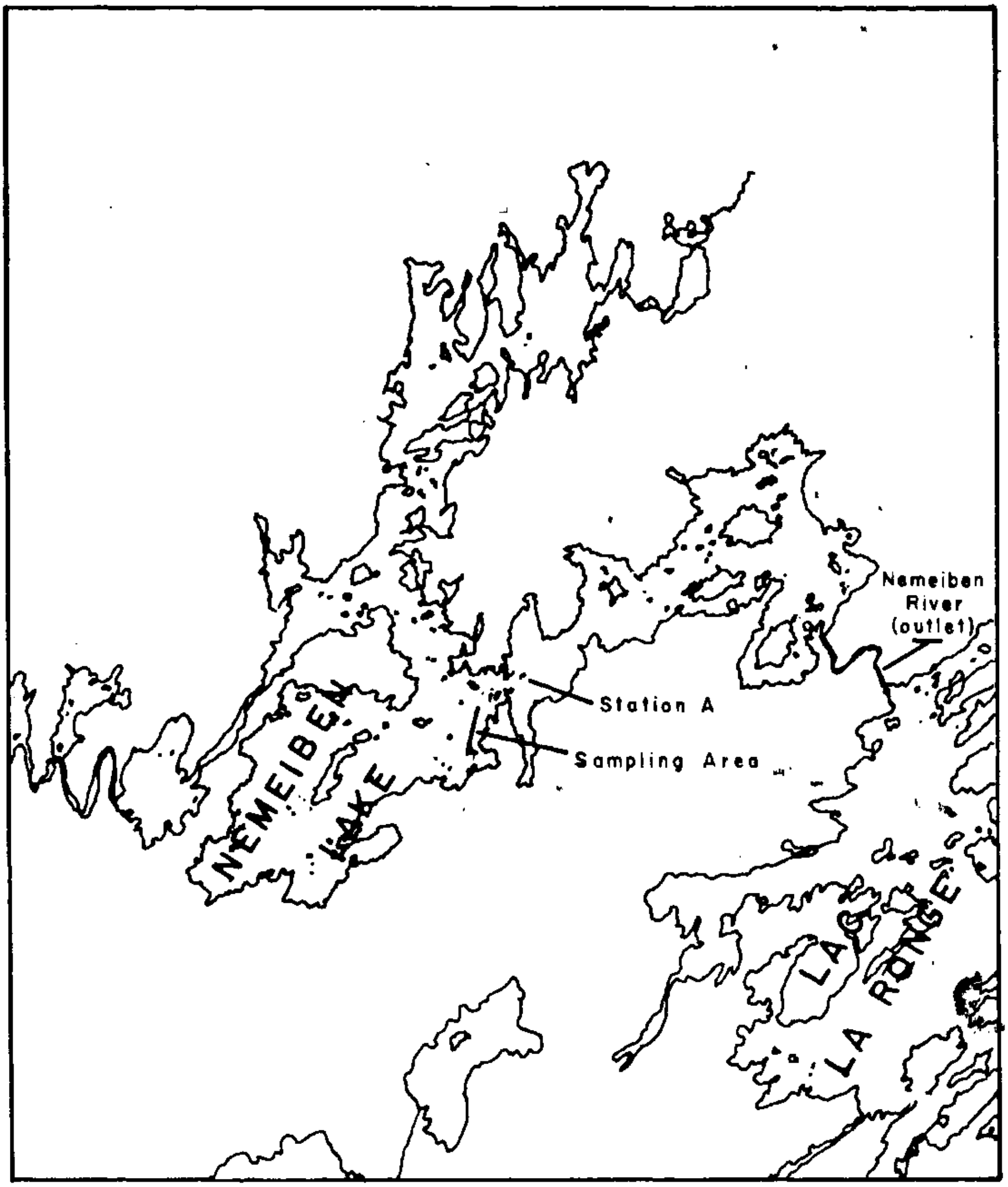
Materials and Methods

Field work for this project was conducted during the summer of 1960 at Nemeiben Lake, which is situated on the southern edge of the Precambrian Shield. The lake is divided into several separate basins, having distinct morphological characteristics. The part from which the material was collected is relatively shallow. Its shoreline is long and irregular with many headlands and sheltered coves. The bottom in the centre of the lake consists of flocculant ooze but near shore consists mainly of bedrock and large boulders. Occasional shoals of sand or silt were found in the coves.

The fish used in the study were caught by means of seines, traps and gill nets. The traps were made of galvanized iron wire mesh. They were cylindrical, one foot in diameter, with a funnel at each end, the innermost diameter of which was reduced to 1 1/4 inches. These traps were not effective for spottails, catching mainly crayfish, darters, sculpins and perch. Bottom-inhabiting species, such as crayfish, darters and sculpins, are susceptible to trapping because of their behaviour patterns, while the perch would be caught because of their abundance. It was of interest that, when set in 40 meters of water in North Bay, Nemeiben Lake, for 24 hours, the traps were quite effective in catching *Mysis*.

Two seines were used, one thirty-foot (1/4 inch mesh) and a smaller ten-foot common sense seine. Both had

Figure 1. Nemeiben Lake.
Scale - 1 inch equals 4 miles.


NEMEIBEN LAKE
Station A
Sampling Area
Nemeiben
River
(outlet)
LAC LA RONGE

their bags lined with fine mesh material so as to retain the fry.

On several occasions, the small seine was towed along the surface of the water in an attempt to sample small pelagic fish. The mouth of the seine was held open by means of a single beam, equal in length to the width of the seine. The bottom was weighted with extra leads so that the seine would remain in a vertical position. However, only ninespine sticklebacks (Pungitius pungitius) were collected in this manner.

Large adult minnows were also collected by means of a gill net consisting of three sections: 30 feet of 5/16, 30 feet of 3/8 and 30 feet of 5/8 inches bar mesh. Except for the time required to mend it, the net was set continuously during the period July 6 - August 28. It was set in nine different locations for periods varying from one to nine days. Both surface and bottom sets were used in deep water. During the first part of the summer, when shallow water sets (one to two meters) were being used, the net formed a complete barrier from the surface to the bottom. In all locations, the net was checked at least once during the day, weather permitting.

All fish (including young-of-the-year) were measured on a measuring board with a scale graduated in millimeters. The measurements were taken after the fish had been in a ten-percent formalin solution (containing four-percent formaldehyde) for two to three months. All lengths given are total lengths unless otherwise stated, this being interpreted as the distance from the most anterior point of the head to the most posterior point on the caudal fin. Total and fork lengths have been shown to be the most accurate when all methods were statistically compared (Carlander and Smith, 1945). As convenience is the only other criterion (Ricker and Merriman, 1945), total length, found to be the most convenient for small fish, such as minnows, was chosen.

The terminology used in describing the life history stages of fish in this study follows. Up to the time of hatching, the young fish is called an "embryo". The term, "larva", applies from the time of hatching until the transformation into the adult form, when it becomes a "juvenile". January 1 was chosen as the date on which one age group changes into the next (Hubbs, 1943). Thus, a fish hatched in July would be designated as age group 0, or "young-of-the-year", until January 1, at which time it would become a "yearling", or age group I.

Although the males of this species are reported to have minute tubercles on the head (Trautman, 1957), they were not readily visible. It was, therefore, found most convenient to examine the gonads in sexing the mature as well as the immature fish. All minnows of the genus, Notropis, have a relatively short intestine and no true stomach. Thus, to determine the food eaten, the contents of the anterior two-thirds of the intestine were examined and identified as far as they could be determined. When the contents were large enough to make it feasible, their volume was determined by displacement of water to the nearest .01 ml. The material was then spread evenly over the bottom of a square plastic dish and the quantities of the various organisms were estimated, by eye, as a percent of the total.

The number of the mature eggs in the ovaries was estimated by measuring the volume of about 1/4 of the ovarian material by the displacement of water and then counting the eggs in it. The total volume of both ovaries having previously been determined, the approximate number of eggs could then be calculated.

In all cases, when it was required to measure the volume of a small object, such as an egg, the following method was used. The object to be measured was placed in a graduated cylinder containing a quantity of water whose miniscus had been previously adjusted to coincide with any suitable mark on the glass. This caused the miniscus to rise above the mark. Water was then drawn off with a graduated pipette until it was down to its original level. The volume of water drawn off by the pipette was equal to the volume of the object being measured.

The average size of the mature eggs in the ovaries was determined by taking a random sample of 25 eggs from one fish and measuring their diameter with an ocular micrometer. The eggs were allowed to fall at random into a small plastic petri dish. The dish was not rotated during measurements so that the diameters of the eggs were always measured along the same plane. A stage micrometer was then used to calibrate the units in millimeters.

The average sizes of the various age groups and the growth rates were calculated from length frequency histograms. The modes on the histograms were quite evident and the normal curves for the various populations of age groups could be seen up to age group III. The troughs evident in the histograms were taken as the points which separated the year classes. The mean lengths of the fish between these points were then calculated to determine the approximate mean size of that particular year class. In cases where there was overlap of two normal curves, the amount of overlap of each age class was assumed to be equal.

Some scale samples were also taken. The scales were read by placing them between two glass slides, the ends of which were then taped together. These readings were used to establish whether or not the age of the fish, as determined by the scale annuli, agreed with the age, as determined by its size from the modes evident in the length frequency histograms.

Samples of fish obtained from the seine hauls made by the Fisheries Branch of the Department of Natural Resources, Saskatchewan, were used in studies of growth rate and reproduction.

Taxonomic Aspects

The species, N. hudsonius, belongs to the family, Cyprinidae. Most members of this family are small, feeble fish. None has teeth in the jaws and, except for the introduced carp and goldfish, no spines on its fins.

The genus, Notropis, contains more species than any other genus of fresh water fishes. All members of this genus have an alimentary canal that is less than twice the length of the head and body. This would be indicative of a diet consisting mainly of animal organisms (Hubbs and Cooper, 1936). In contrast, another cyprinid, Pimephales promelas, has a long, coiled intestine. Coyle (1930) reports that it eats mainly mud and detritus with a small amount of animal food. The intestine of N. hudsonius is approximately equal to the length of the body. In common with other members of its family, N. hudsonius has no stomach. This is believed to be a specialized condition rather than a primitive one (Barrington, 1942). In these stomachless fish, the hepatic duct enters the intestine just behind the oesophogus and the whole alimentary tract posterior to this point functions as an intestine (Kraatz, 1924). The maceration of food organisms, which is necessary for efficient intestinal digestion, would be accomplished by the well developed pharyngeal teeth. In N. hudsonius, these teeth are long and hooked, well suited to holding and tearing animal organisms. They are in sharp contrast to the flat molar-like pharyngeal teeth of the omnivorous carp. The pharyngeal teeth of all North American minnows are in two rows on each of the pharyngeal arches. In some minnows, the outer rows may fail to develop, leaving only one row in each arch. The dental formulae are written from left to right. A formula of 2,4-4,2 would be interpreted as: two teeth in left outer row, four in left inner, four in right inner, and two in right outer. The dental formula of N. hudsonius is given as 0,4-4,0 by Eddy (1957); by Forbes and Richardson (1920), as variable, 0,4-4,1, 1,4-4,2 or 2,4-4,2; and by Trautman (1957), as variable, but usually 2,4-4,2, all combinations between this and 0,4-4,0 occurring. The teeth of a random sample of 15 spottail shiners from Nemeiben Lake were examined and were found to be variable. (See Table I.)

The pigmentation of N. hudsonius consists of a prominent black spot at the base of the caudal fin. This spot was present on juvenile specimens from Nemeiben Lake, which were as small as 19 mm., and reported by Fish (1932), in Lake Erie, to be evident on juveniles 14 mm. long. This characteristic renders the identification of spottail shiners in the field relatively simple, as no other Saskatchewan fish is similarly marked.

On the basis of the characteristics described above, it was concluded that the minnow treated in this study was the species, Notropis hudsonius. No reason was evident for placing it in any of the subspecies described for N. hudsonius.

TABLE I

Pharyngeal Tooth-Counts of 15 Spottail Shiners from Nemeiben Lake

Dental Formula	Number of Fish
2,4-4,2	3
2,4-4,1	4
1,4-4,1	7
1,4-4,0	1

Rate of Growth

Young-of-the-year spottail shiners were first seen on August 2. A sample of 71, taken on August 3, had a mean length of 22.6 mm. No spottails smaller than 19 mm. were taken at any time during the summer. This was not the fault of the seine as the openings in the lining were approximately 1 mm. wide. Fish (1932) found a larva of N. hudsonius, 5 mm. long, to be .96 mm. deep. The age group 0 spottails would have hatched from eggs spawned sometime during the period July 8-12. (The reason for choosing this spawning time will be discussed below.) Thus, they went from fertilization through the embryonic and larval stages in about 20 days.

Specimens of N. girardi, reared under artificial conditions, required 40 days after hatching to reach a total length of 24.5 mm. (Moore, 1944). Hatching time was given as about 24 hours. Fertilized eggs of N. chalybaeus were found by Marshall (1946) to hatch in 52 to about 56 hours. The larvae required 60 days to reach a length of 14.25 mm. The relatively short time required for the development of the juveniles of N. hudsonius may be a factor in allowing this species to inhabit northern lakes where the growing season is short.

From the first appearance of the young-of-the-year spottails, until August 20, samples were taken at intervals varying from one to five days. The minimum number of spottails in any one sample was 19, while the maximum was 140. All were taken in the same area and habitat. The results are plotted on figure 2, which shows the mean, range and standard deviation for each sample. A regression coefficient was calculated and the slope was found to be 0.3. This can be interpreted to mean that the young-of-the-year grew at an average rate of .3 mm. per day during the period August 3 - August 20. The mean length of the age group 0 was 29.27 mm. on August 20 and the mean length, on June 19, of the yearling minnows (age group I, hatched July, 1959) can be estimated from the length frequency histogram as being 38.9 mm. Assuming 1959 and 1960 were typical years, it would seem that the young-of-the-year spottail shiners grow by about 10 mm. during the period August 20 - June 20.

The approximate growth rate of the age group I spottail shiners during late June and early July can be estimated by measuring the difference in position of the mode representing that year class on the length frequency histograms, plotted from fish taken on June 19, June 26, July 16 and July 26 (figure 3). The lengths at which the modes are found on these dates are 38, 40, 45 and 50 mm., respectively. Means were also calculated and were found to be 38.3, 40.0, 46.6 and 50.1 mm. This would give an average growth rate of .33 mm. per day for the age group I spottail shiners during the period June 19 - July 26. This information is plotted on figure 4 as a solid line in the age group I stage of the

Figure 2. Growth rate of age group 0 spottail shiners from samples taken during August, 1960. Means were calculated from the length frequency data. The broken line was fitted by eye.

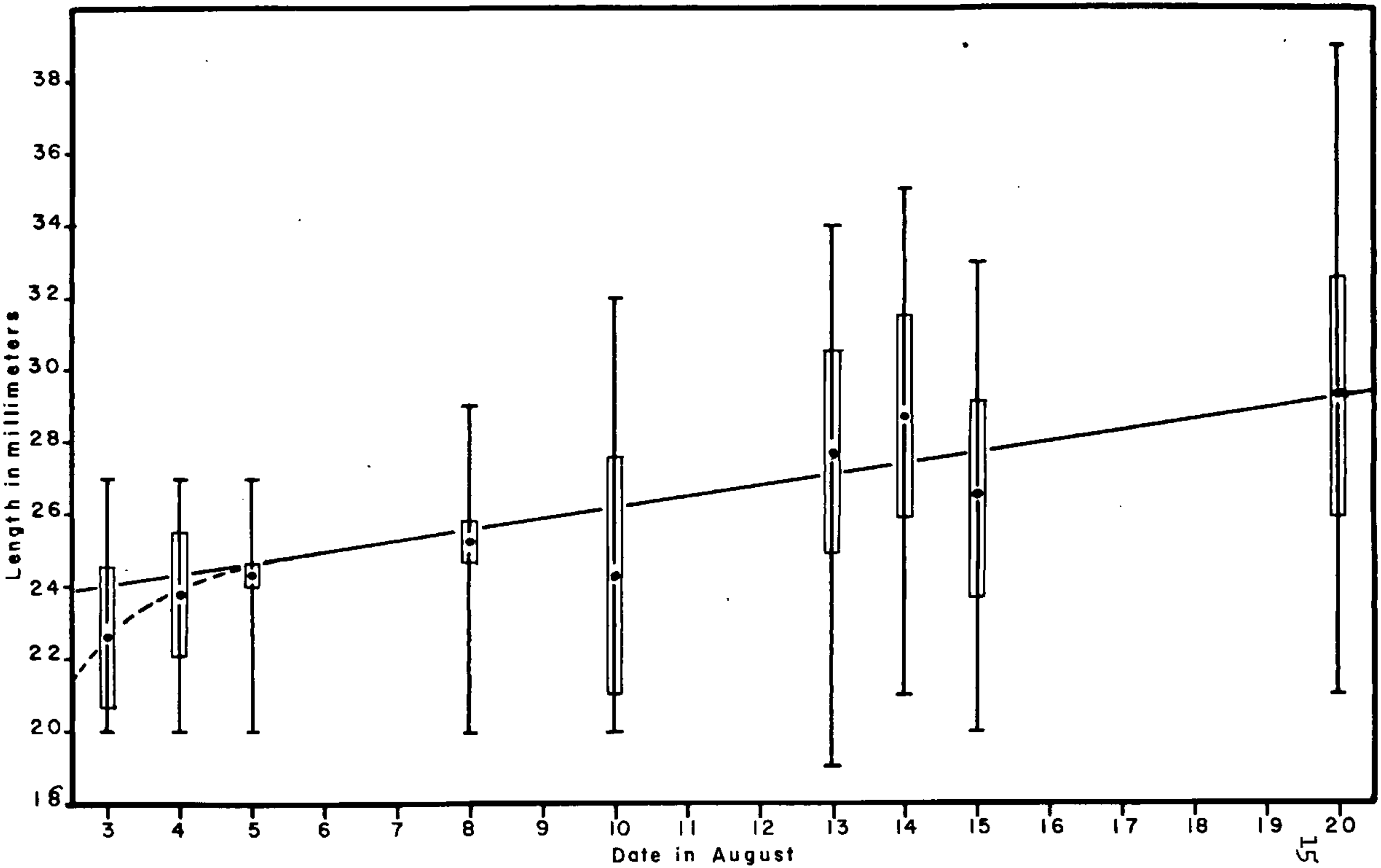

Length in millimeters
18
20
22
24
26
28
30
32
34
36
38
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Date in August

Figure 3. Growth rate of age group I spottail shiners from a series of seine hauls on Nemeiben Lake. Means were calculated from the length frequency data. The line was fitted by eye.

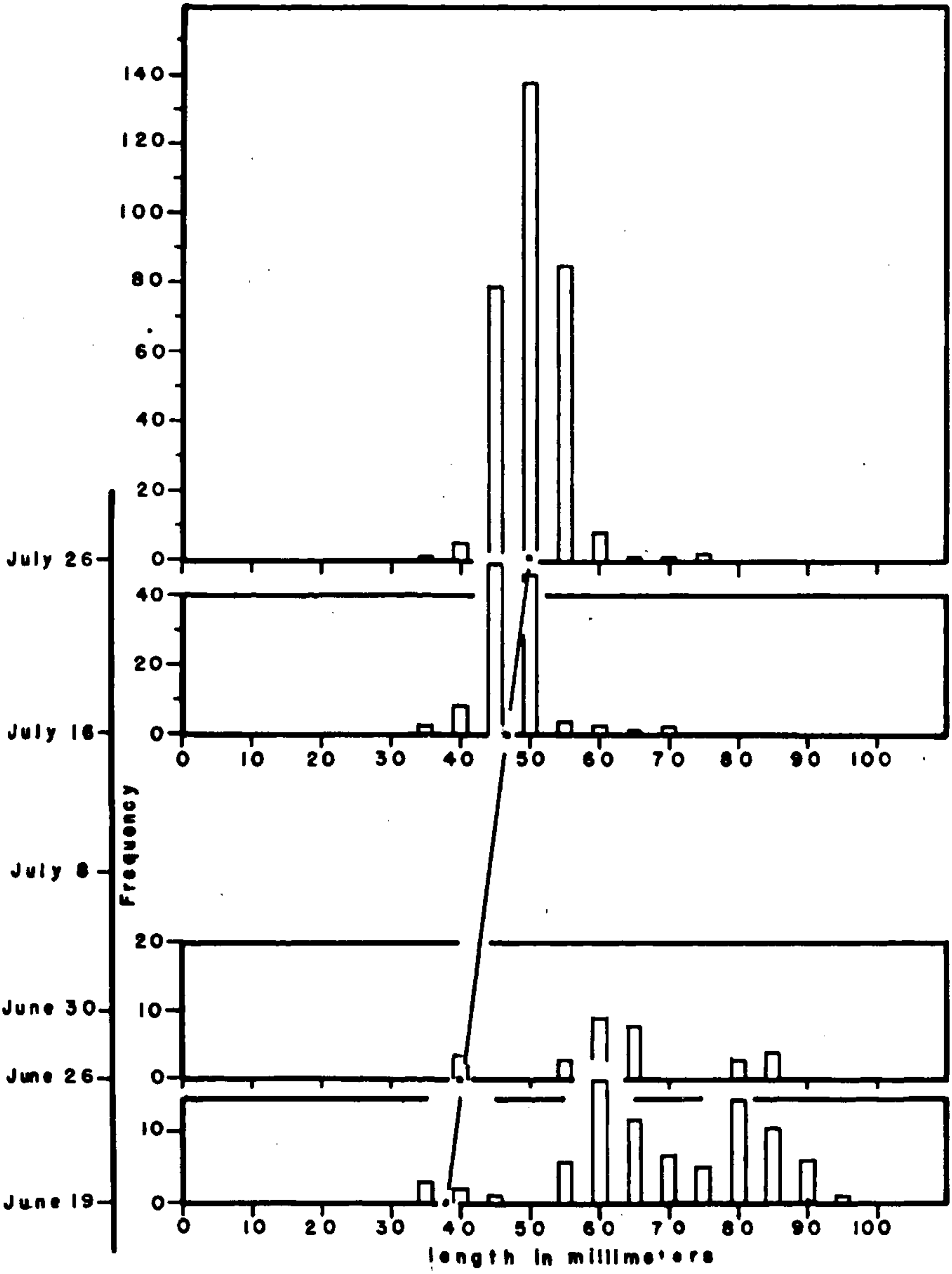
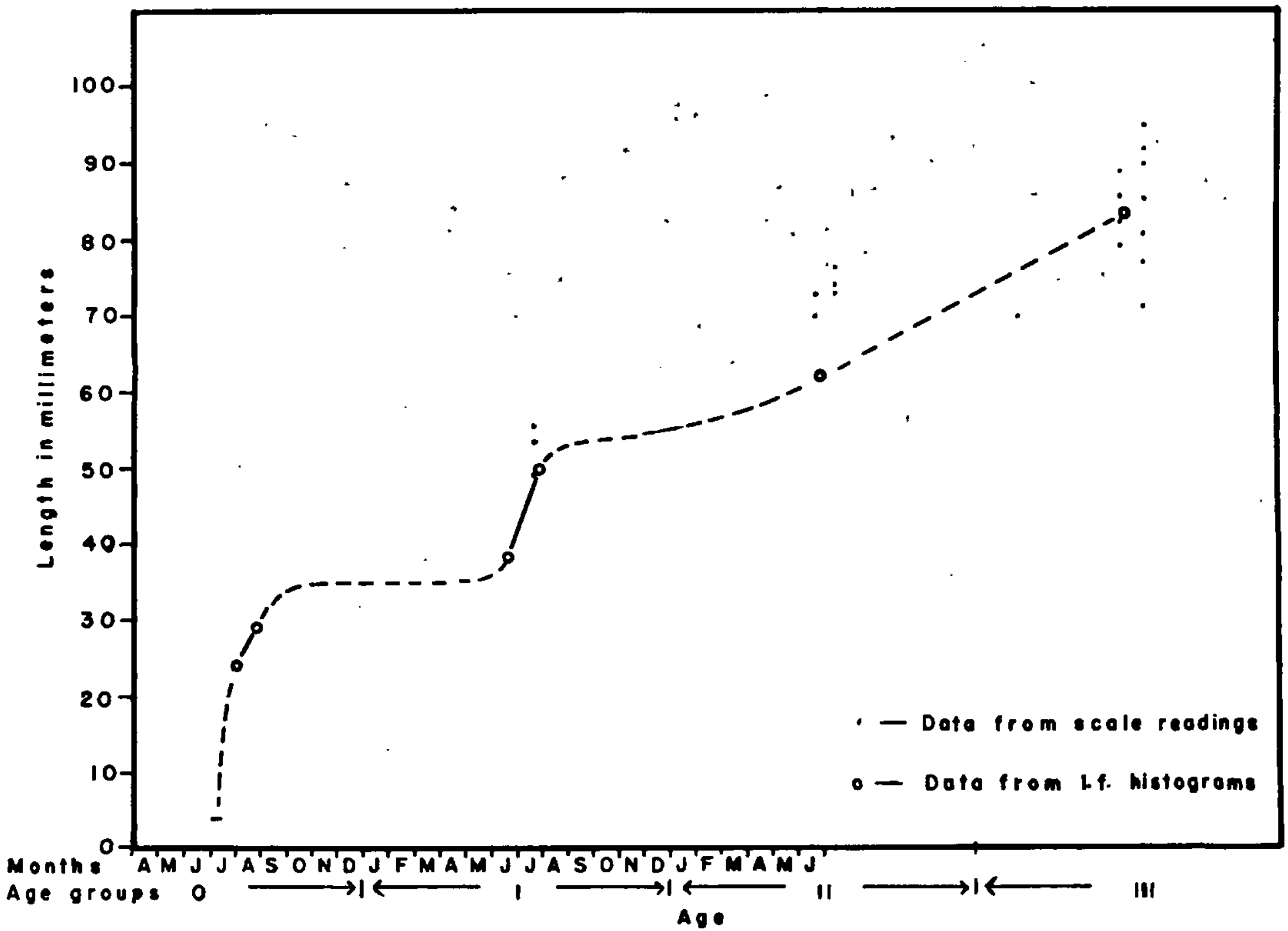

140
120
100
80
60
40
20
0
July 26
40
20
0
July 16
0 10 20 30 40 50 60 70 80 90 100
July 8
Frequency
20
June 30
10
June 26
0
10
June 19
0
0 10 20 30 40 50 60 70 80 90 100
length in millimeters

Figure 4. Average seasonal growth rate of spottail shiners in Nemeiben Lake. Calculated rates are shown by solid lines. Interpolated rates by broken lines.


100
90
80
70
60
50
40
30
20
10
0
Length in millimeters
Months A M J J A S O N D J F M A M J J A S O N D J F M A M J
Age groups 0 I II III
Age
Data from scale readings
Data from l.f. histograms

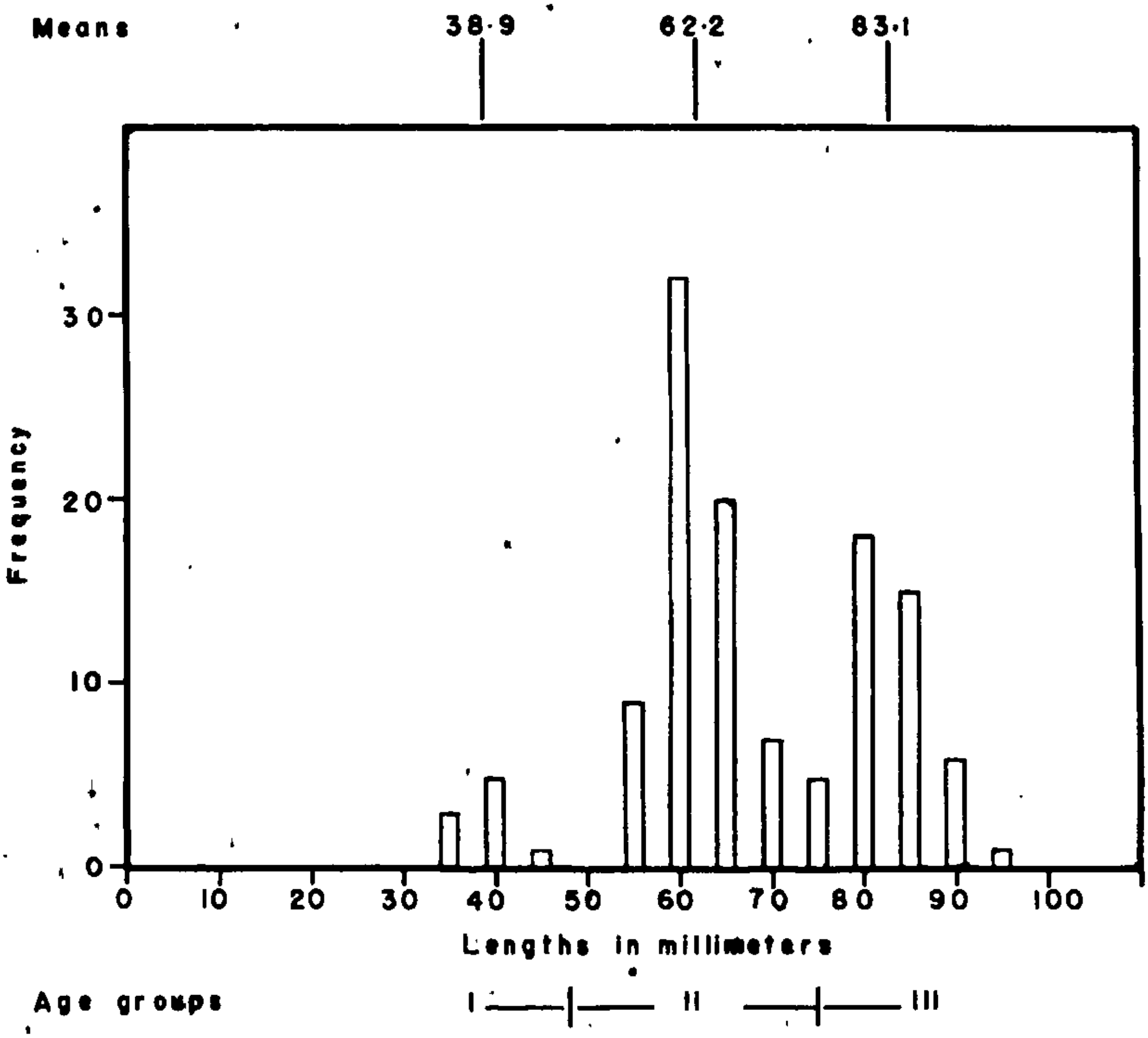
growth rate curve.

No age group II or III spottail shiners were taken after June 26, although special efforts were made to do so. They probably moved into deeper water, as none was seen around the shoals. Therefore, daily increments of length increase were not obtained for either of these age groups. The mean annual increments were estimated from the length frequency histogram plotted for spottail shiners taken on June 19 and 26 (figure 5). The age group means were found to be 38.9, 62.2 and 83.1 mm. for age groups I, II and III, respectively. The means correspond closely with the modes, which are 40, 60 and 80 mm. Assuming a length of four millimeters (to be discussed later) as the size at hatching, the mean annual increments would be 34.9, 23.3 and 20.9 mm. These results are similar to those found by Carlander, with spottail shiners, in Lake of the Woods: 30, 47 and 62 mm. standard lengths for the first, second and third annuli of the scale, respectively (McCann, 1959).

As the annuli have been shown to form in the spring (McCann, 1959), these results can be considered roughly comparable in time. When Carlander's results are converted to total lengths, using the formula, standard length = .805 total length + 0.8 mm. (McCann, 1959), they become 37, 58 and 77 mm. The annual increments would be 33, 21 and 19 mm., as compared to increments of 35, 23 and 21 mm. found in Nemeiben Lake.

Similar data were obtained on growth rates of spot-

Figure 5. Length frequency histogram from measurements of 122 spottail shiners taken from Nemeiben Lake on June 19 and 26, 1960.


Means
38·9
62·2
83·1
Frequency
0
10
20
30
0
10
20
30
40
50
60
70
80
90
100
Lengths in millimeters
Age groups
I
II
III

tail shiners in Crooked Lake, Saskatchewan, from samples taken by the Fisheries Branch, D.N.R. Length frequency histograms are plotted for samples taken on June 16, 22 (figure 6) and September 1 (figure 7). Mean lengths for the age groups were calculated, using the same method as was described for the Nemeiben Lake data. Three year classes were found here as well. The results are seen in Table II. The two modes, evident in the September 1 sample from Crooked Lake, would be the age group 0 (young-of-the-year) and age group I. The age group I had a mean length of 47.0 mm. in June and of 69.36 mm. in September. This would indicate that they increased in mean length about 22 mm. during the summer. The age group 0 spottails, in September, had a mean length of 45.6 mm., while a sample of eight taken July 25 had a mean length of 18.5 mm. This indicates an increase of 27.1 mm. for the 37 day period from July 25 to September 1.

The age group I fish had a mean length of 69.36 mm. in September and the age group II fish had a mean length of 68.5 mm. in June. Similarly, the age group 0 fish had a mean length of 45.6 mm. on September 1 and the age group I fish had a mean length of 47 mm. in June. This would give mean increases of + 0.40 and − 0.86 for the age groups 0 and I, respectively, for the period September - June. It can, therefore, be concluded that no significant increase in length takes place during this period.

Data on growth rates, from both Nemeiben and Crooked

Figure 6. Length frequency histogram from measurements of 140 spottail shiners taken from Crooked Lake on June 16 and 22, 1960, by the Fisheries Branch, Department of Natural Resources, Saskatchewan.

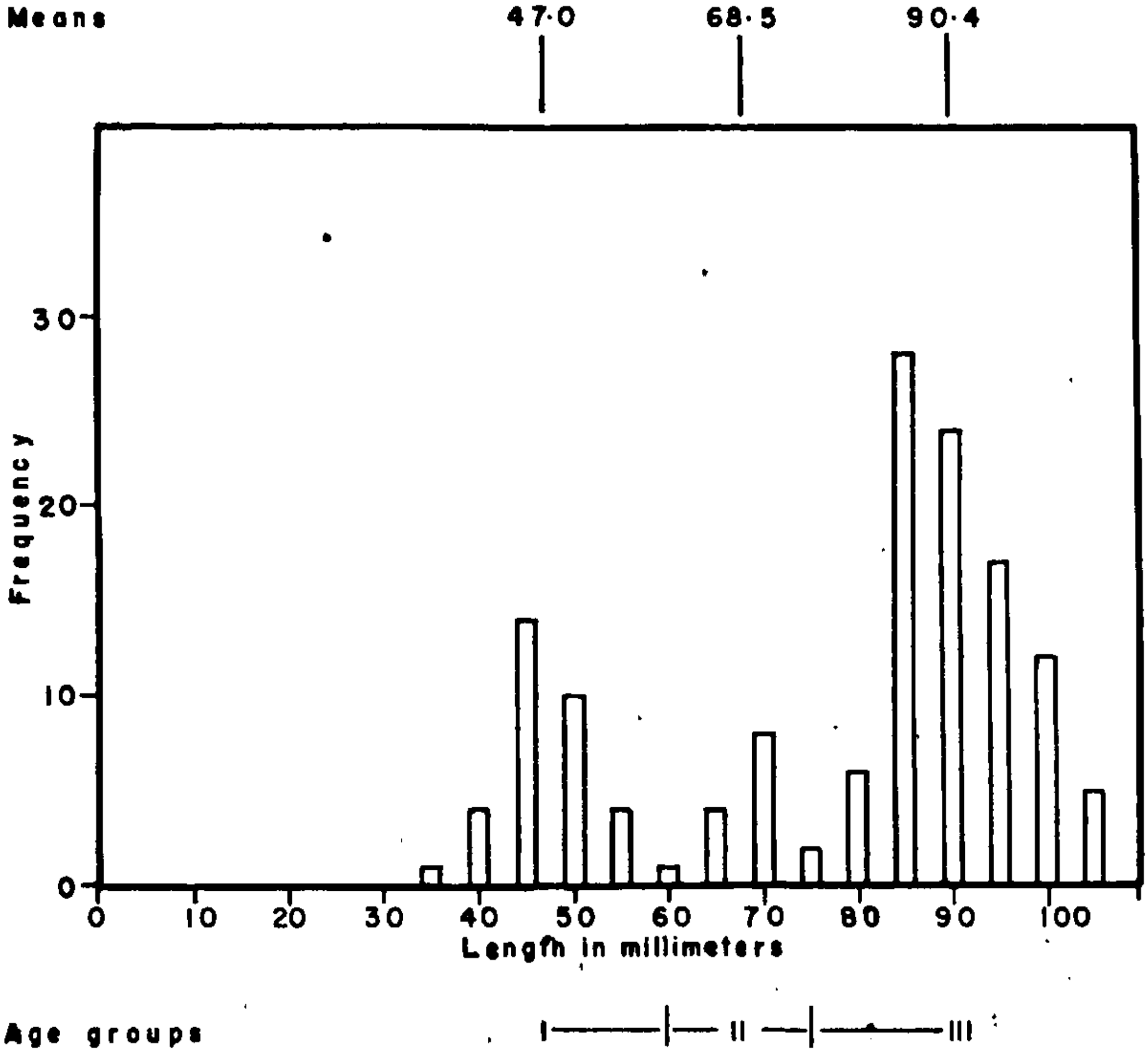

Means
47·0
68·5
90·4
Frequency
0
10
20
30
0
10
20
30
40
50
60
70
80
90
100
Length in millimeters
Age groups
I
II
III

Figure 7. Length frequency histogram from measurements of 83 spottail shiners taken from Crooked Lake on September 1, 1960, by the Fisheries Branch, Department of Natural Resources, Saskatchewan.

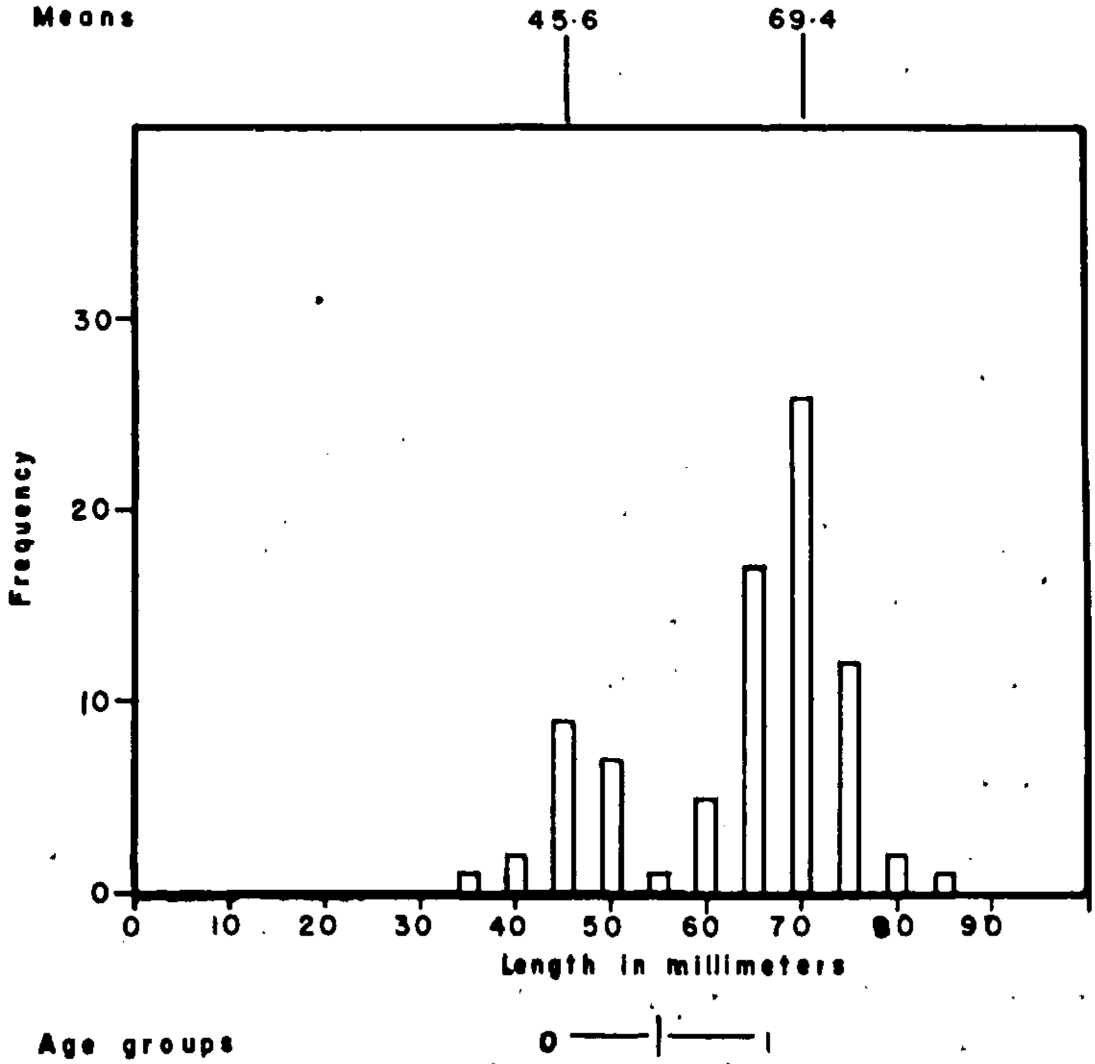

Means
45·6
69·4
Frequency
30
20
10
0
0
10
20
30
40
50
60
70
80
90
Length in millimeters
Age groups
0
I

TABLE II

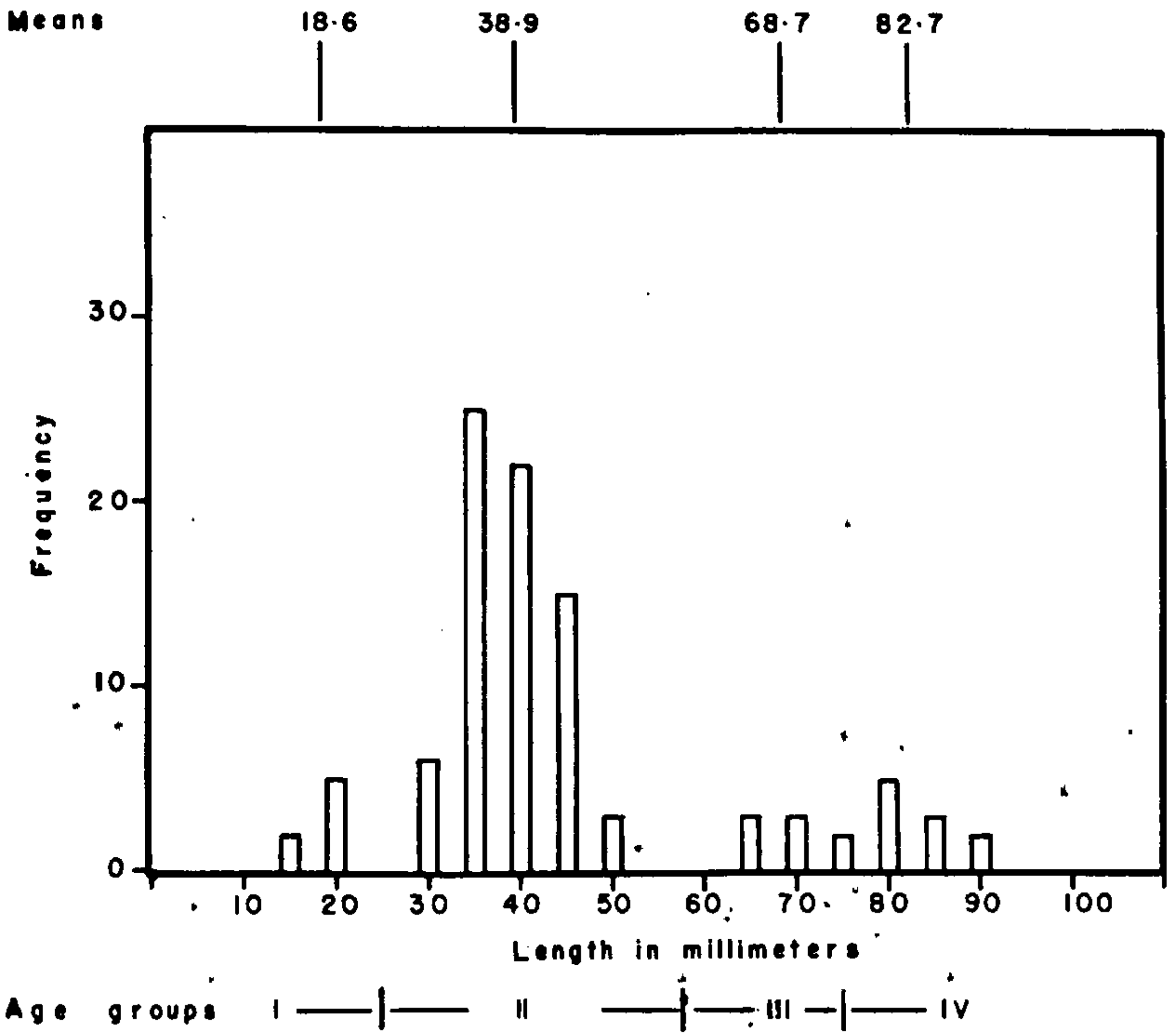
Comparative Growth Rates

	Mean Lengths of Age Groups in Spring				Mean Annual Increments			
Lake	I	II	III	IV	I	II	III	IV
Clear Lake	76.7	98.2	107.9	-	72.7	22.0	9.8	-
Crooked Lake	47.0	68.5	90.4	-	43.0	21.5	21.9	-
Nemeiben Lake	38.9	62.2	83.1	-	34.9	23.3	20.9	-
L. Athabaska	18.6	38.9	68.7	82.7	14.6	20.3	29.8	14.0

Lakes, are shown in Table II, compared with growth rate data from Clear Lake, Iowa, and Lake Athabaska. Since the growth rate is noticeably greater in the more southerly lakes, it is strongly influenced by temperature. McCann (1959) found that variation in the growth rate of spottail shiners coincided with mean air temperature. This is to be expected of poikilotherms. It follows that spottail shiners from a more northerly lake would have their growth rate depressed below that of Nemeiben Lake. A sample of 95 spottail shiners from Lake Athabaska (June, 1943) was examined. The measurements of these fish are plotted on a length frequency histogram (figure 8). With these data, four size groups were evident, having mean lengths of 18.6, 38.9, 68.7 and 82.7 mm., and giving mean annual increments of 14.6, 20.3, 29.8 and 14.0 mm. The first size group is interpreted as age group I for the following reason. Spawning was in progress in the individuals of the two larger size groups. Thus, at the time the sample was taken, age group 0 specimens could not have grown 14.6 mm.

Data on the growth rate of the spottail shiner by McCann (1959) indicate three age groups, suggesting that the life span in Clear Lake, Iowa, and Lake of the Woods is about three to four years. This is in agreements with Hubbs and Cooper (1936), who say that those minnows, in species where

Figure 8. Length frequency histogram from measurements of 93 spottail shiners taken from Lake Athabaska, June, 1943.



Means
18·6
38·9
68·7
82·7
Frequency
0
10
20
30
10
20
30
40
50
60
70
80
90
100
Length in millimeters
Age groups
I
II
III
IV

they commonly reach a length of over six inches, often live to be five to seven years old, while those, in species where they seldom reach a length of four inches, rarely live more than five years. On this basis, *N. hudsonius*, which reaches four to six inches, has a life span of about four years.

Normally, in cold-blooded animals, slow growth, caused by low temperature, is correlated with an increased life span. Miller and Kennedy (1948) found this to be so with northern pike (*Esox lucius*). In Nemeiben Lake, the size distribution of the age group II spottail shiners, as plotted on the length frequency histograms, closely approximates a normal curve. Thus, if these fishes had a longer life span than the normally accepted three to four years, growth must have ceased altogether after maturity. If the life span is only three to four years, then each fish spawns only once during its lifetime. With the Lake Athabaska spottail shiners, the slower growth rate seems to have increased the normal life span from three to four years, to four to five years.

More evidence on the longevity of *N. hudsonius* in Nemeiben Lake is available from the results of readings made on the scales of 33 spottail shiners selected at random from seine hauls on Nemeiben Lake. Of those fish of age group III size, 17 were found to be age group III and two were found to be age group IV. The putting on of scale annuli has been shown to depend upon the occurrance of an increase in length (Alvord, 1954). Those fish identified as age group IV spot-

TABLE III

Results of Aging by the Examination of Scales

of 31 Spottail Shiners from Nemeiben Lake

	Age Groups				
Mid Points Length Classes	0	I	II	III	IV
20	-	-	-	-	-
25	-	-	-	-	-
30	1	-	-	-	-
35	2	-	-	-	-
40	-	-	-	-	-
45	-	-	-	-	-
50	-	1	-	-	-
55	-	4	-	-	-
60	-	-	-	-	-
65	-	-	-	-	-
70	-	-	3	-	-
75	-	-	3	1	-
80	-	-	-	3	-
85	-	-	-	8	-
90	-	-	-	3	-
95	-	-	-	1	1
100	-	-	-	1	1

tails were no longer than some which were identified as age group III.

No spottails were found that were of a larger size than could be included in the normal size range of age group III. Thus, if the large Nemeiben Lake spottails did live past age group III, no further growth took place and annuli would not form.

Figure 9. Central North America, showing the mean July daily temperature. Data from Thomas (1953) and United States Department of Agriculture.

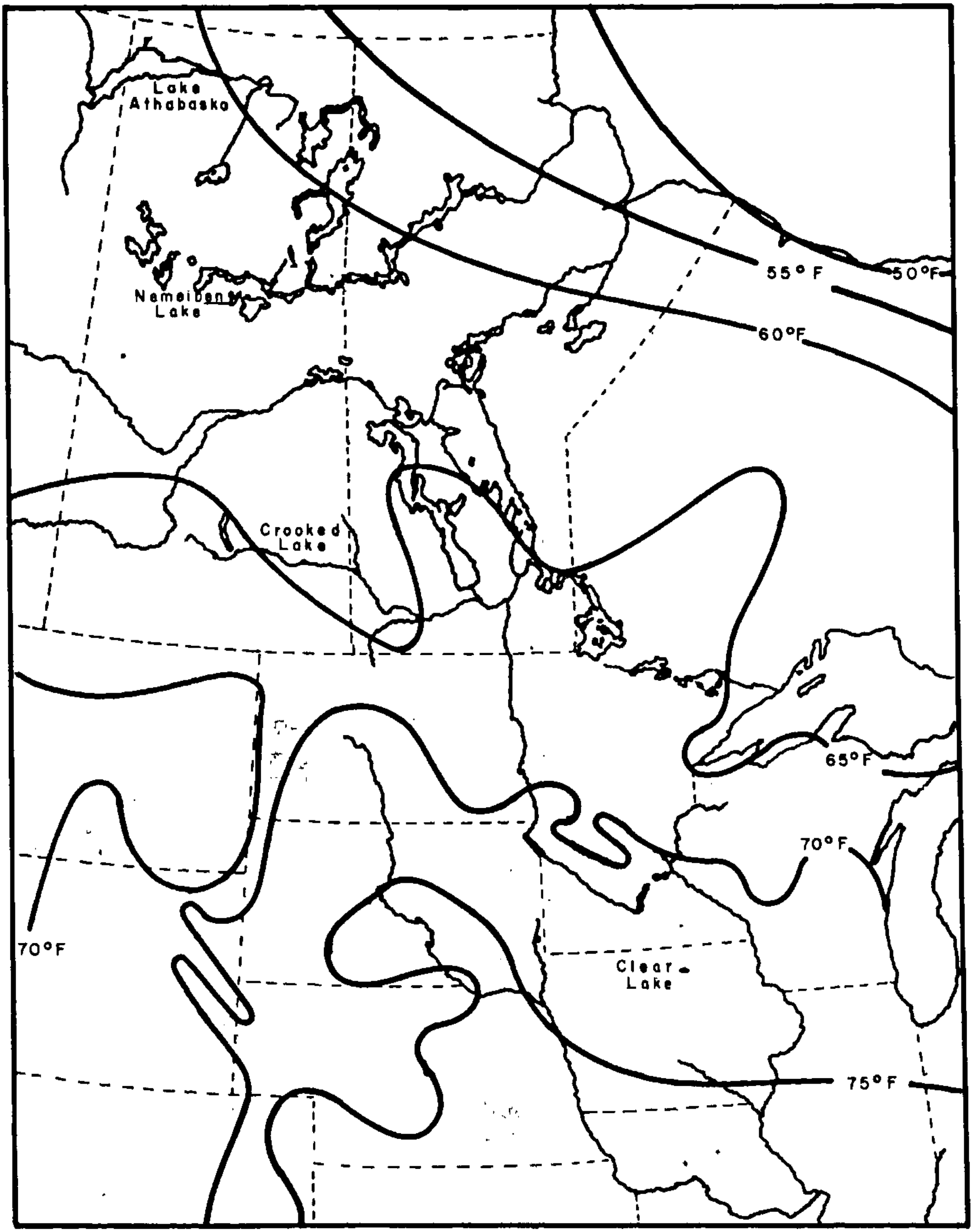

Lake
Athabaska
Nemeiben
Lake
Crooked
Lake
Clear
Lake
55° F
50°F
60°F
65°F
70°F
70°F
75°F

Figure 10. Average growth rates of spottail shiners from four lakes. Data for the Clear Lake population are from McCann (1959). Data for other populations are from length frequency histograms from measurements of fish taken in June.

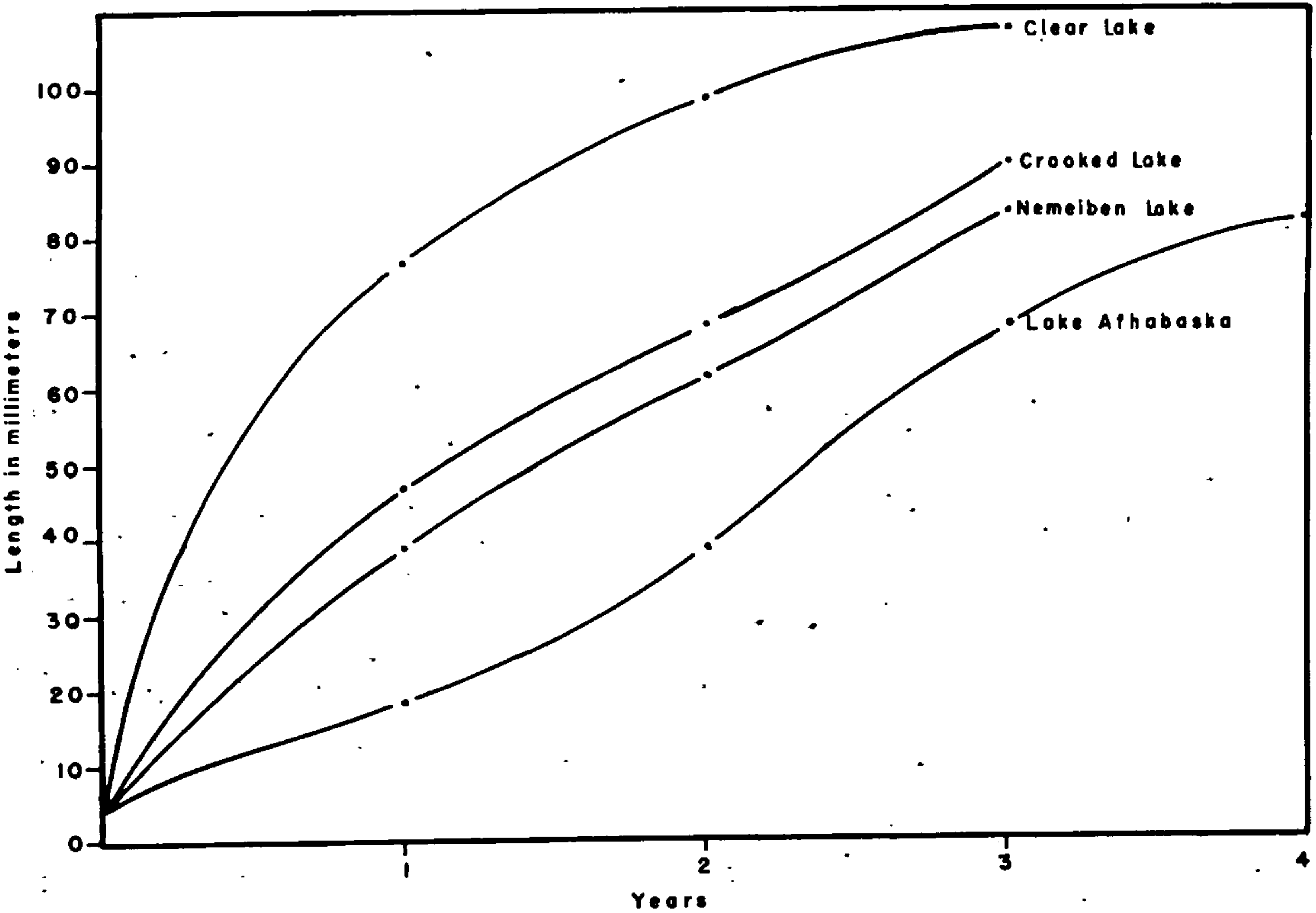
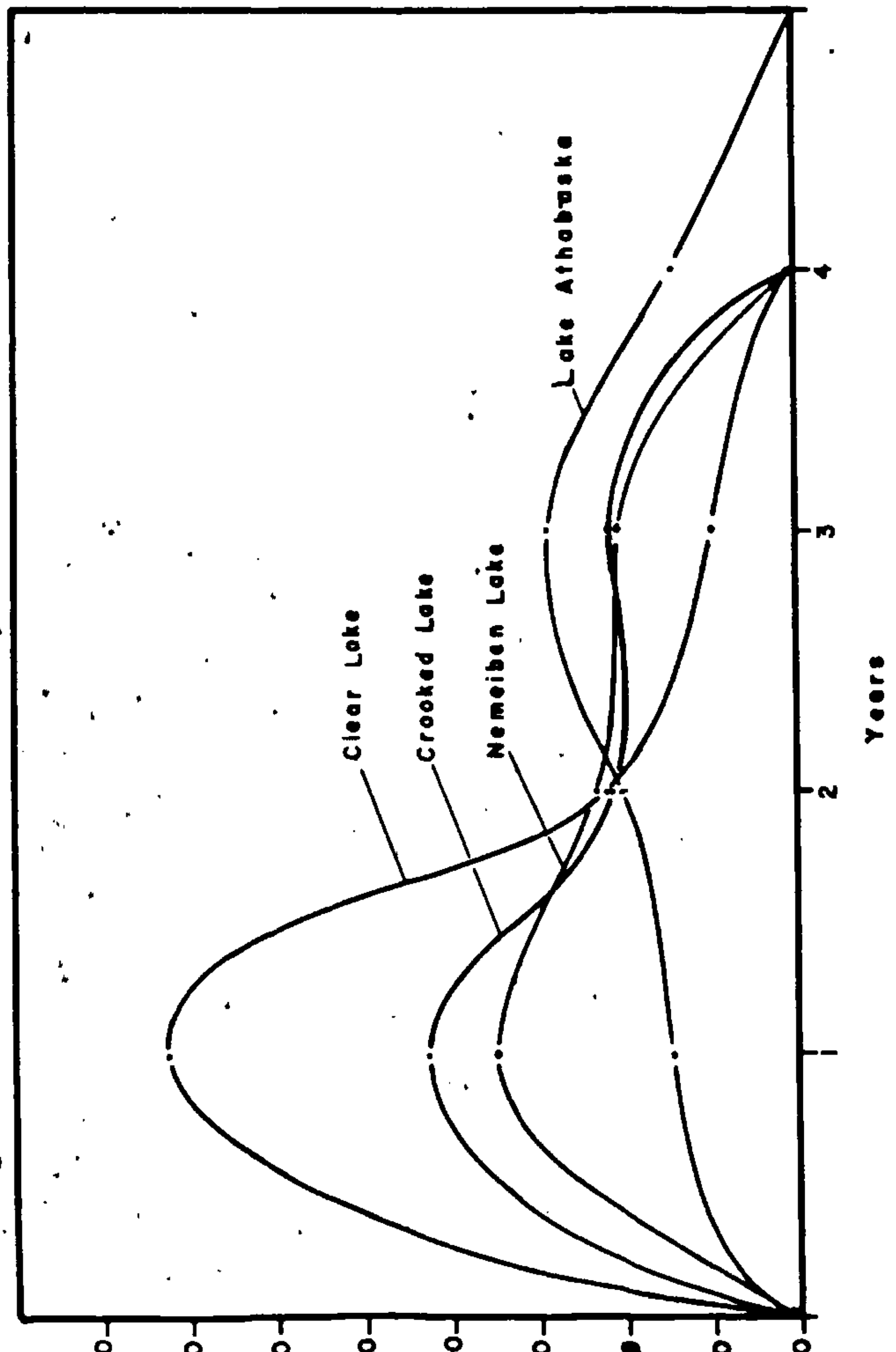

Clear Lake
Crooked Lake
Nemeiben Lake
Lake Athabaska
Length in millimeters
0
10
20
30
40
50
60
70
80
90
100
Years
1
2
3
4

Figure 11. Mean annual length increments of spottail shiners from four lakes.


Lake Athabaska
Clear Lake
Crooked Lake
Nemeiben Lake
Years
1
2
3
4
Length increase in millimeters
0
10
20
30
40
50
60
70
80

Reproduction

A random sample of spottail shiners from seine hauls made in Nemeiben Lake between June 19 and July 8 was examined to determine the condition of the gonads. It was found that all those 77 mm. or over were gravid. These data are shown in Table IV.

The data on growth rates show that this length of 77 mm. falls between those of the age group II and age group III fish, which indicates that those spottail shiners that were spawning were mainly age group III fish. As some overlap in size would occur between the age group II and III fish, some of those spawning over 77 millimeters may have been large, fast-growing age group II fish.

A random sample of spottail shiners taken from Crooked Lake on June 22 was also examined. All those 67 mm. or over were found to be gravid, while all those 64 mm. or under were immature. (See Table IV.) From the data on growth rate, it can be concluded that the Crooked Lake spottails spawned during their third summer (age group II).

Similar data for Lake Athabaska have shown that the spottail shiners there spawned when they were about 65-70 mm. long. This may indicate that all, except a few of the small, slow-growing individuals, spawned in their fourth summer (age group III). Those individuals which did not spawn at this time could do so the following summer as age group IV fish. Examination of the gonads of the mature Athabaska

TABLE IV

Maturity

	Nemeiben Lake				Crooked Lake				Lake Athabaska			
	Mature		Immature		Mature		Immature		Mature		Immature	
Mid Points Length Classes	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂
35	-	-	-	-	-	-	-	-	-	-	-	-
40	-	-	1	1	-	-	-	-	-	-	-	-
45	-	-	-	-	-	-	-	-	-	-	3	3
50	-	-	-	-	-	-	1	2	-	-	-	-
55	-	-	2	1	-	-	1	3	-	-	2	2
60	-	-	9	2	-	-	1	-	-	-	-	-
65	-	-	2	3	-	-	2	1	-	-	2	-
70	-	-	-	2	4	-	-	-	1	-	1	1
75	2	-	2	1	-	1	-	-	1	1	-	-
80	3	4	-	-	1	1	-	-	2	2	-	-
85	5	9	-	-	1	-	-	-	2	-	-	-
90	2	1	-	-	4	-	-	-	1	1	-	-
95	1	-	-	-	3	-	-	-	-	-	-	-
100	1	-	-	-	2	-	-	-	-	-	-	-
105	1	-	-	-	1	-	-	-	-	-	-	-
110	-	-	-	-	1	-	-	-	-	-	-	-

spottail shiners indicates that the age group III fish may spawn at a later date than the age group IV fish. This would result in an early spawning and a late spawning group of spottail shiners in the lake. More data on this subject are necessary before a definite conclusion can be drawn.

In all populations, spottail shiners of a total length of 68 mm. or more became sexually mature. Sexual maturity, therefore, may be dependent upon the attainment of a given size. The phenomenon of the age of maturation being dependent on the rate of growth, i.e., attainment of a given size before a specific date, is known to occur in Atlantic salmon (*Salmo salar*) and the present data show it to be possible in *N. hudsonius*.

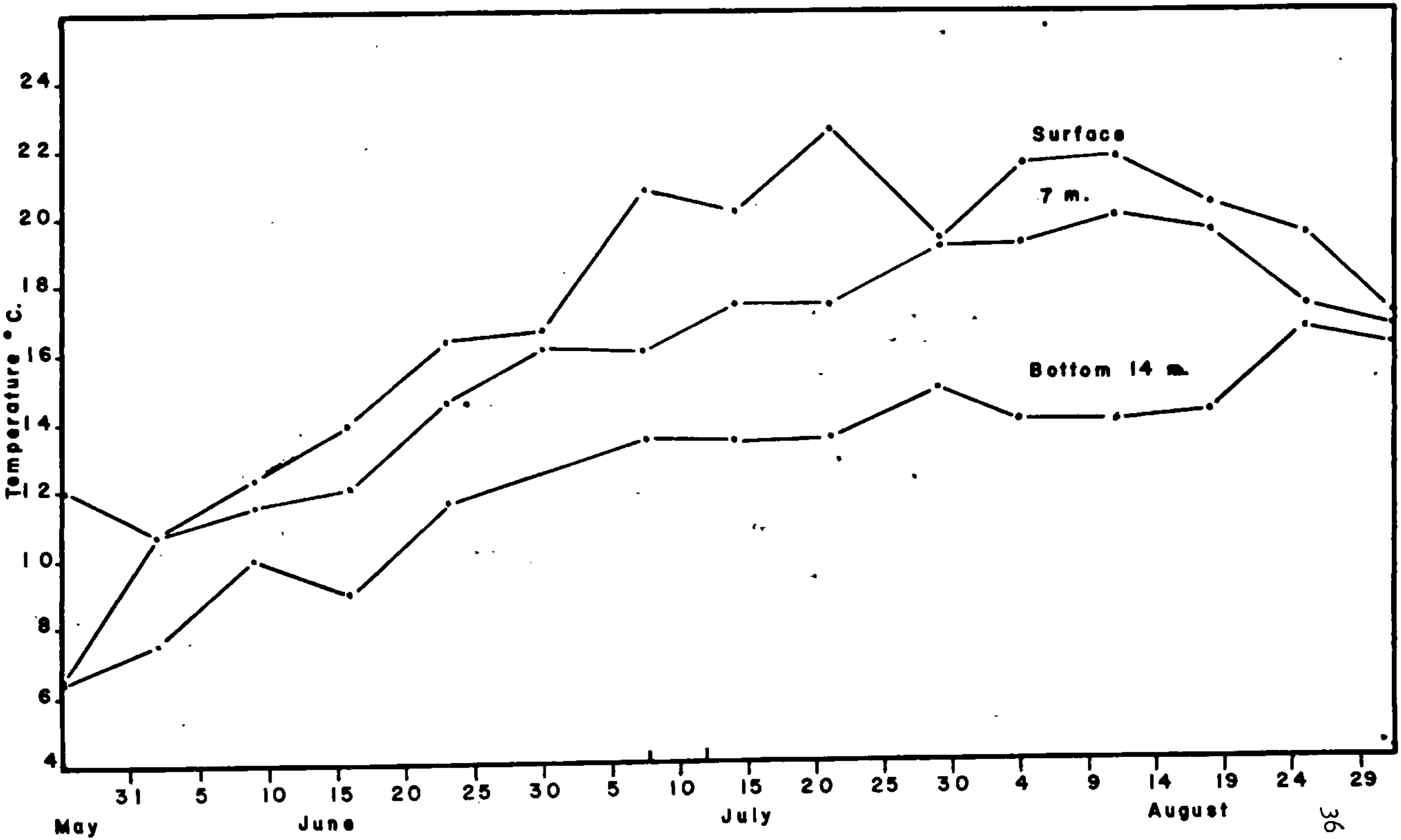
In order to determine as closely as possible the time of spawning, gonads of the mature spottail shiners collected from Nemeiben Lake during the month of July were examined. Those taken up to and including July 8 were gravid. Two females taken in a gill net on July 12 were spent, having about a dozen unextruded eggs. No gravid females were taken during the remainder of the summer. From this, it can be concluded that spawning of *N. hudsonius* in Nemeiben Lake took place some time between July 8 and July 12. Spawning periods for *N. hudsonius* in other areas are given by Fish (1932), for Lake Erie, as late June and early July; by McCann (1959), for Clear Lake, Iowa, as some time in late May; and by Greely and Green (1931), for the St. Lawrence River, as June 4.

The type of bottom over which the spottail shiners spawned in Nemeiben Lake is not known as spawning was not observed. The young-of-the-year were first seen in August over the sandy shoals and the mature adults, in spawning condition, were taken there a month earlier. These data are insufficient to conclude that spawning took place over the sandy shoals. However, observations by Greely and Green (1931) and Hubbs and Cooper (1936) show that this species spawns on sandy shoals and at creek mouths. The same is probably true for Nemeiben Lake.

As the exact time and place of spawning of the spottail shiners in Nemeiben Lake is not known, no data on water temperatures at the time of spawning were obtained. The temperature of the water over the sandy shoals, where spawning is presumed to have taken place, was found to be 20° C. on July 10 and 11. It can be seen from figure 12 that spawning coincided approximately with the attainment of 20° C. by the surface water of the lake. No information on water temperatures at the time of spawning of N. hudsonius was found in the literature.

It is shown by Raney (1947) and Hubbs and Cooper (1936) that there is a correlation in the Cyprinidae between the presence of strong nuptial tubercles on the male, the relative sizes of the sexes, and the tendency for the males to hold territories and fight. Males that fight and actively hold territories are usually larger than females of the same species and have well developed tubercles, espec-

Figure 12. Water temperatures at Station "A", Nemeiben Lake.



Surface
7 m.
Bottom 14 m.
Temperature °C.
24
22
20
18
16
14
12
10
8
6
4
31
5
10
15
20
25
30
5
10
15
20
25
30
4
9
14
19
24
29
May
June
July
August

ially about the head region. No significant difference between sexes was found in the Nemeiben Lake spottails and the males do not have well developed tubercles on the head. Therefore, the males probably do not hold territories and guard nests. This is supported by Greely and Green (1931), who reported seeing a large number of spottail shiners spawning in a closely-knit group. They also reported that one pass with a 20-foot seine over the area later took three quarts of eggs.

The average diameters of the eggs of female spottail shiners were determined for three different dates. An attempt was made to measure 25 eggs from each of five females for each date. However, only three females were taken on July 8. The data are in Table V. A regression line was fitted to these data (figure 13) and it indicates that a uniform gradual increase occurred from June 19 up to spawning. The mean egg diameter on July 8 was 1.143 mm. This may have been less than actual size due to shrinkage in formalin. McCann (1959) found ripe female spottail shiners to contain eggs 0.03 inches (approximately .76 mm.) in diameter.

The number of mature eggs in the ovaries of three female spottail shiners was determined. The results follow:

Length of Fish	Number of Eggs
85	853
79	495
89	646

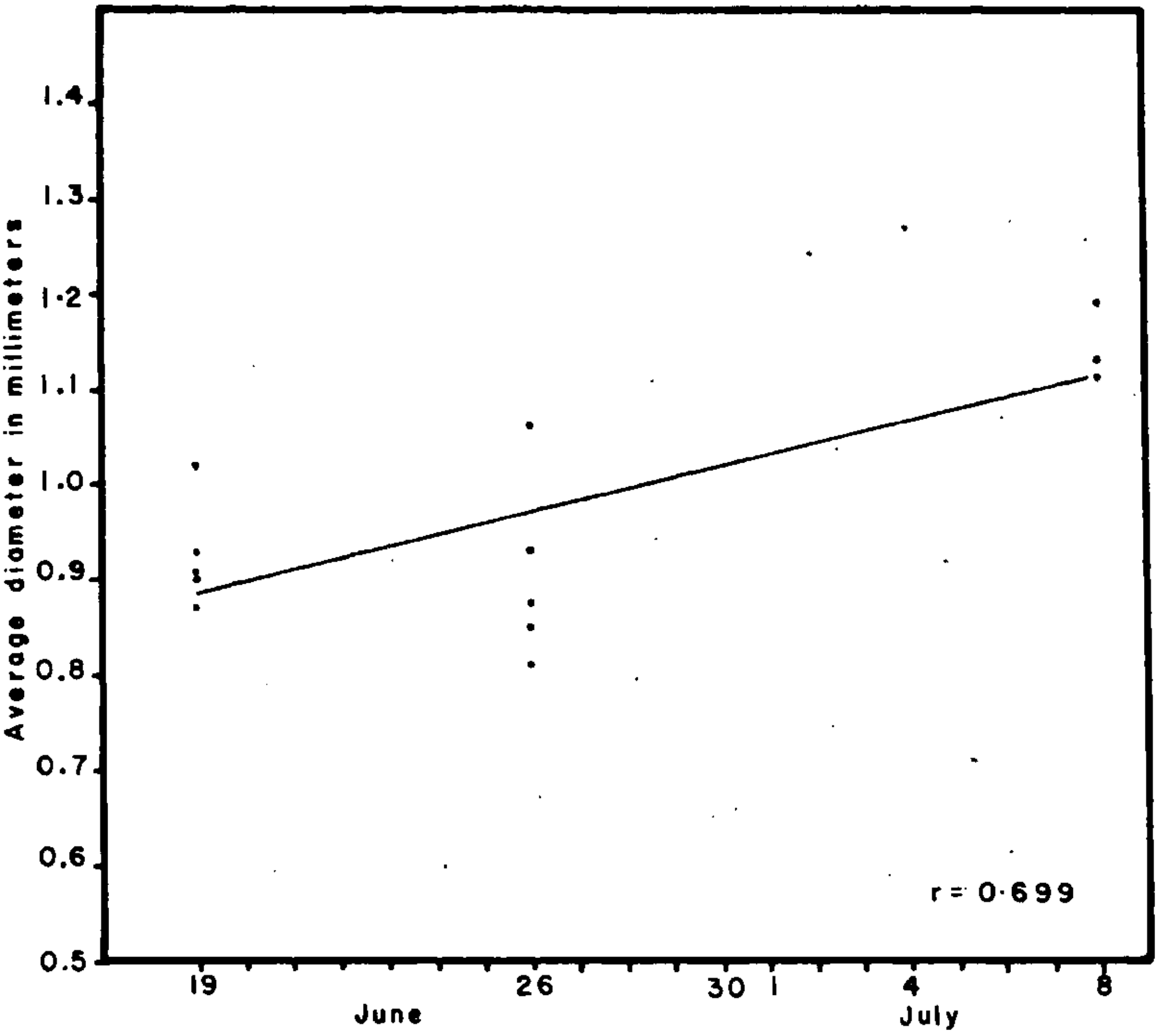
McCann (1959) found yearling spottails, ranging in

TABLE V

Egg Diameters

Date	Length of Fish	Average Diameter Eggs from Each Fish	Average Diameter Eggs for This Date
	77	0.87 ± .053	
	79	0.90 ± .021	
June 19	85	1.02 ± .063	0.926
	85	0.91 ± .104	
	87	0.93 ± .073	
	77	1.10 ± .082	
	80	0.87 ± .087	
June 26	81	0.93 ± .089	0.897
	85	0.81 ± .087	
	95	0.85 ± .064	
	90	1.13 ± .077	
July 8	98	1.11 ± .022	1.143
	101	1.19 ± .093	

Figure 13. Rate of increase in average diameter of eggs from the ovaries of 13 spottail shiners from Nemeiben Lake.


Average diameter in millimeters
1.4
1.3
1·2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
19
26
30
1
4
8
June
July
r = 0·699

size from 70 to 90 mm., to contain from 100 to 1400 mature eggs each. He found females at least two years old to contain 1300 to 2600 eggs each.

No information was obtained on the hatching time of the eggs during the course of this study. The period of time between spawning and the first appearance of the age group 0 juveniles was relatively short (about 20 days). Such rapid larval development would necessitate a short hatching time. This is typical of cyprinids. Battle (1940) gives the hatching time of goldfish (Carassius auratus) eggs as between 64 and 72 hours. N. chalybaeus was found to hatch in 52-56 hours (Marshall, 1946); and N. girardi, in about 24 hours (Moore, 1944).

The length of the larvae of N. hudsonius, at hatching, was estimated in order to provide a convenient starting point for the growth curves and to determine the mean annual increments. This could only be done by a comparison with other cyprinids whose egg sizes and lengths of larvae, at hatching, are known. The average length of four day larvae of N. girardi is given by Moore (1944) as 5.4 mm. total length. The diameter of its egg is slightly in excess of 1 mm. The eggs of N. chalybaeus, obtained by stripping, have an average diameter of 0.8 - 0.9 mm. The larvae, on hatching, have a total length of 2.3 mm. (Marshall, 1947). The goldfish, which has eggs of 1.25 - 1.46 mm. in diameter, has a total length of 4.5 mm. on hatching (Battle, 1940).

From the above evidence, it seems probable that the newly hatched larva of N. hudsonius would have a total length somewhere in the vicinity of four millimeters. This length would allow room for the embryo to fit in the egg capsule by forming a more or less complete circle around its circumference.

Habitat

Collecting was concentrated on a section of shore line about one mile long. Other parts of the lake were sampled periodically for comparison. The section of shore line studied had enough variety in both habitat and exposure that it could be considered as representative of the whole lake. Although the spottail shiners were taken in almost all habitats, including steep, rocky shores and silt-bottom coves, they were most abundant over sandy shoals. That this was not due to the increased efficiency of seining was seen by observations of schools of fish along the shore. It could be easily observed that there was a greater proportion of spottails over sand or gravel than over mud or silt bottom.

No preference for any one type or abundance of vegetation was seen. Spottails were taken in areas having little or no vegetation, as well as areas having a moderate amount of vegetation. No spottails were found in areas of heavy vegetation. However, such regions invariably had silty bottoms.

Trautman (1957) reports the habitat of the spottail shiner, in Lake Erie, as being clear water between three and six feet deep and having a bottom of sand or gravel. McCann (1959) claims that the largest spottail populations were found most frequently in areas with moderate amounts of emergent and submergent vegetation. He also reports that the spottails moved out of some areas when heavy vegetation developed. In areas where the vegetation remained moderate throughout the summer, a fairly constant population of spottails remained. It has been stated by Hubbs and Cooper (1936) that the spottail shiner shows a decided preference for rather large lakes. Forbes and Richardson (1920) state that it is the most abundant minnow in the largest rivers and lakes of Illinois.

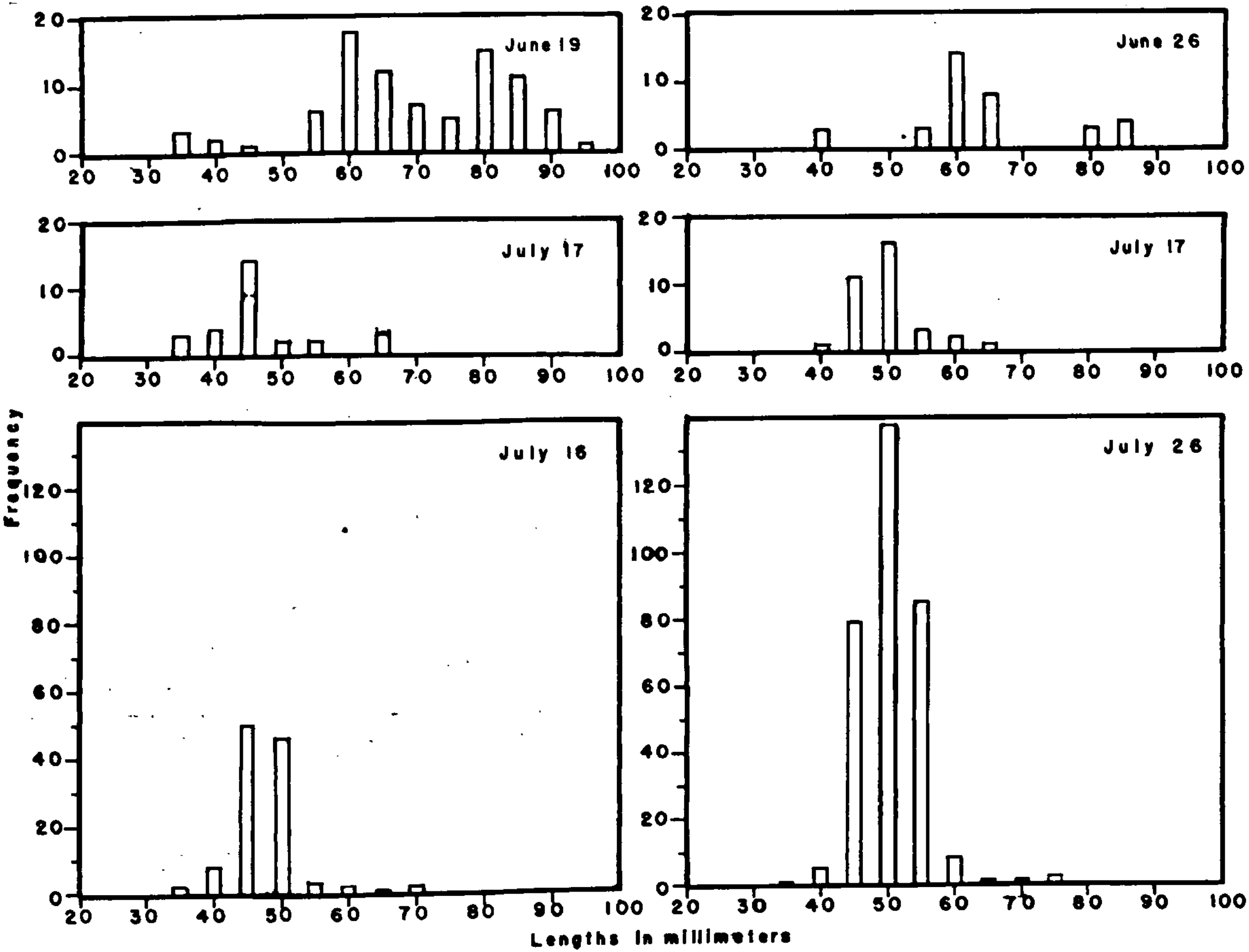
Movement

By reference to the length frequency histograms (figure 14), it can be seen that three size classes are evident, representing age groups I, II, III and over. Figure 14 shows length frequency histograms of fish caught on July 16, 17 and 26, respectively. Between June 26 and July 16, the relative numbers of individuals of age group III or over became considerable fewer. After July 16, no individuals of this size and age class were taken over the sandy shoals.

The fact that the large mature spottail shiners (over 75 mm.) disappeared from the shoals immediately after spawning took place may have had some significance. A few were taken there on July 12 and, on examination of the gonads, were found to have spawned. No spottails of this size group were seen on the shoals after this date, although some were taken in the small gill net when it was set on the bottom in four to seven meters of water.

A noticeable increase in dominance of the age group I spottails could be found throughout late June and early July. On July 26, all spottail shiners caught were of this age group. After this date, no more spottail shiners of the age group I class were taken, although special efforts were made to seine them. It was assumed that they became diffusely scattered throughout the lake, along with the large minnows (age groups II and III) which left earlier. No cause for this movement was evident.

Figure 14. Length frequency histograms from measurements of spottail shiners from Nemeiben Lake.


June 19
June 26
July 17
July 17
July 16
July 26
Frequency
Lengths in millimeters
0
10
20
20
40
60
80
100
120
20
30
40
50
60
70
80
90
100

Doyle (personal communication) reported that, although large adult spottail shiners were common in the seine hauls during the month of June in Crooked Lake, they were not taken at all during the remainder of the summer. McCann (1959) reports that spottail shiners moved out of some areas as the vegetation became heavier through the summer in Clear Lake, Iowa. In Nemeiben Lake, some areas from which the spottails disappeared had heavy growths of vegetation by the end of the summer. However, there were many areas which continuously had little or no vegetation but no large spottails could be found here after July 26.

Evidently, some factor other than increasing vegetation caused the spottails to move off the shoals during late July. This behaviour pattern may have survival value to the species by decreasing competition with, and predation on, the young-of-the-year. (The young-of-the-year appeared on August 2, soon after the older minnows moved out.) During the months of July and August, the large spottail shiners (60-90 mm. range) were caught in the gill net in the open waters of the lake. Details of the net sets are given in Table VI.

All spottail shiners caught during late July and August were taken by a gill net set on bottom in four or five meters of water. The gill net was not set on the surface any time during the month of August because of the difficulty and time involved in removing and re-attaching the ex-

TABLE VI

Gill Net Sets

Date	Depth in Meters	Type of Bottom	Number of Spottails
July 6-8	1-2	sand	7
July 9-10	1-3	bedrock	-
July 11-14	1-2	sand	10
July 16-22	1-2	sand	15
July 26-29	1-2	sand	2
Aug. 2-5	4-5	ooze	5
Aug. 6-15	2-4	sand	1
Aug. 15-20	1-2	sand	-
Aug. 23-28	7	ooze	6

tra leads to the bottom. In order to determine accurately whether or not the spottail shiners stayed close to the bottom at all times during the month of August, gill net sets, on the surface and bottom, would have to be made simultaneously. This was not done in this study as only one net was available.

On August 2, when the young-of-the-year spottail shiners were first observed over sandy shoals, all specimens taken had a total length of 19 mm. or more. The fact that none smaller than this was taken may have been due to behaviour patterns in the larvae, i.e., burrowing into gravel to avoid light or inhabiting deeper water beyond the reach of the seine. After the larvae change into the juvenile form, they may lose their negative reaction to light or deep water and become more susceptible to capture by seining. Fish (1932) reports taking an early larva of N. hudsonius (5.2 mm. total length) in a Helgoland trawl at five meters, near Athol Spring, Lake Erie, on July 12. The fact that this larva was taken in five meters of water and that no larvae were seen on the sandy shoals of Nemeiben Lake, while the young juveniles were found concentrated near the shoreward margin of this area, may indicate that the larvae go into deeper water after hatching, returning to the shoals as juveniles about 20 mm. long.

The behaviour pattern which kept the young juvenile spottail shiners in the shallow water may have been attraction by visual stimuli to any large object. Hubbs (1921) observed that young N. hudsonius were attracted to and tended to cluster about a boat in large schools. As the young fish grew, their response to the boat became less marked. At the same time, they became less restricted to the shore line. The length of the fish when the change in behaviour occurred was not given. Seine hauls made on September 30 on the sandy shoals of Nemeiben Lake took no spottail shiners.

During the early part of July, when the adult spottail shiners were being taken in the gill net, the net was visited two or more times a day, in an attempt to determine whether any diurnal movement took place. There was no evidence of this. (See Table VII.) Hubbs (1921) found that the older spottail shiners moved out beyond the shoal slopes at night. McCann (1959) found that the spottail shiners moved into more shallow water at night or were more susceptible to seining at that time.

TABLE VII

Diurnal Movement

Date Checked	Number of N. hudsonius AM	Number of N. hudsonius PM
July 12	0	8
July 13	0	2
July 17	0	7
July 18	4	0
July 22	4 (net lifted)-	
July 27	2	0

Food

Table VIII contains a summary of the results of the intestinal examination of 31 spottail shiners. The organisms found in the intestines were almost all animals. Small organisms, such as Bosmina and Daphnia, were found in a relatively undamaged condition. Large insects, such as mayfly larvae, were well macerated, probably by the action of the pharyngeal teeth.

There did not seem to be any correlation between the age of the fish and the type of food eaten. There appeared to be a shift at the first of July from a greater proportion of chironomid larvae to a dominance of chironomid pupae. Obviously, this would indicate a change in availability rather than a change in preference. The same would be true of the increased numbers of insects eaten toward the end of July.

No preference for any specific type of food was evident. However, this would be impossible to determine without a collection of potential food organisms made simultaneously with the collections of fish to be examined. A forage ratio could then be calculated, such as is described by Hess and Swartz (1940). There would probably be little value in such a study, however, as it has been found by Boesel (1938), on Lake Erie, that the food organisms found in the intestines of different size groups of N. hudsonius from the same area were more similar in composition than those from

TABLE VIII

Stomach Examination of 31 Spottails

	Date	Ephemeroptera Nymphs	Chironomid Larvae	Chironomid Pupae	Trichoptera Larvae	Scales	Zooplankton	Eggs	Sand	Organic Debris	Unidentified Insects	Volume
65	June 19	-	-	-	-	-	60	40	-	-	-	-
70	June 19	-	25	75	-	-	-	-	-	-	-	.02
73	June 19	-	90	10	-	-	-	-	-	-	-	-
79	June 19	-	-	-	-	-	70	30	-	-	-	-
80	June 19	-	50	45	5	-	-	-	-	-	-	-
80	June 19	-	50	-	-	-	45	5	-	-	-	-
81	June 19	10	90	-	-	-	-	-	-	-	-	.01
83	June 19	-	-	100	-	-	-	-	-	-	-	-
85	June 19	-	75	25	-	-	-	-	-	-	-	.08
85	June 19	-	25	25	25	-	-	-	25	-	-	.09
85	June 19	-	50	40	5	*X	-	-	5	-	-	-
86	June 19	20	5	-	-	X	-	-	-	75	-	-
86	June 19	-	50	10	-	-	-	-	40	X	-	-
89	June 19	-	25	25	50	-	-	-	-	-	-	-
90	June 19	-	-	-	-	-	-	-	50	50	-	.03
62	June 26	-	-	-	-	-	90	10	-	-	-	-
86	June 26	-	-	-	-	-	80	20	-	-	-	-
68	July 8	-	-	-	-	-	-	-	-	100	-	-
73	July 17	-	-	100	-	-	-	-	-	-	-	-
85	July 17	-	-	100	-	-	-	-	-	-	-	-
85	July 17	-	-	5	-	-	95	-	-	-	-	-
85	July 17	-	-	-	-	-	-	-	-	-	100	-
95	July 17	-	-	100	-	-	-	-	-	-	-	-
75	July 17	-	-	-	-	-	-	-	-	-	100	-
77	July 17	-	-	75	-	-	5	-	-	-	20	-
90	July 17	-	-	-	-	-	-	-	-	-	100	-
32	Aug. 14	-	-	-	-	-	-	-	-	-	100	-
32	Aug. 14	-	-	-	-	-	-	-	-	-	100	-
35	Aug. 14	-	-	-	-	-	-	-	-	-	100	-
37	Aug. 14	-	-	50	-	-	-	-	-	-	50	-
88	Aug. 27	-	-	-	-	-	95	5	-	-	-	-

The figures in this table are the percentage which that particular food organism formed of the total stomach contents.

*Trace.

fish of the same size group from different areas.

Starrett (1950) reports that, in the Des Moines River, Iowa, these minnows, classified as general feeders, are capable of modifying their feeding habits and, thus, are able to avoid competition for one particular type of food. Observations on the spottails of Nemeiben Lake seem to indicate that this was the case in this population as well. This adaptibility to different foods may be one of the factors which causes *N. hudsonius* to be successful in populating lakes over so much of North America.

Predation

During the course of the summer, many perch, walleye, pike and burbot stomachs were sampled as part of the limnological investigation of Nemeiben Lake by the Fisheries Branch of the Department of Natural Resources. None of the fish found in the stomachs could be identified as spottail shiners. This may have been due to the relative scarcity of adult spottails as compared with perch of the same size in deeper water. Perch were often found in the stomachs of pike and walleye.

Stomachs of 19 large perch (10-20 cm.) were examined and eight were found to be empty. (These were the only perch caught during the summer which were of sufficient size to make examinations of the stomachs for minnows worthwhile.) Of the remaining 11, five were taken in June and early July and six were taken in late July and August. The stomachs of the first group contained benthic invertebrates, while those of the second contained fish remains. Four small perch (3 cm.) were the only ones that were identified to species, although two others were identified as cyprinids.

Although nothing that could definitely be identified as a spottail could be found, it would seem reasonable to assume that the large perch (15 cm.) seen around the shoals would feed to a large extent on the abundant schools of young-of-the-year spottails. Predation of minnows by perch was actually observed on one occasion. A summary of the stomach contents of the perch examined can be seen in Table IX.

TABLE IX

Stomach Contents of Perch

Length	Date	Fish Unidentified	Cyprinids	Perch	Unidentified Invertebrates	Mayflies	Amphipods	Crayfish	Volume
75	June 19	-	-	-	-	1	-	-	.09
67	June 19	-	-	-	Many	Many	6	-	-
105	July 17	-	-	-	-	-	2	4	-
127	July 17	-	-	-	-	Many	-	-	2.39
142	July 17	-	-	-	-	Remains	-	-	.80
112	July 27	1	-	-	-	-	-	-	.08
90	Aug. 13	Several	-	-	-	-	-	-	-
131	Aug. 15	-	-	3	-	-	-	-	-
112	Aug. 15	-	1	-	-	-	-	-	-
142	Aug. 15	-	-	1	-	-	-	-	-
132	Aug. 18	-	1	-	-	-	-	-	-

Parasites

During the stomach examinations of the spottail shiners, 12 of the 31 were found to contain intestinal parasites (Nematodes). Of those 12, eight were found to have the larvae of the Cestode, *Ligula intestinalis*, in their coelomic cavity. Five of those examined had *Ligula* larvae but no intestinal Nematodes. Fifty-two more minnows were examined for *Ligula* alone of which only two were found. Usually, one single *Ligula* would be found in any one fish but one fish contained two *Ligula* larvae and two contained three. The size of the larvae varied from one or two centimeters to almost twice the length of the fish.

Bangham (1929) and Bangham and Hunter (1939) found this parasite in Lake Erie. *N. hudsonius* were found containing from one to five larvae in the body cavity, this being attributed to the abundance of terns which have been reported as definitive host by European workers.

McCann (1959) reports that the Clear Lake population of spottail shiners was relatively free of parasites. *Ligula* was not reported at all. The occurrance of the larvae of this parasite in minnows would be dependent on the presence of a suitable final host for the adult. No attempt was made to determine which of the fish-eating birds in Nemeiben Lake were infected with adult *Ligula*.

Ecological Relationships

Members of the family, Cyprinidae, are considered to be valuable as forage fish, as most members of this family never attain a size so large that they cannot be used as food for the larger game fish. The presence of minnows in a lake would, therefore, relieve some of the pressure of predation on the young game fish (Hubbs and Cooper, 1936). Minnows, such as the fathead, that have specialized feeding habits, would be especially valuable in this respect, as they would not be competing directly with the young game fish for any specific type of food (Coyle, 1930).

General feeders, such as the adult _N. hudsonius_, would utilize the same food as some young carnivorous fish. The young-of-the-year would also occupy the same niche as young-of-the-year game fish. However, as the spottails spawned much later than most game fish, they may fill this niche just as it would be vacated by young game fish. In Nemeiben Lake, age group 0 perch were taken by seining during the month of July on the sandy shoals less than one meter deep. A sample of 25 taken on July 16 had a mean length of 25 mm. During the month of August, schools of perch, 47 mm. long, were seen along the steep, rocky shores. (This length was determined by measuring a random sample of 25.) Assuming a growth rate of about .5 mm. per day, such as is reported by Pycha and Smith (1955), it would seem reasonable to assume that these were the same year class seen in the shallows during the preceding month.

Perch of this size would probably be feeding on plankton and insects, the nature of the food mainly dependent on what was available (Pycha and Smith, 1955). As the perch were observed to be the chief forage fish in the lake, they would serve as a medium to channel the energy contained in the biomass of small invertebrates inhabiting the steep, rocky shores. A situation in which a walleye population was dependent on a perch population was described by Maloney and Johnson (1957).

During August, the only fish permanently occupying the sand-bottom area, less than one meter deep, were young-of-the-year minnows of which over half were spottails. Occasionally, perch, 100 to 150 mm. long, were taken in this area. Two were found to contain cyprinids in their stomachs. A food chain may exist here: plankton → small juvenile minnows → small piscivours (mainly perch but also small pike)

walleye → large piscivours (such as pike, walleye and burbot). Thus, young juvenile minnows may be a factor in channeling the productivity of the sandy shoals into the production of game fish flesh. In this respect, they would occupy a niche similar to that of carnivorous aquatic insects, such as members of the family, Odonata, and dytiscid beetles. The relative importance of fish in this role would, therefore, vary according to the species composition of the littoral zone.

During the month of July, the plankton ⟶ minnow perch ⟶ walleye food chain evident in August would be replaced by a plankton ⟶ perch (young-of-the-year) ⟶ perch ⟶ walleye food chain.

Although no attempt was made to determine mortality of any age group, it must have been fairly light in all age groups, due to the comparatively few eggs laid per female. Low mortality would be particularly important for the survival of this species as the spawning does not occur until the fourth summer. A sufficiently high percentage of the population would have to survive for three years to ensure that enough eggs were laid.

Summary and Conclusions

In Nemeiben Lake, gravid adult spottail shiners were common on the sandy shoals during the month of June and the early part of July. Spawning is believed to have occurred there some time between July 8 and July 12. The mature eggs in the ovaries of the adult females had an average diameter of 1.14 mm. just prior to spawning. The mature adults left the shoals soon after spawning and during the remainder of the summer were taken only over the ooze bottom of the lake in four to seven meters of water. The age class I fish remained on the shoals until late July. The young-of-the-year were first seen over the sandy shoals as juveniles on August 2. They were at this time about 23 mm. long. The habitat of the young-of-the-year in August was the extreme shoreward margin of the shoals, in water less than one meter deep.

The average growth rate of the young-of-the-year spottail shiners in Nemeiben Lake was found to be .30 mm. per day during the period August 2 - August 20. The mean length at the beginning of this period was 22.5 mm., while that at the end was 29.3 mm. The age group I shiners had a mean growth rate of .33 mm. per day during the period June 19 - July 26. The mean lengths in June were 38.9, 62.2 and 83 mm. for the age groups I, II and III, respectively.

In Crooked Lake, the mean growth rate of the age group I fish was .30 mm. per day during the period June 22 - September 1. The mean lengths in June of the age groups I, II and III fish were 47.0, 68.5 and 90.4 mm.

The mean lengths in June of the Lake Athabaska spottail shiners were 18.6, 38.9, 68.7 and 82.7 mm. for the age groups I, II, III and IV. This life span was apparently one year longer than the Nemeiben and Crooked Lake populations.

Most of the growth took place during the months of July and August. The amount of growth during the remainder of the year was small. In Nemeiben Lake, the age group 0 fish appeared to increase in length by about 10 mm. during this period, while those in Crooked Lake increased by 0.40 mm. These apparent increases would not have been caused solely by growth during the period September - June. The growth increases were calculated from two consecutive year classes. Therefore, differences in the lengths of the growing season from year to year would also have an effect. The fact that the age group I spottails in Crooked Lake appeared to decrease in length by 0.86 mm. during the winter season would be a result of this factor.

In all three lakes from which samples of spottail shiners were examined, maturity seemed to coincide with the attainment of a total length of 65 mm. Shiners in the more northerly lakes, where growth rate was the slowest, matured later than those in lakes where growth was more rapid. Thus, the shiners in Lake Athabaska and Nemeiben Lake became mature in their fourth summer, while those in Crooked Lake became mature in their third. McCann (1959) reports that spottail shiners in Clear Lake, Iowa, were mature in their second summer.

This characteristic enables the spottail shiner in northern lakes, where scarcity of food and a short growing season are limiting factors, to use all available energy for growth. Those in the more southerly lakes, where increased competition with other fish and predation are the limiting factors, would adapt themselves to this environment by expending more energy on reproduction.

The family, Cyprinidae, due to its Miocene introduction into North America, has not yet developed strongly divergent lines (Miller, 1958). It can be considered to be an unspecialized and rapidly evolving group. This is suggested by the great numbers of species found within the family, many of which readily hybridize, as well as by the many endemic species found in southwestern North America. Thus, a species, such as _N. hudsonius_, which is abundant in many watersheds of North America, may have many ecotypes. Hubbs and Lagler (1949) consider _N. hudsonius_ to be composed of two subspecies, differentiated by characteristics of the pharyngeal teeth. In Nemeiben Lake, some specimens had the characteristic of one subspecies, while some had those of the other. This can be interpreted in two ways. Both subspecies occur in the same collecting area; or, the division into subspecies by this criterion is not valid in this area, there being instead one highly variable species. The latter interpretation would seem to be more reasonable.

In view of the above information, a suggestion for further study would be the investigation of several populations of spottail shiners from different watersheds for evidence of any incipient speciation. The observed differences in the characteristics of the growth rate curves between lakes in the north and south seem to offer possibilities for this. These differences may be due only to different thermal conditions. However, it has been suggested by Walford (1946) that the deceleration of the specific growth rates may be characteristic of races within a species and used to differentiate between them. By raising the fish under artificially controlled conditions, it could be determined if any adaption to different thermal conditions had taken place.

Another suggestion for further study would be to compare the growth rate and fecundity of those fish infected with *Ligula* to those of the uninfected fish. Investigations into the life history of this parasite in Nemeiben Lake and its effect on other species would be interesting.

A more detailed study of the value of this species as a forage fish could be made on a lake where it was more abundant. By using a method of quantitative sampling, the mortality of the different age classes could be determined and a life table drawn up.

The value of data on feeding obtained from stomach examinations would be increased if collections of potential food organisms were made at the same time and in the same place as the fish samples.

Valuable additions to the growth rate data would be provided by a detailed study of the early larvae. With this information the sigmoid structure of the growth curve could be shown, as the point of inflection seems to be somewhere in the larval stages.

Investigations on the behaviour patterns influencing habitat selection by the larvae, juveniles and older fish would also be of interest. To do this, it would be necessary to determine where the large adult minnows went after spawning. This could be done by setting gill nets on both the surface and bottom of various parts of the lake. It would also be necessary to begin sampling immediately after the spring break-up in order to determine when the mature shiners first appeared over the shoals. Also, sampling should be continued until freeze-up to determine when the young-of-the-year shiners left the shoals.

The best sampling method for the adult shiners in deep water seems to be the use of a gill net with a 5/16 or 3/8 inches bar mesh. In shoal water, seining would seem to be best, as the shiners were most often seen over a sand bottom which was easily seined. Collections of large adult minnows for age and growth or taxonomic studies should be made in late spring or early summer when the shiners are abundant over the sandy shoals.

The limiting factors preventing the northward extension of the range of this species would make a worthwhile study. As maturation is dependent upon the attainment of a given size, the inability of a sufficiently large proportion of the population to live long enough to reach this size may be one such factor.

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