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BEHAVIOR OF AGE-0 AND AGE-I LAKE TROUT UNDER LABORATORY CONDITIONS [1]

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Abstract

Habitat preferences and early migration of young lake trout (Salvelinus namaycush), as well as methods of catching them are not clearly understood. Such information is necessary to assess natural reproduction quickly and efficiently. My experiments with hatchery-reared trout at Marquette Hatchery add to the knowledge of habitat preferences, early migration and sampling methods.

Observations of substrate selection and spatial distribution of 546 late sac fry, 16 feeding fry and 6-10 trout (age-0, 60-90 mm TL) were made at different times in an indoor tank. The tank was 3.3 m long, 1.5 m wide and 0.4 m deep and had a bottom type of sand, gravel, or rubble. Zooplankton provided a limited supply of food for fry, but no food was provided for the larger trout. Early migration was assessed by placing eggs (that were about to hatch) or feeding fry (29-48 mm TL) in central compartments (20-36 cm deep) of four raceways, and observing subsequent migration to adjacent shallower (4-19 cm) or deeper (37-51 cm) areas. The efficiency of Mason jars (1.1 liter) with inverted funnels and plastic minnow traps (5-mm mesh, 45 cm long, 15-22 cm diameter, with inverted funnels at both ends) as sampling tools was tested in a tank (described above) containing 13 feeding fry (45-90 mm TL). Another efficiency test of minnow traps was conducted in an outdoor hatchery pond (26 m long, 4 m wide, and 0.6 m deep) during January-April. Six groups of age-I lake trout (60-110 mm TL) were placed in the pond at various times during the experiment.

My observations showed that sac fry, feeding fry, and older age-0 trout were benthic in nature. Sac fry and feeding fry did not demonstrate a bottom type preference when given a choice of sand, gravel and rubble although older age-0 trout evidenced a preference for rubble bottom. Sac fry dispersed gradually at random from the location where they had been placed as ready-to-hatch eggs. Dispersal occurred from hatching to about 2 weeks after swim-up, a 12-week period. Within this period, fry showed no preference for deep or shallow water but older fry that had been feeding for a month or so showed a preference for deep water. Minnow traps showed promise as a method of catching small lake trout.

[1] Contribution from Dingell-Johnson Projects F-31-R and F-35-R, Michigan.

Introduction

Millions of lake trout (Salvelinus namaycush) have been stocked in Lake Superior since 1958 and in Lake Michigan since 1965 (Great Lakes Fishery Commission 1974). Although these trout survive well to maturity, their reproduction (as well as that of a remnant stock of wild trout in Lake Superior) has been disappointingly low and hard to detect, at least until the progeny reach a relatively large size. Thus, there is a time lag of several years before reproduction from a given year can be assessed. Reproduction could be assessed much quicker if the habitat preference and migration of small trout were more clearly understood and if good sampling techniques were available for small trout. In this report, I describe my observations at Marquette Hatchery on bottom type and spatial preference of fry and older age-0 trout, movement of sac fry and feeding fry in relation to depth, and catchability of age-0 and age-I lake trout in stationary traps.

There are some data available on habitat of age-0 trout. Pycha (personal communication) reported catching age-0 lake trout in trawlable areas within 3 km of spawning areas. These were caught in August, usually in 21-30 m of water where temperatures were 10-12 C. Eschmeyer (1956) caught 338 age-0 trout in Lake Superior during June-October, by trawling for 10 hours on smooth bottom in 18-73 m of water where temperatures were 6-17 C. Age-0 trout appeared to be at greater depths as the season progressed. Miller and Kennedy (1948) collected 14 age-0 lake trout and observed many others along the rocky shores of bays in water only a few inches deep. According to DeRoche (1969), "Young lake trout leave the spawning beds soon after absorption of the yolk sac. Skin divers observed lake trout fry darting about the larger boulders near spawning beds until May 4 (water temperature, 46° F). No trout were seen in shallow water after this date, when water temperatures neared 50° F. Late in May young-of-the-year lake trout were taken by otter trawl in water 60 to 100 feet deep (Rupp and DeRoche, 1960). These data indicate that young lake trout move rapidly into deep water early in May; no long residence at intermediate depths is apparent." Martin (1957) made observations with scuba equipment on lake trout spawning beds in 0.8- to 3.7-m depths, which indicated that fry had left the spawning bed before mid-May. Royce (1951) believed that fry deserted the spawning beds in lakes in New York state during May 20-25.

The information on habitat of age-I lake trout is scant. Martin (1952) studied lake trout in inland lakes in Ontario. From his and other work (which he cites), one would expect to find yearling lake trout on steep and rocky underwater slopes. Age-I, hatchery-reared lake trout are commonly caught on smooth bottoms with trawls in Lake Michigan (Mercer Patriarche personal communication), but rough bottom could not be sampled with a trawl.

Methods and results

<u>Substrate selection and spatial distribution</u>.--These observations were conducted in an inside hatchery tank during September 1973-June 1974. The tank was 3.3 m long, 1.5 m wide, and 0.4 m deep. Fifteen plastic dishpans (45 cm long, 35 cm wide, and 15 cm deep) were set in a false floor of the tank so their edges were flush with the floor. Equal numbers of pans were filled with sand, gravel, or rubble, according to a randomly selected pattern. Fluorescent light, of the type used to stimulate plant growth (four 40-watt gro-lux bulbs), was used for illumination. The tank was illuminated between 8:00 a.m. and 5:00 p.m., Monday through Friday, during September-November and continuously thereafter for the balance of the experiments. The flow of water through the tank was about 1 liter per minute. Water temperatures ranged from 10 to 16 C and oxygen levels were near saturation.

In December 1973, the contents of five overnight sets of a plankton net in Cherry Creek (the water source for the hatchery) were emptied into the experimental tank to provide the initial source of the food supply for young trout. A brief examination of the plankton net catch revealed diatoms, Elodea, mayflies, paramecia, filamentous algae and chironomids. Beginning in December, growth of food organisms was enhanced by periodic application of an inorganic fertilizer and tortula yeast. By the middle of January, the tank was heavily scummed over with filamentous algae and moderate growths of algae were present on the bottom and sides. Abundance of algae remained about the same for the duration of the experiment. In late June, the algae was composed of Fragilaria, Anabaena, Mougeotia, and Ulothrix. In January 1974, copepods and paramecia were fairly abundant and some cladocerans were present. By early summer, cladocerans were abundant (at least two species), copepods were common and tendipedids were rare.

To observe substrate preference, age-0 hatchery-reared lake trout (about 60-90 mm, TL) were placed in the experimental hatchery tank at intervals in September and November 1973 (Table 1). After a few days of acclimation, the location of each trout was recorded at randomly selected times between 8:00 a.m. and 5:00 p.m. on weekdays. Predators were used when age-0 lake trout failed to make a choice of substrate. "Naive" trout were used in trials A, B, and D; those in C and E were the same trout as in B and D, respectively. The trout were not fed and little natural food was present in the tank. Each trial was terminated when it became apparent that starvation was affecting trout behavior. In trial A, lake trout were usually seen within 75-100 mm of the tank bottom and were generally stationary. There was a tendency for them to remain at the same location during a day. They most likely moved at night because the location where they were seen was frequently different from day to day. The trout apparently preferred rubble bottom because about two-thirds of the trout were observed over rubble or were concealed there (Table 1). In trial B, the lake trout first behaved as did those in trial A, but, after 2 days, they became restless and swam at random--sometimes well off the bottom. When trial C began with the introduction of a larger lake trout, most young lake trout soon concealed themselves in the rubble. Essentially, the same behavior occurred in trials D and E as in B and C.

To assess spatial distribution of newly hatched trout, 546 fry in the late sac fry stage were introduced into the tank on March 4, 1974. General observations of sac fry location were made during March 4 to April 24 when

Table 1.--Percentages of age-0 lake trout observed over different types of substrate in a hatchery tank, September-November 1973.

Item	Trial A	Trial B	Trial C	Trial D	Trial E
Initial number of trout	6	10	10[a]	6	6[b]
Duration of trial (days)	7	7	11	7	10
Number of observation periods	14	42	67	40	19
Percentage observed					
Over sand	6	5	1	0	1
Over gravel	20	16	3	1	0
Over rubble	48	35	13	6	0
Over floor[c]	6	5	0	0	0
Swimming[d]	0	36	11	86	0
Percentage not seen[e]	20	3	72	7	99

[a] One 33-cm lake trout present; seven age-0 trout remained at the end of the trial.

[b] One 33-cm lake trout present; three age-0 trout remained at the end of the trial.

[c] The board floor of the tank that separated the various types of substrate.

[d] Could not be associated with a particular substrate.

[e] These must have been in the rubble substrate because they could not have been concealed anywhere else.

sac fry were numerous. In May and June, horizontal and vertical distribution of fry was observed. It was difficult to see fry in the middle of the tank because of the heavy algal cover. The sac fry introduced into the tank on March 4 were largely benthic for the first few days after introduction although a few were pelagic. No substrate preference was noted. For the remainder of the time to button-up (about March 27), some fry became pelagic while others remained on the bottom. Again there was no apparent habitat preference although many could have been hidden in the gravel and rubble substrate. From button-up and the start of feeding to April 24, most were seen near the bottom although a few were pelagic.

During May and June 1974, there were at least 16 feeding fry present (average length in July was 45 mm). There may have been others that were hidden. Most fry (70%) were observed on or near the bottom, a few (15%) were near the top, and a few (15%) were in between (Table 2). Most fry observed on or near the bottom were seen on the board floor around the edge of the tank either motionless or swimming slowly. They did not show a preference for a rubble bottom. Fry were either alone or grouped in loose schools of two to four fish. Not infrequently fry were observed at the tank wall, nearly motionless with the head up or slowly swimming upward. The corners and ends of the tank were the favored locations. Two-thirds of the fish observed were seen in the corners and ends which comprised about 40% of the bottom area.

Movement of sac fry and feeding fry.--Four plywood raceways, each 0.4 m wide and 3.0 m long were used in these tests. Each raceway was divided into three compartments separated by two-way fish traps to assess migration from the center section of intermediate depth (20-36 cm) to and from the adjacent shallow (4-19 cm) and deep (37-51 cm) sections. Five centimeters of gravel was placed on the bottom to simulate a natural substrate. Light was excluded by a styrofoam cover to eliminate it as a cause of migration. Water currents were absent except for slight vertical currents created by a small aerator in each compartment. Water temperatures were 4-6 C in February and March, 6-8 C in April, and 7-11 C in May, while oxygen levels were usually near saturation. The fry were not fed.

Table 2.--Percentages of lake trout fry seen at different distances from the bottom of a tank, Marquette Hatchery, 1974. About 16 fish were present.

Inclusive dates	Number of counts each period	8:00 a.m. - 12:00 p.m. Distance (cm)			1:00 p.m. - 5:00 p.m. Distance (cm)		
		0-13	14-27	28-40	0-13	14-27	28-40
May 1-10	8	82	9	9	89	7	4
May 11-20	5	79	0	21	56	18	26
May 21-31	8	61	21	18	68	14	18
June 1-10	6	61	10	29	71	19	10
June 17-20	4	65	26	9	65	30	5
June 21-28	6	74	14	12	72	14	14
Average percentage		70	13	17	70	17	13

Part I of this experiment was designed to determine the time at which fry leave the spawning substrate and their subsequent dispersal as related to depth. On February 22, 1975, 100 eggs from hatchery stock that were ready to hatch were placed in the gravel of each center compartment. The eggs hatched during February 22-26, the yolk sac was about 50% absorbed by April 7 and completely so by May 2. Movement of the fry from and to the center compartment was monitored by the two-way fry traps that separated the compartments. The traps were examined three times weekly and the fry were released in the direction of migration. The experiment terminated on May 19 with the removal of the fry which had begun to die. Prior to this time, an undetermined number of fry (estimated as about 50%) died in the yolk-sac stage in the center compartments.

Fry migrated from the simulated spawning substrate (intermediate depth) at all stages of development after hatching during the 12 weeks of study but an "en masse" movement did not occur. Of the total fry (140) that migrated out of the simulated spawning substrate, 26% migrated in week 1 after hatching, 24% in weeks 2-6 (yolk sac about 50% absorbed at 6 weeks), 36% in weeks 7-10, and 14% in weeks 11-12 (yolk sac completely absorbed). There was no evidence that sac fry migration was oriented to deeper water (Table 3). Migration of sac fry from the intermediate depth to shallower or deeper water was at random in raceways 1, 2, and 3. The numbers did not differ significantly from a 50-50 ratio (binomial tests). In raceway 4, however, significantly more migrated to the shallower depth. Usually larger numbers returned to the intermediate depth from the shallower sections than from the deeper sections, but this was not significantly different from a 50-50 ratio, except for raceway 1.

In part II of this experiment, advanced, semi-wild, feeding fry (29-48 mm) were placed in the compartments of intermediate depth to observe their direction of migration. These fry originated from hatchery eggs but had been reared in a hatchery tank containing microcrustaceans which served as food. Twenty-three trout were introduced into each raceway and observed as in part I during May 21-June 6, 1975 (water temperature was 9-11 C). Feeding fry tended to migrate toward deeper

Table 3.--Migration of lake trout fry from areas of intermediate depth to and from shallower or deeper depths, Marquette Hatchery, February - June 1975.

Development stage and raceway	Number caught migrating from and to the intermediate depth			
	Intermediate to shallow	Shallow to intermediate	Intermediate to deep	Deep to intermediate
Sac fry [a]				
1	16	13	11	3
2	10	9	19	10
3	9	6	17	3
4	38	25	20	16
Total	73	53	67	32
Feeding fry [b]				
1	2	0	11	6
2	4	1	17	6
3	3	0	9	0
4	7	2	11	1
Total	16	3	48	13

[a] One hundred about to hatch were introduced on February 22 into the intermediate depth of each raceway and migration was observed for 12 weeks thereafter.

[b] Twenty-three semi-wild feeding fry were introduced into the intermediate depth of each raceway on May 21 and migration was observed for 2 weeks thereafter.

water (Table 3). In each raceway more migrated to the deeper water than did to the shallower water and in raceways 1 and 2 this was significantly different from a 50-50 ratio. Although some returned to the intermediate depth, there were still 2.7 times more fry in the deep end than in the shallow end at the conclusion of the experiment (14% in the shallow depth, 48% in the intermediate depth, and 38% in the deep depth).

Catchability of young lake trout in stationary traps.--Three tests were made at the hatchery to determine if age-0 and age-I lake trout could be caught by stationary traps. In the first test, four 1.1-liter Mason jars with inverted screen cones were used in a hatchery tank (1.5 × 3.3 × 0.4 m deep) containing 13 age-0 trout (average, 45 mm TL). The trout had been living in the tanks since March 1974 when they had been introduced as yolk-sac fry. A heavy growth of algae in the tank (encouraged by constant light, fertilizer, and tortula yeast) supported a population of microcrustaceans that served as food for the trout. Two clear and two opaque Mason jars were "fished" in the tank for 17 days in June and July 1974. The two clear jars caught five trout the opaque traps caught none.

The second test took place in the hatchery tank in December 1974 under conditions described for the first test, except that the 13 trout (see previous paragraph) were somewhat bigger (60-90 mm TL). Four plastic minnow traps made of plastic mesh (5 mm) were tested. These were 45 cm long, 22 cm in diameter in the middle, 15 cm in diameter at the end, and had funnels at both ends. The four plastic minnow traps caught 9 lake trout within 24 hours and the remaining 4 within 96 hours.

The third test was conducted in an outdoor hatchery pond (4 m wide, 26 m long, and 0.6 m deep) from January 8 to April 14, 1975, with six of the plastic minnows traps. There was little current in the pond, but enough to prevent formation of heavy ice cover. Water temperature was 1-8 C and ice cover was intermittent. Positioning and modifications of the traps were as follows: during January 8-22, they were positioned singly; on January 23, half were covered with black opaque plastic; and on March 5, the traps were repositioned in pairs (one covered and one uncovered). Six groups (each with an identifying mark) of age-I lake trout were introduced into the pond at various times. Traps were examined one to three times a week and captured trout were removed from the pond. The traps proved to be efficient since they caught 55-84% of the various groups of trout introduced into the pond (Table 4). Most trout were caught within a month after introduction. The efficiency of the traps probably was increased because they provided the only fish cover in the pond. Frequently, trout were hiding under the traps when they were lifted. During the time that traps were paired, the catch of the three pairs was 14 and 14, 9 and 5, and 1 and 2 in the covered and uncovered traps, respectively. A paired $\underline{t}$-test ($\underline{t}$ = 0.38) could detect no difference in catch between covered and uncovered traps at the 95% level.

Discussion

My laboratory observations indicated that sac fry dispersed gradually and at random from the location where they had been placed as ready-to-hatch eggs. Dispersal occurred from hatching to about 2 weeks after swim-up, a 12-week period. Within this period, fry showed no preference for deep or shallow water but fry that had been feeding for a month or so showed a preference for deep water. My observations also showed that sac fry, feeding fry, and older age-0 trout were benthic in nature. Sac fry and feeding fry did not demonstrate a bottom type preference when given a choice of sand, gravel, and rubble although older age-0 trout evidenced a preference for rubble bottom.

My observations that fry dispersed gradually after hatching is contrary to the findings of DeRoche (1969) who indicated that "young lake trout leave the spawning beds soon after absorption of the yolk sac." My findings, however, are supported by my observations of considerable movement of sac fry in production hatcheries and of escapement of sac fry from enclosures in the Great Lakes. DeRoche (1969) also concluded that young lake trout move rapidly into deep water. However, my data suggest that movement to deep water may not be immediate because of the random dispersal of sac fry from the hatching site.

Some tentative conclusions about areas and relative times to sample for age-0 lake trout in the Great Lakes can be drawn from the

Table 4.--Number of age-I lake trout (60-110 mm TL) caught in six plastic minnow traps in a hatchery pond, January-April 1975.

Period caught	Number of lifts	Test fish origin, date introduced, and number				
		Semi-wild[a]	Hatchery			
		Jan. 7 (11)	Jan. 7 (25)	Feb. 10 (25)	Mar. 5 (25)	Mar. 27 (25)
Jan. 8-15	6	2	4			
Jan. 16-31	5	0	5			
Feb. 1-15	4	0	1	10		
Feb. 16-28	2	1	1	5		
Mar. 1-15	4	2	2	0	13	
Mar. 16-31	4	1	0	3	7	5
Apr. 1-15	4	0	3	1	1	9
Total number	29	6	16	19	21	14
Percentage caught		55	64	76	84	56

[a] Trout of hatchery origin reared on natural food (zooplankton) since beginning of feeding in a hatchery tank containing a sand, gravel and rubble substrate and a heavy growth of filamentous algae.

above observations. From hatching to about 2 weeks after swim-up, fry should be sought on the lake bottom in areas of egg deposition and the vicinity, irregardless of bottom type. After fry have fed and reached lengths of 29-48 mm, deeper areas near spawning sites should be searched in preference to shallow areas. Sampling for fry in spawning areas and vicinity should be productive for at least several weeks (dependent on rate of development) because of the gradual rate of dispersion.

Minnow traps caught age-I lake trout at a rate of 0.2 fish per trap-day in a hatchery pond. In the Great Lakes, minnow traps should be tested further in areas and at times described above.

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