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BREEDING HABITS OF LAKE TROUT IN NEW YORK

By William F. Royce

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By WILLIAM F. ROYCE, *Fishery Research Biologist*

The several races of lake trout (*Salvelinus* [=*Cristivomer*] *namaycush*) are widely sought in all the more accessible parts of their range. In the Great Lakes, where this species is one of the most valued food fishes, it is the object of a major fishery. In smaller lakes of the northeastern United States and southern Canada, where commercial fishing usually is prohibited, it is sought as a game fish.

This popularity has been accompanied by severe declines in the populations of lake trout in some lakes, notably the Great Lakes. Detailed knowledge of the species, particularly of the eggs, larvae, and juveniles below the sizes commonly caught, is needed for devising measures to prevent such declines, and for successfully introducing this desirable species in additional lakes.

Almost nothing is known of the habits of young lake trout, probably because of their deep-water habitat; in fact, very few wild lake trout less than 8 inches long have even been seen. The reproductive habits of the species have been imperfectly known, and very little has been published on size and age at maturity. Accordingly, a study of the breeding habits of this species and the life history of its young was made in 1939, 1940, and 1941, on several lakes in the State of New York.

SEXUAL DIMORPHISM

The lake trout, unique among the salmon family, lacks almost completely the malformed jaws or kype common to mature males of other species. Examination of several hundred lake trout from various lakes in New York State showed that it is almost impossible to distinguish the sex of mature lake trout by examination of the head alone. The males have only a slight tendency toward a more pointed snout—although J. R. Westman reported in a personal communication that he had seen a very large male lake trout from Lake Simcoe, Ontario, with a well-developed kype.

It is pertinent to compare the jaws of the lake trout with those of the Pacific salmon, in which the kype attains its maximum development. The Pacific salmon migrate enormous distances to the spawning ground and live entirely on stored food for almost a year before spawning. Mottley (1936) [1] suggests that the development of the kype in the male may occur because its demand on the material mobilized for the development of the gonads differs from that of the female. He postulates that the ovaries would have a general requirement for stored materials, while the testes would require little albuminoid or fat. Thus, these materials might be utilized in the growth of the kype instead of being excreted.

The lake trout would appear to be a diametric opposite. It rarely has a kype, migrates only the short distance from the deep to the shoal waters of a lake, and feeds up to and through the spawning period.[2] Inasmuch as the lake trout does not acquire a kype and as the maturation of the gonads parallels that of the salmon, Mottley's suggestion leaves some things to be explained. Possibly, since the lake trout feeds right up to and through the spawning season, the gonads can develop from ingested food instead of mobilizing stored material from the body.

Alike in external structure, male and female lake trout are also very similar in color when removed from the water. However, in New York State, the normal coloration of both sexes varies widely from lake to lake. The lake trout of the large, clear Finger Lakes are light olivaceous, almost silvery on the back and sides, with a little yellow or orange in the fins. There are all gradations between the color of these trout and the very dark trout of the brown-water Adirondack lakes.

NOTE.—This paper is a revision of a thesis that was submitted to Cornell University in 1943 in partial fulfillment of the requirements for the degree of doctor of philosophy.

[1] Publications referred to parenthetically by date are listed in Literature Cited, p. 75.

[2] Rayner (1941) found that stomachs of ripe lake trout taken on the spawning area contained fish, lake-trout eggs, and miscellaneous invertebrates.

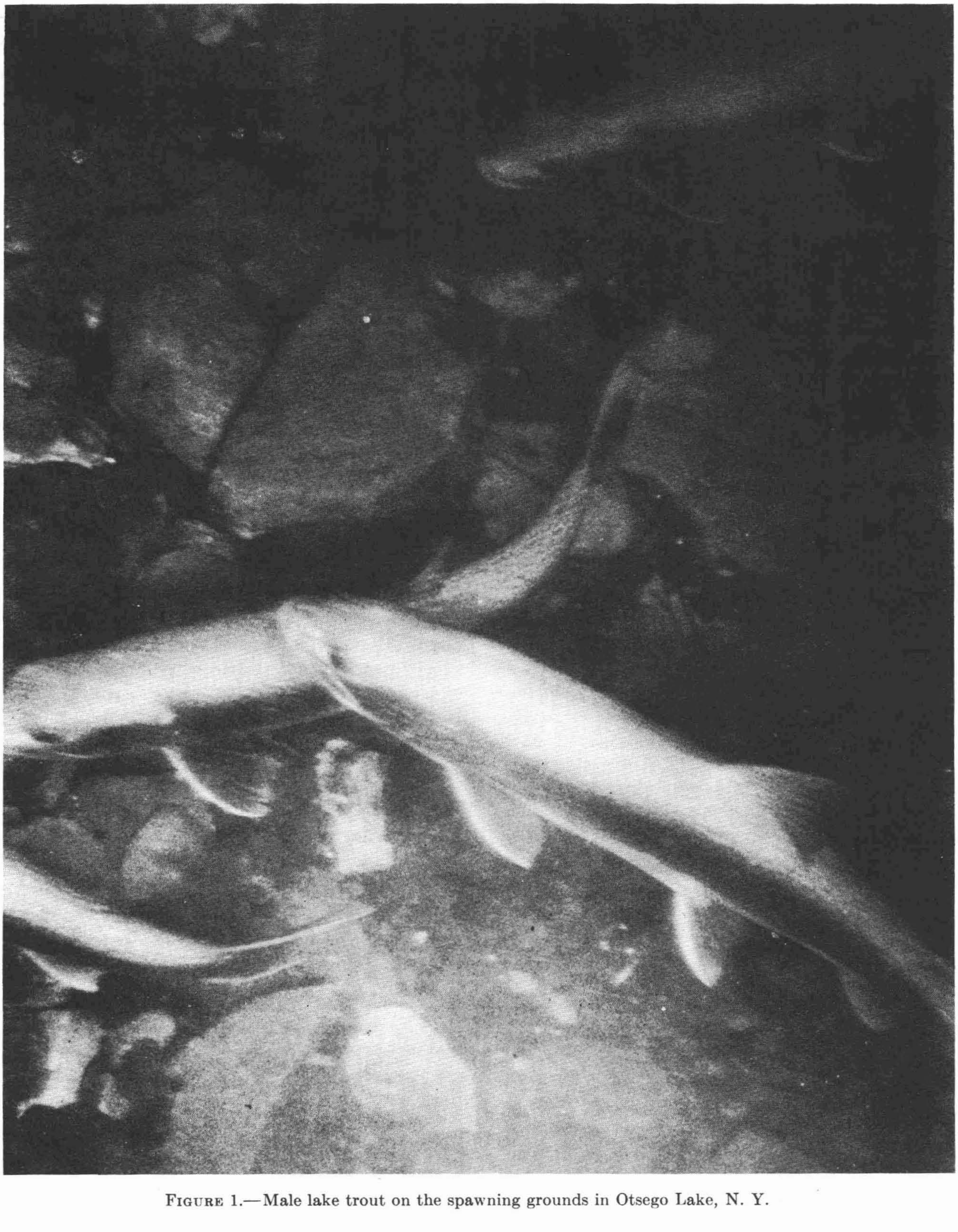

FIGURE 1.—Male lake trout on the spawning grounds in Otsego Lake, N. Y.

The latter have stronger colors, and the sexual differences are a little more pronounced; the males tend to have more brilliant yellow, orange, and black in the paired fins than the females. But even in these lake trout it is not always possible to distinguish the sexes on the basis of external differences.

This normal coloration is considerably changed when the male lake trout are excited on the spawning area. While they are courting, the chromatophores on their backs contract, making the backs appear decidedly light colored, while the sides, flooded with pigment, become very lustrous and almost black (fig. 1). Merriman (1935) observed this condition in the lake trout of Squam Lake, N.H., and it was seen by the writer in Otsego Lake, N. Y., in 1940 and 1941, when selected fish were speared and the brilliant coloration was found to be restricted to the males. Striking as this coloration was during the courting or spawning, the colors were most ephemeral. After the fish were netted or speared, color differences between the sexes could not be detected.

SPAWNING HABITS

AGE AND SIZE AT MATURITY

The age analysis, by means of scales, of 33 mature lake trout caught by gill net on the spawning area off Peach Orchard Point in Seneca Lake, N. Y., showed that 13 had 5 annuli and the remaining 20 had 6 annuli. Comparison of the lengths of the lake trout in this sample with the length frequency of 424 lake trout taken during the spawning season in 1941 showed that these age groups comprised the bulk of the catch, but probably an appreciable quantity of older fish were taken.

Data collected during 1940 by J. R. Westman on the lake trout of Lake Simcoe, Ontario, showed that 13 out of 20 five-year-old and 16 out of 17 six-year-old lake trout were mature. Samples from Keuka Lake, N. Y., in the same year showed similar results: 15 out of 18 five-year-old and 5 out of 6 six-year-old trout were mature. There was a slight tendency for the greater proportion of the young males to be mature in these two lakes, as well as in Seneca Lake.

Fry and Kennedy (1937) estimated, by means of the modes of a length frequency distribution, that the lake trout of Lake Opeongo, Algonquin Park, Canada, reached the minimum age at maturity in their fifth year of life (corresponding, presumably, to four annuli). Inasmuch as they had only five lake trout less than 13 inches long, and as my observations indicate very small growth of lake trout in the first year, I believe that they assigned to each mode an age 1 year less than it should have been.

These data are substantiated by studies made on the growth of hatchery-reared trout. Surber (1933) secured eggs from female lake trout, aged 4 years 6 months, whose lengths varied from 18 to 26 inches; but at this time only 10 females out of somewhat less than 2,000 males and females spawned, producing an average of only 962 eggs per female. No data on subsequent spawning were presented, but certainly the majority of these fish did not spawn before their sixth year. Surber considered that this age at maturity was comparable to that attained by wild fish. He gave the length of the trout at the end of their first, second, third, and fourth years of life as 10, 14, 16 to 18, and 18 to 26 inches, respectively. This rate of growth in the first and second years of life is markedly greater than that existing in Keuka Lake. With this start it is possible that the hatchery fish spawned earlier than they would in the wild, which is known to be true of some other species of hatchery-reared trout, especially brook trout.

The rapidly growing lake trout of Seneca Lake, whatever their age, do not mature until they are 26 to 30 inches in total length; those of Keuka Lake mature at a total length of 18 to 24 inches. In Skaneateles Lake, N. Y., however, Rayner (1941) captured many mature lake trout of 15 and 16 inches total length. Fry (1939) reported that the minimum size at maturity in some lakes of Algonquin Park, Canada, varied from 14 to 18 inches according to the lake.

Obviously with this variation in size at maturity, a uniform minimum legal-size limit of 15 inches, such as exists in New York State, may permit the taking of many immature, rapidly growing fish in some lakes while providing entirely too much protection in other lakes. It would appear necessary to consider the growth rate and fishing pressure in each lake in setting a minimum size limit.

Slowly growing lake trout may be subject to senility at a small size. Fry and Kennedy (1937) reported that none of the lake trout of more than

22 inches fork length in Lake Opeongo, Algonquin Park, Ontario, were capable of spawning. Such widespread impotency was not observed in any of the New York lake trout. The conservation department employees engaged in spawn-taking operations on the Adirondack and Finger Lakes reported that only occasionally would an impotent fish be found. The more limited observations I made also failed to show any impotency, and it is quite likely that after the lake trout in New York State lakes are mature they may spawn several times before succumbing to the infirmities of age.

TIME OF SPAWNING [*]

The available information shows that lake trout, and most other trout, spawn once a year in the fall when the temperature is dropping and the days are becoming shorter. Among different races of lake trout, small variations in the spawning date are found. This is true also of the same race of lake trout in different lakes, and of the same race in the same lake in different years. It appears probable that fluctuations in light and temperature, in the physical characteristics of different lakes, and in the responses of different races are the determining factors.

These factors have proved important in influencing the spawning time of other species. Hoover and Hubbard (1937) have shown that brook trout which normally spawned in December could be induced to spawn in late August and early September by increasing the amount of light in early spring and decreasing it in late summer. Bissonette and Burger (1940) state that "there is no uniform control of the sexual cycle applicable to all fish. In some fish, temperature seems to be the major factor; in others, light and temperature play cooperative roles; while in still others, light appears to be the most important factor."

Merriman and Schedl (1941), on the basis of laboratory experiments on the four-spined stickleback, *Apeltes quadracus* (Mitchill), concluded that light influenced oögenesis but not spermatogenesis, while temperature somewhat unequally affected the maturation of the gonads of both sexes. McCay et al. (1930) concluded on the basis of feeding experiments that the spawning time of brook trout could be influenced by the food supply. They found that the age at maturity could be advanced or postponed by increasing or decreasing the amount of food fed to the hatchery trout, but the question of changing the spawning date of mature trout was not clarified.

After several years of netting lake trout in Raquette Lake for spawn taking, the hatchery men of the New York Conservation Department have observed that the lake trout run earlier after a sudden drop in temperature. The extensive data on their operations were made available to me, and weather data were obtained from the United States Weather Bureau (table 1).

TABLE 1.—*Weather conditions in relation to peak of lake-trout egg take at Raquette Lake, 1933–41*

Year	Air temperature [1] (° F.)	Cloudy days [2]	Peak of egg take
1933	56.8	22	Oct. 22
1934	54.9	21	Oct. 18
1935	52.4	24	Oct. 13
1936	54.0	19	Oct. 19
1937	55.0	21	Oct. 21
1938	(3)	(3)	(3)
1939	55.4	18	Oct. 23
1940	53.4	22	Oct. 19
1941	56.6	21	Oct. 19

[1] Average air temperature for the month of September at nearby Indian Lake.
[2] Number of cloudy days in July, August, and September in the northern plateau region of New York.
[3] No eggs taken.

The average air temperature for September reported by the Indian Lake weather station was used because it was the nearest station to Raquette Lake, with complete weather records for the 8 years of spawning data. The average number of cloudy days for the entire northern plateau region of New York was selected because many of the smaller stations had no automatic sunshine recorders and their estimates of cloudiness varied considerably. The number of cloudy days in July, August, and September was used because the work of Hoover and Hubbard (1937) indicated that changes in the light required a considerable time to influence the development of the eggs, and these 3 months were the ones preceding the spawning season which had decreasing amounts of daylight.

The analysis of these data by multiple regression (table 2) indicated that the date of spawning was advanced by lower temperatures or a greater number of cloudy days and retarded by warmer weather or fewer cloudy days. However, neither on air temperature alone nor on cloudiness alone was the partial regression of the spawning date statistically significant. When both factors were considered in a multiple regression coefficient the result was significant ($R=.8643$ when R of .836 or greater is to be expected 5 percent of the time with 5 degrees of freedom).

TABLE 2.—*Reduced data for multiple regression analysis of the date of peak of lake-trout egg take at Raquette Lake*

x_1 = Average air temperature for the month of September at Indian Lake.

x_2 = Number of cloudy days in July, August, and September in the northern plateau region of New York.

y = Date of peak of lake-trout egg take.

Number of observations: $n=8$

Means:
$\bar{x}_1=54.81$ $\bar{x}_2=21.00$ $\bar{y}=19.25$

Sums of squares:
$Sx_1^2=16.01$ $Sx_2^2=24.00$ $Sy^2=65.50$

Sums of products:
$Sx_1x_2=-6.80$ $Sx_2y=-27.00$ $Sx_1y=23.08$

Correlation coefficients:
$r_{12}=-.3469$ $r_{y2}=-.6810$ $r_{y1}=.7534$

Standard partial regression coefficients:
$B_{y1.2}=.5675$ $B_{y2.1}=-.4841$

Multiple regression equation:
$E=-80.3+2.32X_1-1.32X_2$

TESTS OF SIGNIFICANCE:

Standard partial regression coefficients: ($DF=5$)

$$\text{for } B_{y1.2}\ t=\frac{.5675}{.2398}=2.366$$

$$\text{for } B_{y2.1}\ t=\frac{.4841}{.2398}=2.019$$

neither significant

Multiple correlation or multiple regression: ($DF=5$)

$R=.8643$ significant

A similar analysis of data on the peak of egg take from Upper Saranac Lake (tables 3 and 4) was less conclusive. The date of peak of egg take in 1941 was about a month later than usual, but if we omit this aberrant observation the date of the peak at Upper Saranac Lake seems to bear the same relation to air temperature and cloudiness as at Raquette Lake. However, neither the partial nor the multiple regression coefficients are significant. ($R=.699$ when R of .930 or greater is to be expected 5 percent of the time with 3 degrees of freedom).

TABLE 3.—*Weather conditions in relation to peak of lake-trout egg take in Upper Saranac Lake, 1935–41*

Year	Air temperature[1] (°F.)	Cloudy days[2]	Peak of egg take
1935	52.3	24	Oct. 17
1936	56.9	19	Oct. 23
1937	54.8	21	Oct. 21
1938	52.0	28	Oct. 15
1939	54.8	18	Oct. 24
1940	52.4	22	Oct. 26
1941	57.2	21	Nov. 20

[1] Average air temperature for the month of September at nearby Tupper Lake.
[2] Number of cloudy days in July, August, and September in the northern plateau region of New York.

TABLE 4.—*Reduced data for the multiple regression anaylsis of the date of the peak of lake-trout egg take at Upper Saranac Lake*

x_1 = Average air temperature for the month of September at Tupper Lake.

x_2 = Number of cloudy days in July, August, and September in the northern plateau region of New York.

y = Date of peak of lake-trout egg take.

Number of observations: $n=6$ [1]

Means:
$\bar{x}_1=53.87$ $\bar{x}_2=22.00$ $\bar{y}=21.00$

Sums of squares:
$Sx_1^2=19.03$ $Sx_2^2=66.00$ $Sy^2=90.00$

Sums of products:
$Sx_1x_2=-28.10$ $Sx_2y=-62.00$ $Sx_1y=19.00$

Correlation coefficients:
$r_{12}=-.7929$ $r_{y2}=-.6263$ $r_{y1}=.4591$

Standard partial regression coefficients:
$B_{y1.2}=-.1008$ $B_{y2.1}=-.7062$

Multiple regression equation:
$E=50.94-.219X_1-.825X_2$

TESTS OF SIGNIFICANCE:

Standard partial regression coefficients: ($DF=3$)

$$\text{for } B_{y1.2}\ t=\frac{.1008}{.6776}=.1488$$

$$\text{for } B_{y2.1}\ t=\frac{.7062}{.6776}=1.0421$$

neither significant

Multiple correlation or multiple regression: ($DF=3$)
$R=.6990$ not significant

[1] 1941 data omitted.

Other things must be considered in evaluating these analyses. The data are few, only 6 years in one instance and 8 in the other, and the Weather Bureau data on air temperature and cloudiness cannot be a precise measurement of the temperature and the light actually affecting the fish. Furthermore, the period during which the light and the temperature changes are influential can only be surmised, and other factors may be important. For example, in Raquette Lake in 1938 the notably high water level was suspected of being the cause of almost no lake trout being caught. However, it was not certain whether this affected the migrations or prevented the nets from operating effectively.

Considering that a significant relation was established in one instance, and that other data were inconclusive but showed a similar tendency, it is probable that both light and temperature do influence the spawning time of lake trout.

Lake trout in Raquette Lake (Oliver R. Kingsbury, report to the New York Conservation Department, November 1935) spawn at about the time of the lake turn-over. In the middle of the 1935 spawning season, temperatures taken at the surface and at depths down to 56 feet revealed no more than a 3° F. difference between top and bottom. This seems to be more important than the actual surface temperature in influencing spawning, for the surface temperature on the day the first eggs were taken was 58° F. in 1933, 52° F. in 1934, and 50° F. in 1935. Merriman (1935) reports lake trout spawning in Squam Lake, N. H., when the surface temperature was 42° F. In Otsego Lake in 1940 the lake trout were observed spawning December 5, when the surface temperature was 37° F. No facilities were available for taking deep-water temperatures at that time, but in 1941 the fish were observed late in their spawning season on December 3, when the water temperature was uniformly 43° F. from the surface down to 60 feet. These wide variations in surface temperature indicate its slight value as a determinant of the date of spawning.

Such differences in the progress of cooling in different lakes are probably associated with the depths of the lakes, and it appears that the depth of a lake is associated with the time of lake-trout spawning. Table 5 presents data from the files of the New York State Conservation Department on the time and duration of lake-trout spawn taking

TABLE 5.—*Duration of lake-trout spawn taking operations by State Conservation Department in some New York lakes*

Year	Date first eggs received at hatchery	Date of peak of egg take	Date last eggs received at hatchery
Raquette Lake (alt. 1,762 ft.; max. depth 96 ft.):			
1933	Oct. 14	Oct. 22	Oct. 24
1934	Oct. 14	Oct. 18	Oct. 20
1935	Oct. 11	Oct. 13	Oct. 16
1936	Oct. 16	Oct. 19	Oct. 21
1937	Oct. 16	Oct. 21	Oct. 26
1939	Oct. 16	Oct. 23	Oct. 26
1940	Oct. 12	Oct. 19	Oct. 24
1941	(1)	Oct. 19	(1)
Lake George (alt. 322 ft.; max. depth 187 ft.):			
1928	Nov. 5	(1)	Nov. 14
1929	Oct. 31	(1)	Nov. 5
1932	Nov. 5	(1)	Nov. 13
1936	Nov. 2	Nov. 6	Nov. 9
1938	Nov. 4	Nov. 8	Nov. 11
Lake Pleasant (alt. 1,724 ft.; max. depth 53 ft.):			
1930	(1)	Oct. 14	(1)
1932	Oct. 12	(1)	Oct. 15
Sacandaga Lake (alt. 1,724 ft.; max. depth 60 ft.):			
1929	Oct. 13	(1)	Oct. 13
1930	(1)	Oct. 22	Oct. 26
1932	Oct. 12	Oct. 16	Oct. 23
1933	Oct. 16	Oct. 21	Oct. 23
Piseco Lake (alt. 1,661 ft.; max. depth 129 ft.):			
1930	Oct. 17	Oct. 25	Oct. 29
1931	Oct. 15	Oct. 24	Nov. 5
1932	Oct. 13	(1)	Oct. 28
1933	Oct. 10	(1)	Oct. 15
Seventh Lake (alt. 1,786 ft.; max. depth 85 ft.):			
1933	Oct. 20	Oct. 24	Oct. 24
Seneca Lake, (alt. 444 ft.; max. depth 625 ft.):			
1939–41 [2]	Sept. 23	Oct. 10	Nov. 3
Keuka Lake (alt. 709 ft.; max. depth 187 ft.):			
1936–39 [2]	Nov. 20	Nov. 25	Dec. 3
Upper Saranac Lake (alt. 1,571 ft.: max. depth 100 ft.):			
1935	(3)	Oct. 17	(3)
1936	(3)	Oct. 23	(3)
1937	(3)	Oct. 21	(3)
1938	(3)	Oct. 15	(3)
1939	(3)	Oct. 24	(3)
1940	(3)	Oct. 26	(3)
1941	(3)	Nov. 20	(3)

[1] Data not available.
[2] Same dates were reported for each year.
[3] Data depended on hatchery schedule rather than lake-trout migrations.

operations in some New York lakes. Figure 2, which incorporates information from table 5, from Rayner (1941) for Skaneateles Lake, and from my observations on Otsego Lake, shows this relation graphically.

It appears that the lake trout spawn early in the shoal lakes and later in the deep lakes. If, as indicated previously, they spawn at about the turn-over time of the lake, this would be expected, as the deeper lakes cool off more slowly.

Like so many rules, the one that the deeper the lake the later the lake trout spawn has an outstanding exception. In Seneca Lake, the deepest lake in New York State (625 feet maximum depth), the lake trout spawn the earliest. They start in late September and continue through October, spawning in water from 100 to 200 feet

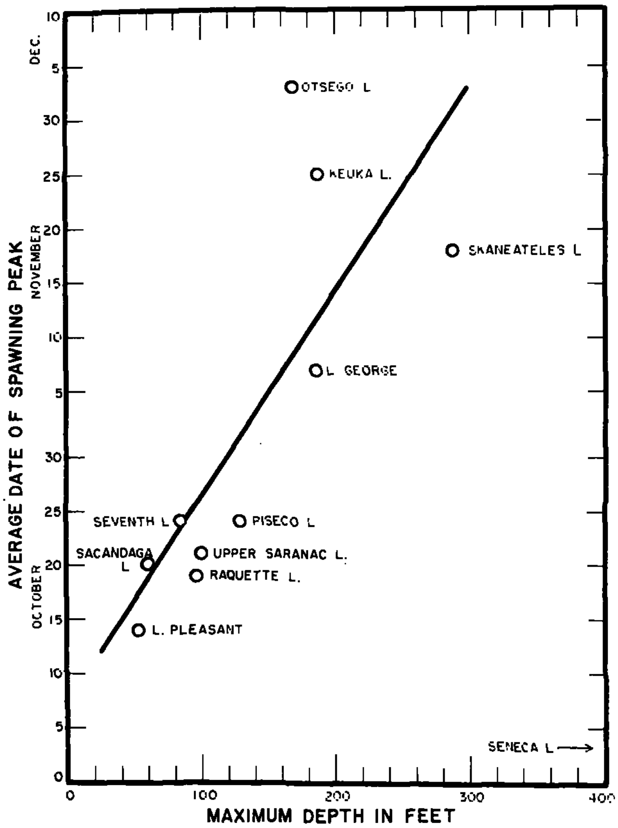

FIGURE 2.—Relation of average date of peak of lake-trout spawning activity and maximum depth of some New York lakes.

deep at a time well in advance of the turn-over period of the lake. Data, taken from September 29 to October 17, 1941, showed that the surface temperature ranged from 57° to 62° F.

This large deviation in the time of spawning may be attributed to racial differences in the lake trout. Milner (1874) gives the spawning time of the siscowet (*Cristivomer namaycush siscowet*) as late August and early September in the deep waters of Lake Superior. In the same lake the common lake trout (*Salvelinus* [=*Cristivomer*] *namaycush*) spawns in from 7 feet to 15 fathoms of water during the month of October and in early November (Milner 1874, Van Oosten 1935). Hubbs (1930) has described the Rush Lake trout (*Cristivomer namaycush huronicus*) and states that it spawns in deep water in late summer rather than in fall, as does the common lake trout in the same lake. Dymond (1926) gives the time of spawning of the common lake trout as the month of October in Lake Nipigon, Ontario. But he points out that there is a race of black trout in the same lake which ascends some of the tributary streams and starts spawning about September 20, and a third race which is said to spawn in deep water from October 20 to November 10.

In New York State the spawning data indicate that two races [3] of lake trout exist: One, the Seneca Lake trout, spawns early in deep water, and the other, widespread in the Finger and Adirondack Lakes, spawns in shallow water at about the time of the turn-over of the lake.

With these differences in reactions and spawning habits, it would be desirable to determine if the Seneca Lake trout can adapt themselves to the conditions existing in Adirondack Lakes and vice versa before extensive stocking is attempted. Until such knowledge can be secured it would be wise to stock lake trout in lakes similar to those from which the eggs were obtained.

DURATION OF THE SPAWNING PERIOD

Data on the receipt of lake-trout eggs at some of the New York State hatcheries are summarized in table 5. The date of receipt of eggs corresponds closely to the date of take, except for the first one or two days of the spawning season. Ordinarily, only a few ripe fish are found at first, and if only a few thousand eggs were obtained, they often were held for a day or two until more eggs were available to make the trip to the hatchery worth while. The date the first eggs were taken probably averages about 1 day earlier than the date of their receipt at the hatchery. At the peak of the spawning season the eggs were usually rushed to the hatchery immediately, so the date of the peak receipt of eggs corresponds to the date of the peak egg take.

The data in table 5 do not indicate the complete spawning season but rather the season during which it was feasible to catch and strip the trout. High water sometimes so affected the fishing of the nets that it was not practical to continue fishing, and bad weather sometimes cut short the stripping operations. Hence, a short period of egg take is not necessarily indicative of a

[3] Other evidence of racial difference is available. New York State fish hatchery foremen agreed that eggs from Seneca Lake trout averaged about 240 an ounce, while eggs of lake trout of comparable size from Adirondack lakes averaged about 200 to 210 an ounce. No measurements of the actual diameters of the eggs were available, but the counts of the hatchery foremen appeared to be fairly consistent. D. C. Haskell (unpublished material gathered in 1941) also reports that the Seneca Lake trout grow significantly faster under hatchery conditions than the young lake trout from Raquette and Upper Saranac Lakes.

short spawning season. It seems likely, however, that the longer periods of spawn taking closely approximate the spawning season.

It appears that the lake-trout spawning season lasts from 10 to 20 days in the smaller New York lakes and the duration is fairly uniform in the same lake from year to year. The lake trout of Lake George consistently completed their spawning in 7 to 10 days at the most.

The length of the spawning season increases in the larger lakes. Van Oosten (1935) gives the duration of the spawning season in Lake Michigan as October 10 to November 21; in Lake Huron, October 10 to November 15; and in Lake Superior, October 1 to November 6. Seneca Lake is similar to the Great Lakes in both date and duration of the spawning season. The earliest and latest dates on which the New York State Conservation Department obtained eggs in Seneca Lake were September 23 and November 3. These dates are for different years, but the earliest and latest dates were similar from year to year.

PLACE OF SPAWNING

The observations of Merriman (1935), Royce (1936), and the writer indicate that lake-trout spawning areas are restricted to bottom of clean gravel or rubble, free of sand and mud. As the fish make no effort to bury the eggs, the bottom must have crevices into which the eggs can roll, if eggs and larvae are to be protected.

The location of these suitable areas of bottom in the lake is primarily determined by currents or wave action which keep the bottom swept clean. The lake trout will roll the smaller stones around and fan off the silt, but they cannot remove sand or mud from the crevices. Any bottom that is not swept by currents or waves eventually becomes covered with mud, although in the usual oligotrophic lake-trout lake this process would take a very long time.

In the littoral zone, the width of the area of clean rocks or sand is dependent directly on the size of the lake and its exposure to the wind. In the smaller New York lakes the lake trout generally may be found spawning by windy points near deep water (Royce 1936), on bottom kept clean by the waves. A typical example of such shallow-water spawning is to be found in Otsego Lake.

In larger lakes the lake trout may go to deeper water for their spawning. Milner (1874) reports that the lake trout in Lake Superior spawn in 7 feet to 15 fathoms of water. Evidence of spawning in the deep water was provided by the capture of ripe fish at that depth and by raising in the nets fragments of honeycombed rocks containing eggs. In Seneca Lake the lake trout are captured for stripping in 100 to 200 feet of water at a time when no lake trout are found in shallow water. The fact that ripe lake trout are captured over bottom that is suitable for spawning is strong evidence that the trout actually are spawning at these depths. Further proof was provided by the capture on the spawning bed in Seneca Lake, in April 1940, of a lake-trout fry 25 millimeters in total length, in water 130 feet deep.

There is much evidence that these deeper spawning areas are swept by strong currents. The hatchery fishermen reported that their nets were often rolled over and over by the currents in Seneca Lake. In this same lake off Peach Orchard Point the 40° F. isotherm rose from a depth of 260 feet on September 29, 1941, to 100 feet on October 1 after a strong south wind; on October 7 it was back down to a depth of 230 feet. Such a change must be accompanied by the movement of a huge quantity of water.

These currents in Seneca Lake and the other Finger Lakes have left evidence of a prevailing direction of flow. All these lakes are very long and narrow and lie with their long axes in very nearly a north-south direction. Seneca Lake is the largest, being about 40 miles long and 3 miles wide at its widest point. The prevailing winds come from the northwest or the southeast, blowing obliquely to the south on the eastern shore and obliquely to the north on the western shore of the lake. The general result has been to form the tips of deltas to the south of the stream mouths on the eastern shore of the lake and to the north of the stream mouths on the western shore.

In addition to the characteristic orientation of the deltas, there is a definite gradation in the size of the material deposited in the various parts of the delta. Off the tip of Peach Orchard Point in Seneca Lake down to a depth of at least 300 feet, only clean gravel and rubble could be found with a clamshell dredge, or seen in bottom photo-

FIGURE 3.—The bottom of Seneca Lake west-southwest off the tip of Peach Orchard Point where the lake trout congregate during the spawning season. The picture covers an area on the bottom about 18 by 24 inches at a depth of 120 feet.

graphs [4] (fig. 3). The lighter materials, such as mud, were deposited in the coves adjacent to Peach Orchard Point.

Evidently other deltas in this lake have similar deposits, since lake trout are captured in large numbers during the spawning season near the tips of the points.

The writer has found no evidence that lake trout select a lake bottom supplied with spring water for the deposition of their eggs. The spawning area in Otsego Lake was on a fill about 100 feet out from the original shoreline which was bedrock and showed no evidence of any spring seepage. Comparison of numerous water temperatures taken on the spawning area and in the nearby lake at all seasons of the year showed no difference in temperature. Additional evidence was the presence of as thick an ice cover over the spawning area on March 31 as on other parts of the lake, just before the spring breakup, when any springs should have caused some erosion of the ice. No mention of spring water on lake-trout spawning areas has been found in the literature I have reviewed. It is concluded that for lake trout, unlike some other species of trout, spring water is a negligible factor in selection of a spawning area.

[4] Ewing, Vine, and Worzel (1946) describe submarine photographic equipment and techniques in detail.

SPAWNING ACT

All my observations on the spawning act of lake trout reported here were made at a spawning area on Otsego Lake, N. Y. Otsego Lake is about 8 miles long and averages three-fourths of a mile in width. Its maximum depth is 168 feet, and about 90 percent of the lake is more than 60 feet deep (Odell and Senning 1936). Chemical conditions are ideal for lake trout, and the lake has produced fairly good lake-trout fishing for

FIGURE 4.—The courtship act. The male at the left is nudging the female in the side.

many years. The spawning area kept under observation—the only one well known to the local residents and the only one that could be found—was along the middle of the west shore opposite the deepest part of the lake.

Observations were made in this area on November 16 and 30 and on December 1 and 5, 1940, and on December 1, 2, and 3, 1941. The trout were observed from 7 a. m. to 11 p. m. on some of those days, but the area was visited mostly in the evening.

Some trout were on the spawning area at all times of day during the spawning season, but most of the activity was restricted to the evening hours. During periods of bright sunlight only a few males could be seen and they kept to fairly deep water so that obsêrvation was difficult. The direct rays of the sun were cut off by a mountain about 4 p. m. and then many trout, both males and females, would arrive on the spawning area, and the males would start courtship and attempt the spawning act. The peak of the activity was from 5 p. m. to 9 p. m. Later in the evening the trout again disappeared until only a few were left at 11 p. m., when observations were discontinued.

No nest or redd was built. The males spent their time cruising along close to the bottom, occasionally giving the stones a little fillip with their tails, and several showed considerable abrasion on the lower jaw and under side of the tail from this fanning and digging. This activity cleaned several hundred square feet of bottom so thoroughly that it was easy to distinguish the area on which the trout were working even when they were not present.

It has been the experience of employees of the New York State Conservation Department in netting lake trout for spawn that the males appear in the nets on the spawning area earlier in the season than the females, and usually more males are caught. From this experience, and from the fact that the males predominated on the area in Otsego Lake, it seems probable that the males

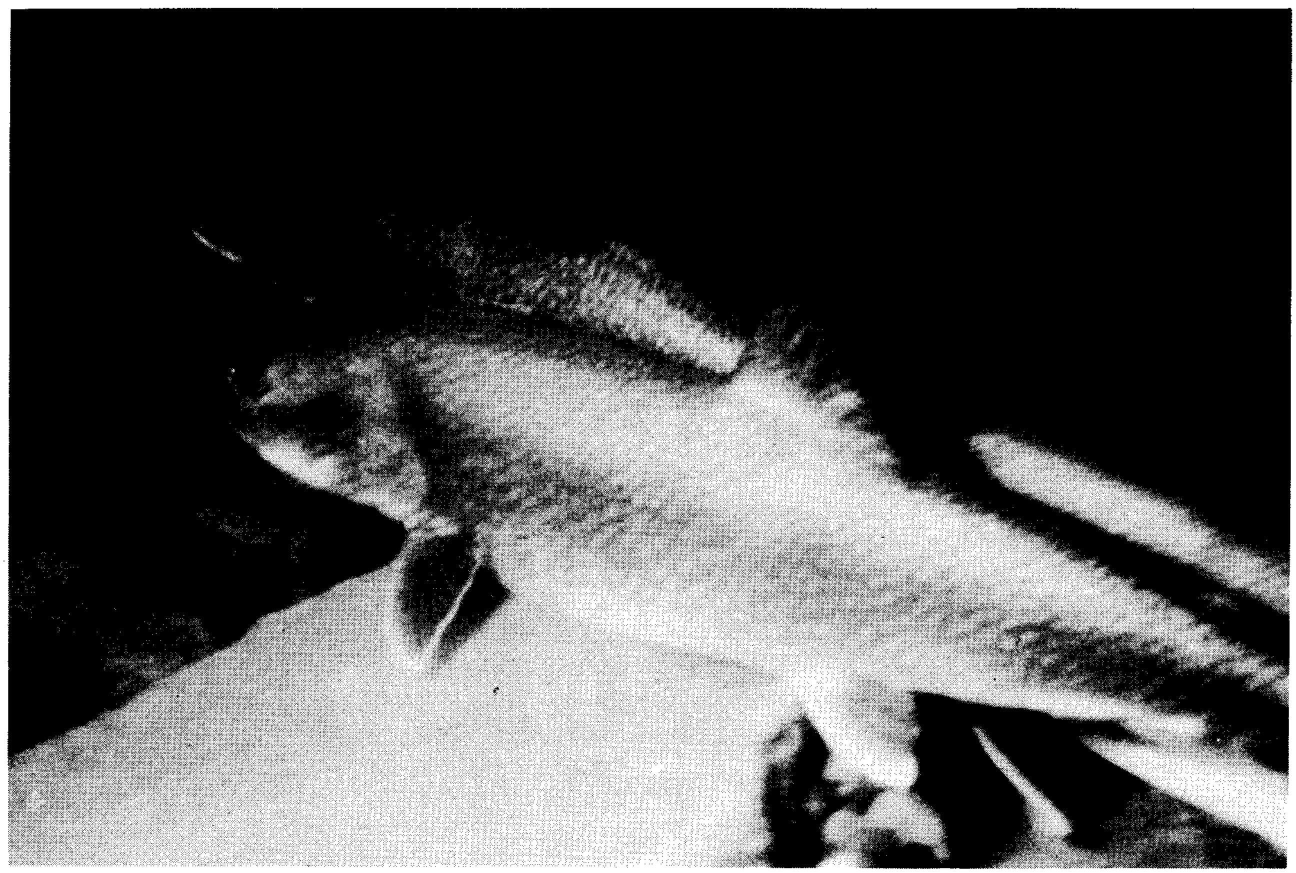

FIGURE 5.—Just after completion of the spawning act. Two males have spawned with the female in the center.

are almost entirely responsible for any cleaning of the spawning area before spawning.

Belying their appearance, the males are not pugnacious. Occasionally one would make threatening motions at another male, but no vigorous fighting was observed. Several whitefish (*Coregonus clupeaformis*) and a large eel (*Anguilla bostoniensis*) were seen among the milling lake trout and were unmolested. It was noted, however, that the males were nearly of the same size. Perhaps they had already disposed of any venturesome small males.

Merriman (1935) and others have observed the spawning lake trout splashing at the surface. In Otsego Lake this was noted only infrequently, possibly because the spawning was on a steep slope in 2 to 15 feet of water—deeper water than that in which Merriman made his observations.

The males began their courtship upon the appearance of the females on the spawning area. Usually the male nudged the female in the side with his snout (fig. 4) and then attempted the spawning act. Frequently two or more males courted and attempted to spawn with a female at the same time. During courtship the males displayed the characteristic coloration (fig. 1) and commonly held the dorsal fin erect. These displays were apparently identical to those noted by Merriman (1935).

The spawning act or attempts at it normally consisted of one or two males approaching a female, pressing against her sides with their vents in close proximity and then quivering all over (fig. 5). Usually the mouths of both sexes were open and the dorsal fin of the male was held erect. This act was seen clearly at close range several times when no eggs or milt were expressed. On two occasions a cloudiness was noted in the vicinity of the vents which probably was caused by the emission of sperm. No eggs were seen but this could have been because of the distance of the observer from the fish and the turbidity of the water. No other act or behavior was seen which could be construed to accompany oviposition. Probably the attempt at the spawning act is a part of courtship and is repeated over and over again until fulfillment.

The spawning act was not limited to two or three trout; as many as seven males and three females were seen at one time, all pressing together in one large group and quivering in unison. No spawning act lasted for more than a few seconds, and it seems that a female must accomplish many unions to empty the ovaries completely. The trout are not monogamous and it was impossible to follow the movement of any one pair in the milling group.

No tendency toward oviposition in any definite place on the spawning area was observed. The trout mated at random over the area cleaned off, and there was no attempt by either sex to bury the eggs. This seeming carelessness in regard to the fate of their young was justified when one attempted to find the eggs. A casual examination of the bottom revealed practically no eggs, but they could be picked up by the hundreds when the stones were turned over carefully. Eggs were recovered in water from 3 inches to 14 feet in depth. Those collected in more than 2 feet of water had to be taken in a Petersen dredge and no estimate of their abundance could be obtained. Along shore in less than 2 feet of water, however, where only an occasional trout was seen spawning, from 20 to 50 eggs could be recovered per square foot of bottom. The eggs were difficult to pick up, and the slightest motion of the water sent them rolling further into crevices between the rocks. In their selection of the bottom on which to spawn, the lake trout had chosen an ideal shelter for their eggs and young.

ENVIRONMENT AND DEVELOPMENT OF EGGS AND LARVAE

EFFICIENCY OF FERTILIZATION

It has been a long-cherished belief of fish culturists that the natural spawning of trout is a highly inefficient, hit-or-miss process. Critical investigations have shown this belief to be untrue. White (1930) was able to hatch 79 percent of a sample of naturally fertilized brook-trout eggs removed from their redd and placed in a hatchery, and 66 percent of another lot placed in a screen basket and reburied in the redd. Hobbs (1937), after intensively investigating the redds of brown trout, rainbow trout, and quinnat salmon, found that more than 99 percent of the eggs were fertilized. He also found that subsequent heavy loss in the pre-eyed, eyed, and alevin stages was a result of adverse environmental conditions. Under favorable conditions the natural reproduction was a highly efficient process.

A check of the natural spawning of lake trout in Otsego Lake provided further evidence that natural reproduction is efficient. On December 28, 1941, about 25 days after the trout were observed on the spawning area, a sample of 309 eggs was collected from under the rocks along shore with a small rubber bulb and tube. Of these 309 eggs, 18, or 5.8 percent, were not fertilized, and 47, or 15.2 percent, had died. Seventy-nine percent of the eggs were alive and apparently entirely normal after having been on the lake bottom nearly a month. This probably represents a near minimum figure for the survival (exclusive of those eaten by predators) inasmuch as the eggs were of necessity collected in only a few inches of water where they were subject to heavy wave action. The vast majority of the eggs were laid in deeper water out of reach of available collecting apparatus and where they should have been better protected.

TEMPERATURE REQUIREMENTS

Lake-trout eggs appear both to require and to withstand slightly lower temperatures than the eggs of other trout. Embody (1934) found that brook- and rainbow-trout eggs suffered excessive mortality and developed at a different rate when the water temperature was below 37.4° F.[5] He found, also, that lake- and brown-trout eggs followed the same rate of development down to 35.2° F., and he judged that development proceeded normally. Brook trout usually spawn in spring water so that their eggs are not subjected to near-freezing temperatures during the winter (Greeley 1932, Hazzard 1932, White 1930). Rainbow trout normally spawn in the spring when the water is warming (Rayner 1941). Cook (1929) reports that lake-trout eggs develop satisfactorily at the Duluth, Minn., hatchery where water temperatures remain about 32.5° F. throughout the winter. The 140-day incubation period of lake-trout eggs in Otsego Lake indicates an average temperature of 36° or 37° F. in the egg-development tables of Embody (1934). At the Rome, N. Y., State hatchery high mortality occurred in lake-trout eggs developing at water temperatures above 50° F. when other trout eggs developed normally. In other hatcheries, lake-trout eggs from the same source developed normally at lower temperatures. These facts would indicate that lake-trout eggs can develop successfully in a lake in the winter, so long as they do not freeze, and that they do not require spring water.

No data are available on the temperature requirements of the alevins. In the spring of 1941 they left the spawning area in Otsego Lake when the water temperature was about 55° F. It seems likely, therefore, that they avoid temperatures above 60° F.

EFFECTS OF PREDATION

The data on the survival of eggs in Otsego Lake do not indicate the true value because they do not consider the removal of eggs by predators. Predators are an ever present danger to lake trout from the egg stage almost to maturity, and cause a loss which is exceedingly difficult to evaluate. No precise measurements have ever been made on the effects of predation at any stage in the growth of wild trout.

Many are the potential predators of eggs and alevins. Table 6 lists the animals captured within 100 yards of the lake-trout spawning area in Otsego Lake during April and May 1941. Many of these would destroy eggs if eggs were availabe to them. Atkinson (1931) and Greene, Hunter, and Senning (1932) found that numbers of lake-trout eggs were eaten by suckers (*Catostomus commersonii*) and bullheads (*Ameiurus nebulosus*). Both of these species occur in Otsego Lake although they were not captured in the immediate vicinity of the lake-trout spawning area. Greeley (1936) states that a fisherman reported finding lake-trout eggs in the stomachs of Otsego Lake whitefish. Rayner (1941) found many lake-trout eggs in the stomachs of adult lake trout. A female taken by the writer on the Otsego Lake spawning area had 13 lake-trout eggs in its stomach. Small lake trout may be even more voracious predators. W. C. Senning, in a letter to me, reported finding lake-trout eggs in every one of 31 small lake trout taken on the spawning grounds in Seneca Lake in the fall of 1942. These lake trout ranged from 6½ to 13 inches in length, and one 12-inch individual had eaten 147 eggs. White (1930) found large numbers of brook-trout eggs in brook-trout stomachs. Metzelaar (1929) reported that rainbow trout ate numbers of their own eggs. Greeley (1932) found brooks, browns, and rainbows to

[5] Rainbow-trout eggs suffered high mortality at temperatures below 43° F., but Embody thought that in some cases this was due to inferior eggs.

TABLE 6.—*Animals found on and near lake-trout spawning area in Otsego Lake, Apr. 27–June 2, 1941*

Phylum and order	Species	Common name	Stage
Coelenterata	*Hydra* sp		
Platyhelminthes	*Planaria* sp		
Arthropoda:			
Amphipoda	*Hyalella* sp		
Neuroptera	*Sialis* sp	Alderfly	Larva.
Ephemerida	*Blasturus* sp	Mayflay	Nymph.
Do	*Ephemerella* sp	do	Do.
Do	*Stenonema* sp	do	Do.
Do	*Hexagenia* sp	do	Do.
Do	*Ephemera* sp	do	Do.
Odonata	*Gomphus* sp	Dragonfly	Do.
Do	*Didymops transversa*	do	Do.
Do	*Epicordulia princeps*	do	Do.
Do	*Helocordulia uhleri*	do	Do.
Do	*Neurocordulia obsoleta*	do	Do.
Do	*Argia moesta*	Damsel fly	Do.
Do	*Enallagma* sp	do	Do.
Plecoptera	*Neoperla* sp	Stone fly	Do.
Coleoptera	*Dineutes* sp	Whirligig-beetle	
Trichoptera	*Stenophylax scabripennis*	Caddisfly	Larva.
Do	*Molanna* sp	do	Do.
Do	*Phryganea* sp	do	Do.
Do	*Glossosomatinae* [1]	do	Do.
Diptera	*Chironomus* sp	Midge	Do.
Do	*Tanytarsus* sp	do	Do.
Mollusca:			
Gastropoda	*Limnea* sp	Pond snail	
Do	*Planorbis* sp	Wheel snail	
Pelecypoda	Unidentifiable	Clam	
Chordata:			
Pisces	*Coregonus clupeaformis*	Whitefish	
Do	*Cristivomer n. namaycush*	Lake trout	
Do	*Notropis h. hudsonius*	Spot-tail shiner	
Do	*Hyborhynchus notatus*	Blunt-nosed minnow.	
Do	*Esox niger*	Chain pickerel	
Do	*Anguilla bostoniensis*	American eel	
Do	*Perca flavescens*	Yellow perch	
Do	*Stizostedion v. vitreum*	Yellow pike-perch	
Do	*Bolesoma nigrum olmstedi*	Johnny darter	
Do	*Micropterus d. dolomieu*	Small-mouthed bass.	
Do	*Lepomis gibbosus*	Pumpkinseed (sunfish).	
Do	*Ambloplites rupestris*	Rock bass	
Do	*Cottus cognatus*	Slimy muddler	
Amphibia	*Triturus viridescens*	Newt	

[1] Two or more species.

be trout-egg eaters. On the Otsego Lake spawning area, an eel (*Anguilla bostoniensis*) and several whitefish (*Coregonus clupeaformis*) were seen industriously feeding among the stones where the lake trout were spawning. In addition, a slimy muddler (*Cottus cognatus*), which is known to eat trout eggs, was captured in the immediate vicinity.

What is the effect of this predation? Greeley (1932) concluded that practically all the eggs of rainbow, brown, and brook trout eaten were waste eggs not buried in the redd, and that the effect of egg predators on reproduction was negligible. Hobbs (1937) thought that the number of eggs eaten from the redds of rainbow and brown trout and quinnat salmon was very small. The spawning trout themselves are important predators but they could scarcely be accused of eating all their own spawn.

It seems likely that predation would have no more effect on the eggs of lake trout than it has on those of other trout. If the lake trout can spawn on the type of bottom they seem to prefer, the eggs and alevins are certainly well protected until they emerge from the rubble. It was necessary to dig deep into the rubble in the Otsego Lake spawning area to capture either eggs or alevins.

Additional evidence is provided by the lack of any lake-trout alevins in the stomachs of the following fish captured in the immediate vicinity of the lake-trout spawning area between April 27 and June 2, 1941:

- 6 whitefish (*Coregonus clupeaformis*)
- 1 adult lake trout (*Salvelinus* [=*Cristivomer*] *namaycush*)
- 11 shiners (*Notropis hudsonius*)
- 1 blunt-nosed minnow (*Hyborhynchus notatus*)
- 1 chain pickerel (*Esox niger*)
- 17 yellow perch (*Perca flavescens*)
- 22 johnny darters (*Boleosoma nigrum olmstedi*)
- 1 smallmouth bass (*Micropterus d. dolomieu*)
- 4 common sunfish (*Lepomis gibbosus*)
- 13 rock bass (*Ambloplites rupestris*)
- 11 slimy muddlers (*Cottus cognatus*)

These fish were all captured during the presumably vulnerable time the alevins were absorbing the yolk sac and leaving the spawning bed. Such negative evidence is inconclusive but reassuring.

It is important to note that most trout-egg predators have been indicted for their activities during the time the eggs were being laid and not after the eggs were hidden in the gravel. It is concluded that lake-trout eggs and alevins suffer little from predation after the spawning season, and that during spawning the eggs that are eaten are only those left exposed on the bottom.

DEVELOPMENT OF EGGS AND ALEVINS

Greeley (1936) collected eyed eggs and newly hatched alevins on the Otsego Lake spawning area on April 12, and more-advanced alevins on May 9. I took newly eyed eggs on February 17, 1941, and later-eyed stages on March 31, 1941, by chopping holes through the ice. (The lake trout had been observed spawning December 5, 1940.) Later, on April 27, with the surface water temperature 44° F., newly hatched sac fry were taken, and on May 17, 1941, many more-advanced fry were taken (temperature data in fig. 6). All the stages were taken from the rubble on the spawning area.

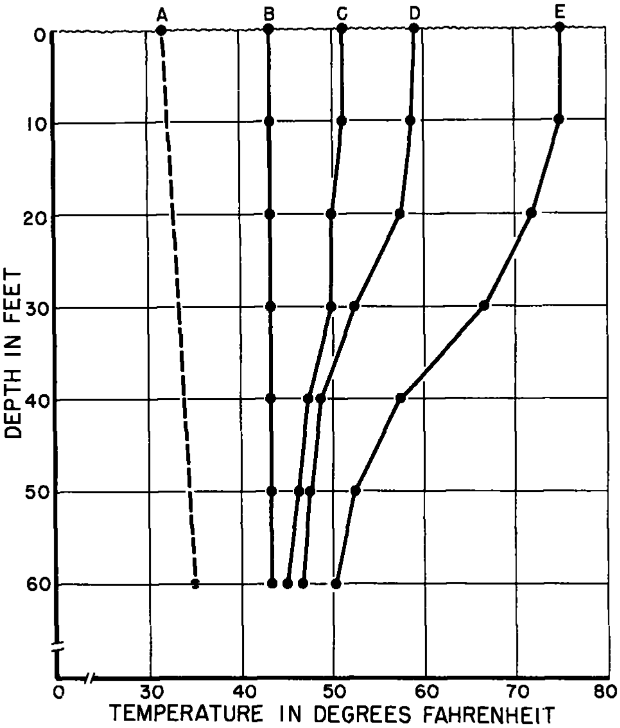

FIGURE 6.—Temperature stratification of Otsego Lake associated with different stages of larval development of lake trout.

(Several hauls of the trawl in the vicinity of the spawning area on April 27 and May 17 produced no fry.) Both eggs and fry were well buried in the stones. The eggs were taken with a Petersen dredge, and only after the surface stones were removed could they be found. The fry were all taken with a trawl fitted with a heavy weight in front which turned over the stones. On June 2, 1941, 18 tows of the trawl over the spawning area and in the vicinity down to depth of 60 feet failed to produce any young lake trout. They had definitely moved from the spawning area and the habitat of the earliest feeding stages was still unknown.

Comparison of the development of wild fry which were captured and of those grown in a hatchery indicates that the time of hatching in Otsego Lake in 1941 was about April 15, and the fry left the shelter of the spawning area May 20 to 25.

In Seneca Lake, where the lake trout spawn during late September and October, a single advanced fry was captured in about 130 feet of water off Peach Orchard Point on April 2, 1940. This fry was considerably more advanced than a hatchery fry 2 months old. This would place the time of hatching in late January and indicate an incubation period of approximately 4 months.

Consideration of the type of bottom and the kinds of invertebrate inhabitants (table 6) of the lake-trout spawning area in Otsego Lake emphasizes the striking resemblance of this area to a typical trout-stream environment. Clean gravel and rubble bottom inhabited by stonefly and mayfly nymphs and caddis larvae ordinarily would be associated with a stream instead of a lake. Certainly it seems that lake-trout fry and fingerlings would fare best under conditions similar to those selected by the young of other trout.

This trout-stream-like environment in Otsego Lake gave me high hopes of capturing the early fingerling stages in the vicinity. But all efforts, including those with minnow traps, trawl, and shore seine, were unsuccessful. No helpful clues were found in the literature, for lake-trout fingerlings have been reported only from shoal water and small tributaries. Kendall and Goldsborough (1908) captured several lake trout, 1.87 to 2.37 inches long, in small spring tributaries of First Connecticut Lake on July 16 and 18 and August 10. Neave and Bajkov (1929) reported taking 10 lake trout, 32 to 45 mm. long, with a hand net in a small inlet creek at Pyramid Lake, Nev. Miller and Kennedy (1948) noted that fry, and 1-, 2-, and 3-year-old lake trout were found in shallow water along a bouldery shoreline of Great Bear Lake, Mackenzie, Canada. Lake-trout fingerlings are not found in such habitats in the summer in New York. The biological survey of the New York State Conservation Department captured none in extensive seining of the shores of the Adirondack lakes and streams, many of which were adjacent to lake-trout waters. There seems to be little doubt that in New York they live in the deeper waters of the lakes in the summer and probably seek rocky bottom.

JUVENILE LAKE TROUT OF KEUKA LAKE

Intermittently from April 18 to September 16, 1940, effort was made to capture fingerling and juvenile stages of lake trout in Keuka Lake. Their capture was attempted with gill nets, trawls, set lines, and minnow traps. A number of 100-foot sections of gill nets of ⅝-inch to 1½-inch bars were set for an aggregate of 67 nights at depths of

10 to 130 feet. Fifty-nine tows of a trawl were made over a similar range of depths. A set line equipped with 80 No. 7 hooks was set for 4 days covering depths from 15 to 40 feet. Minnow traps were set for 8 days at depths from 40 to 80 feet.

Included in the catch were 41 lake trout (all caught in gill nets) of which 13 were more than 15 inches in total length—the minimum legal size in New York. The stomach content of the 13 legal-sized trout, and of 11 others of legal size gathered from anglers, was 100 percent alewives (*Pomolobus pseudoharengus*) or unidentifiable fish, probably of the same species (anglers report finding practically nothing but alewives in lake-trout stomachs).

The lengths and stomach contents of the sublegal specimens are listed in table 7. Of the 16 specimens between 10 and 15 inches in length, only one had eaten arthropods, while the principal food of those between 6 and 10 inches was arthropods, mostly *Mysis relicta*.

TABLE 7.—*Food of lake trout less than 15 inches long from Keuka Lake, 1940*

Total length (inches)	Date of capture	Stomach contents
14⅞	May 11	Empty.
14¼	do	Unidentifiable fish remains.
14	do	3 *Pomolobus pseudoharengus*; 2 unidentifiable fish.
13¾	do	2 *Pomolobus pseudoharengus*.
13	do	4 *Cottus cognatus*.
12⅞	do	Unidentifiable fish remains.
12½	June 29	Do.
12⅛	May 11	Do.
11¼	June 29	Do.
11¼	May 24	Do.
11⅛	do	Do.
10⅞	May 11	Do.
10¾	do	Empty.
10⅝	do	Unidentifiable fish remains.
10⅝	Sept. 11	1 mayfly nymph (Ephemerinae); 1 unidentifiable fish.
10¼	May 25	5 *Pomolobus pseudoharengus*.
9⅞	Sept. 13–16	1 *Pungitius pungitius*; 23 *Mysis relicta*.
9⅝	May 24	Unidentifiable fish remains.
9½	Sept. 13–16	1 *Pungitius pungitius*; 1 unidentifiable fish.
7⅞	do	1 *Cottus cognatus*; 9 *Mysis relicta*.
7⅞	do	12 *Mysis relicta*.
7½	do	16 *Mysis relicta*.
7½	do	34 *Mysis relicta*.
7⅛	do	25 *Mysis relicta*.
6⅞	do	10 *Mysis relicta*.
6¾	do	20 *Mysis relicta*.
6¾	do	19 *Mysis relicta*.
6½	do	28 *Mysis relicta*.

SUMMARY: Of lake trout 10 to 15 inches in total length, 14 stomachs contained fish remains and 1 stomach contained arthropod remains. Of lake trout 6 to 10 inches in total length, 4 stomachs contained fish remains and 10 stomachs contained arthropod remains.

In most cases capture of the lake trout was very erratic. The 10 small specimens taken May 11 were found in the same place at very nearly the same depth of 100 feet. Nets set there on following nights caught nothing. The other small specimens taken during May and June and all the larger lake trout were caught, one or two at a time, in different places but almost entirely at depths of 80 to 120 feet.

Some consistency was found, however, in the capture of the young lake trout caught September 11 to 16, 1940. These were taken, two or three a night, in ⅝- to ¾-inch bar gill nets set in one restricted location off the southern tip of Bluff Point, a very rocky, steep underwater slope, between depths of 40 and 70 feet. Nets of the same mesh set at the same depths in the vicinity on mixed mud and rubble bottom failed to catch any trout. As large lake trout were taken in larger-mesh nets in the same area, it seems that the juveniles must have been relying on the shelter of the rocks for protection from their voracious elders.

Scale examination indicated that these 6½- to 10-inch trout were yearlings and 2-year-olds. Since the lake trout of Keuka Lake spawn in late November and probably hatch in late April (see p. 64, table 5), a rate of growth comparable to hatchery growth would allow them to reach only 2 or 3 inches by the first September. Possibly these fingerling fish could be found in the same location as the yearlings were found. Lack of time and equipment prevented any further effort in this direction but it is a good stage at which to resume the search in the future.

SUMMARY

Lake trout were observed during their spawning season in 1939, 1940, and 1941 in several lakes in New York State, and actual spawning was seen in Otsego Lake, N. Y. Extensive data on spawn-taking operations were obtained from the New York State Conservation Department, and existing literature on the subject was reviewed.

It was found that, except for a striking color change in the males while on the spawning area, lake trout lack sexual dimorphism. They mature in about their sixth year at lengths varying from 15 to 30 inches in the different lakes.

Spawning occurs once each year, during the autumn. The date varies from late September to early December depending on the race of trout, the amount of sunlight, the autumnal drop in temperature, and the depth of the lake.

In the deep water of Seneca Lake, one race spawned early. In all other lakes studied, the lake trout spawned in shallow water and usually later. Increased cloudiness in July, August, and September, and low temperatures in September, advanced the date of spawning in Raquette Lake. Shallower lakes had earlier spawning dates. At the time of spawning, water temperature varied from 58° to 37° F., but in Raquette and Otsego Lakes it was observed that spawning times approximated the turn-over times of the lakes. Generally, the spawning period was about 20 days, but it varied from 10 to 40 days and was fairly consistent from year to year in any one lake.

Spawning, whether in shallow or deep water, took place on gravel or rubble bottom that had crevices into which the eggs could roll. No nest or redd was built. No evidence of spring water was observed near any spawning area.

In the spawning act, which usually occurred during the evening, from 2 to 10 lake trout participated. Each attempt at spawning lasted only a few seconds; the act was repeated many times.

Approximately 1 month after spawning, a sample of eggs recovered from the crevices in the rocks of Otsego Lake was found to be 79 percent alive. No measurement of the effects of predation on eggs was possible, but it was estimated that only eggs that failed to roll into crevices between the stones could be eaten by predators.

In Otsego Lake in 1941 the eggs hatched about April 15 and the fry left the spawning area about May 22. In the deep water of Seneca Lake where the lake trout had spawned in early October a single advanced fry was taken April 2, 1940. Its development indicated that hatching occurred in late January.

Extensive operation of a small beam trawl, set lines, and minnow traps in Otsego, Keuka, and Seneca Lakes failed to produce any lake trout between advanced fry stage and a length of about 6 inches. Twelve specimens between 6 and 10 inches long that were captured in gill nets in Keuka Lake were found to be 1- and 2-year-olds and to be feeding mostly on *Mysis relicta*.

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