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Use of a Remotely Operated Vehicle to Study Habitat and Population Density of Juvenile Lake Trout

C. L. DAVIS, L. M. CARL, AND D. O. EVANS

Ontario Ministry of Natural Resources, Aquatic Ecosystems Science Section
Research, Development and Transfer Branch
Post Office Box 7000, Peterborough, Ontario K9J 8M5, Canada

Abstract.—We determined the feasibility of using a remotely operated vehicle (ROV) to observe juvenile lake trout *Salvelinus namaycush*. The ROV was equipped with a high-resolution, low-light, black-and-white video camera and two halogen headlamps and was tethered by a 152-m umbilical cable. We used the ROV to sample two central Ontario lakes: Source Lake in summer and fall and Lake Opeongo in summer. We surveyed the lake bottom at depths of 2.5–40 m in both lakes during day and night. The ROV traveled slightly above the substrate recording a field of view 1.8 m wide and 0.3–0.5 m high at a distance of 1.8 m in front of the ROV. Overall, 54,594 m^2 of lake bottom were sampled, and 114 juvenile lake trout (<300 mm, total length) were observed. Juvenile lake trout exhibited minimal avoidance of the ROV with some individuals being observed for several minutes (mean, 41.6 s). The observed distribution suggested movement to shallower habitat at night. Mean (±SE) lake trout densities varied between the study lakes for depths of 5–25 m (Opeongo: 5.2 ± 2.0 fish/ha; Source: 25.9 ± 6.5 fish/ha), which was consistent with catch per unit effort in small-mesh gill nets for these lakes (Opeongo: 0.9 ± 0.1 fish/net-night; Source: 5.8 ± 0.4 fish/net-night). The ROV allowed nonlethal sampling and direct estimation of fish density, thereby offering a good alternative to conventional netting techniques.

Juvenile lake trout *Salvelinus namaycush* inhabit the cool, deep waters of oligotrophic lakes during periods of summer stratification in the southern part of their range (Martin and Olver 1980). Knowledge of the early life history of lake trout, especially from young of the year to the age of 3–4 years, however, is limited to a few observations (Martin and Olver 1980). Conventional sampling techniques, such as gillnetting, trapping, and trawling, have provided general information on distribution and abundance of juvenile lake trout in many lakes (Odell 1932; Rawson 1961; Elrod and Schneider 1987). These sampling gears cannot provide precise information about habitats or fish behavior, however, and are usually lethal to small fish. In addition, these techniques often fail because of structural features of the habitat that interfere with operation of the gear.

The remotely operated vehicle (ROV) is nonlethal to fish and causes minimal damage to fish habitat. This is particularly important for sensitive species, such as lake trout, that have low recruitment rates (Evans and Willox 1991). Our objectives were (1) to describe the response of juvenile lake trout to the ROV and (2) to compare estimates of juvenile lake trout density from the ROV survey with the relative density measures from a small-mesh gill-net survey that was conducted concurrently.

Methods

Study lakes.—The study was carried out on two pre-Cambrian-Shield lakes, Source Lake and Lake Opeongo, located in Algonquin Park, Ontario, Canada. Source Lake is 266 ha in area with a maximum depth of 41 m. The east arm of Lake Opeongo, has a surface area of 1,772 ha and a maximum depth of 40 m. The adult lake trout population in Source Lake is primarily planktivorous (Martin 1966), whereas the Opeongo population is mainly piscivorous (Martin 1970). Source Lake was sampled June 23–July 7, 1993, and again October 5–7, 1993. Lake Opeongo was sampled July 13–18, 1993.

Remotely operated vehicle.—The ROV (Hydrobot model, Hydrobotics, Inc., Ajax, Ontario) measured 1.1 m long by 0.6 m wide by 0.5 m high. It was equipped with a low-light-sensitive (to 0.02 lx), black-and-white video camera (capable of 600 horizontal lines of resolution), on screen depth readout, and adjustable-intensity halogen headlamps.

The ROV was deployed from an anchored boat, and transect sampling was done from the point of anchor. The anchor sites were selected so that a variety of habitats and depths were within the range of the ROV umbilical cable (152 m long). During sampling, the ROV traveled along the lake bottom in a direction generally parallel to the depth contours. Some fish were followed to obtain positive identification and to investigate response behaviors. These fish were abandoned if their course took the pursuing ROV over an area that had been previously sampled during that transect. This could be determined by the silt raised by the ROV as it traveled. Any fish encountered while the ROV was following another fish were included in the transect count.

Sampling effort along strip transects was quantified by timing the video records at the ROV speed used during sampling. A mean (±SE) ROV speed of 0.32 ± 0.01 m/s was determined from three in situ timed transects of 120 m each at depths of 10–18 m and, used to calculate distance sampled. Each sampling transect required 4.8 min of running time, which was equivalent to a distance of approximately 90 m. Transects were classified by the bottom depth and time of day. Depth was stratified into 5-m intervals from 0 to 40 m. Since many fish species change their behavior and distribution from day to night (Emery 1973), time of observation was stratified into three categories: day, 1 h after sunrise to 1 h before sunset; dusk, 1 h before sunset to 1 h after; and night, 1 h after sunset to 1 h before sunrise. Temperature at each lake trout observation was estimated from both the depth at sighting and a midlake temperature profile conducted during each survey.

We calibrated the video camera's field of view in a test tank in the laboratory. The field of view measured 0.4 m wide at 0.4 m in front of the ROV and 1.8 m wide at 1.8 m in front. The distance from which the lake bottom could be effectively illuminated and observed by the camera was approximately 1.8 m, so the width at this distance was used as the strip width. The maximum height above the lake bottom that was within the field of view was 0.3 m when the ROV was sitting on the bottom. Since the ROV travelled about 0–0.2 m above the bottom, the effective height of the field of view was 0.3–0.5 m. In the laboratory, hatchery lake trout of known total length (TL) were placed into the test tank one at a time and observed and recorded by the ROV. These images were then compared with lake trout from the video records to classify lake trout as juvenile (<300 mm, TL) or adults (>300 mm, TL). Based on known age–length relationships and age at maturity for lake trout in these lakes (Evans et al. 1991), lake trout with TL greater than 300 mm could be adults. For this reason, only the data for lake trout less than 300 mm in TL are presented in this paper.

Sampling effort was concentrated at depths where densities of lake trout were highest. A minimum of five transects per depth strata was used for calculation of density and for comparison with gill-net catches. Depth strata with fewer observations were excluded from the analysis. For Lake Opeongo, four depth strata (5–10, 10–15, 15–20, and 20–25 m) were sampled with five or more transects each. The summer and fall surveys in Source Lake were combined to increase sample size to a minimum of five transects for the same four depth intervals used for Lake Opeongo. The overall density estimate for each lake was the mean of the density estimates for the four depth strata, weighted by surface area of the strata. Density data were pooled across the three surveys to examine possible diurnal shifts in depth distribution.

Gillnetting.—Small-mesh gillnetting was conducted in Lake Opeongo on July 10–11 and in Source Lake on August 5–6, 1993. Each lake received 12 bottom gill-net sets. Each net consisted of three panels of mesh: 19, 25, and 38 mm stretched measure. Each panel measured 15.2 m long and 2.4 m high. The mesh size of the middle panel was randomly assigned. Grid squares (100 m per side) were drawn and consecutively numbered on a depth contour map of each lake. Three gill-net sites were randomly chosen within each of three depth strata (10–20, 20–30, >30 m). The three additional sets were assigned in proportion to the area of each stratum. Dissolved oxygen and water temperature were measured at each site before the nets were set. Any site in which oxygen was less than 4 mg/L was rejected because lake trout are known to require at least this concentration for normal activity (Evans et al. 1991). Nets were set between 1700 and 1940 hours and retrieved between 0931 and 1200 hours and fished for an average (SD) of 16.0 (1.1) h. The position of each juvenile above the lead line was recorded to determine the fish's distance above the lake bottom at the time of capture. Catch per unit effort (CUE) in the two lakes was calculated as a strata-area-weighted mean.

Results

ROV Observations

In total, 337 transects or 54,594 m^2 of lake bottom were sampled in the two lakes. We observed 350 fish, 300 of which could be definitively identified. Lake trout accounted for 119 of the observations, all but five of which were estimated to be less than 300 mm, TL. We also observed white suckers *Catostomus commersoni* (24) and yellow perch *Perca flavescens* (75) in both lakes, and from only Lake Opeongo, we saw sculpins *Cottus* spp. (74), smallmouth bass *Micropterus dolomieu* (3), burbot *Lota lota* (2), and coregonines *Coregonus* spp. or round whitefish *Prosopium cylindraceum* (3).

TABLE 1.—Density estimates (mean ± SE) of juvenile lake trout in Source and Opeongo (East Arm) lakes, Ontario, determined by remotely operated vehicle. Densities were determined by using a transect length of 90 m and a 1.8-m strip width. Source Lake was sampled both summer and fall, and the data were pooled for the four depth strata shown. Opeongo densities were based on summer sampling of the same four depth strata. Combined mean count per transect and density estimates are weighted by the area of the strata.

Depth strata (m)	Area of strata (ha)	Number of transects	Number of lake trout observed	Mean count per transect	Density (fish/ha)	Estimated number of lake trout
			Source Lake			
5–10	59.7	7	1	0.14 ± 0.14	8.8 ± 8.8	526 ± 526
10–15	31.0	17	13	0.76 ± 0.28	47.2 ± 17.2	1,463 ± 533
15–20	14.6	39	34	0.87 ± 0.22	53.8 ± 13.5	786 ± 197
20–25	13.5	39	14	0.36 ± 0.11	22.2 ± 6.5	299 ± 89
Combined	118.8	102	62	0.42 ± 0.11	25.9 ± 6.5	3,074 ± 776
			Opeongo Lake			
5–10	271.4	9	0	0	0	0
10–15	301.9	35	0	0	0	0
15–20	261.2	28	5	0.18 ± 0.07	11.0 ± 4.5	2,879 ± 1,175
20–25	204.0	10	2	0.20 ± 0.13	12.4 ± 8.2	2,518 ± 1,673
Combined	1,038.5	82	7	0.08 ± 0.03	5.2 ± 2.0	5,403 ± 2,056

More than 80% of our transects had no fish sightings and another 15% had only one sighting. A maximum of six lake trout were observed on one transect in Source Lake.

Juvenile lake trout were easily observed and showed little distress when approached by the ROV. Most (52%) were stationary and resting on the lake bottom when first observed. Of the remaining juveniles, 45% were swimming slowly along the bottom whereas 3% were swimming away from the ROV at high speed. Often juvenile lake trout were observed or followed for several minutes (mean time of observation for all lake trout, 41.6 s). In general, lake trout avoidance of the ROV increased with fish size. Young of the year (<50 mm, TL) did not move when approached, whereas the largest lake trout were quick to move out of visual range. None of the 114 juvenile lake trout were observed more than 0.3 m above the substrate, even when frightened.

It was also possible to determine when a fish had escaped detection because of the cloud of silt raised as the fish moved away. During the three survey periods, we encountered 71 silt clouds not associated with any observed fish. Assuming each silt cloud was caused by a different fish, this represents 17% of all combined fish and silt observations. This suggests that at least 83% of the fish closely associated with the bottom were observed with 86% (300/350) of these being identified.

Lake trout densities (mean ± SE) at depths of 5–25 m were higher in Source Lake (25.9 ± 6.5 fish/ha) than in Lake Opeongo (5.2 ± 2.0 fish/ha; t_{182} = 2.718, $P < 0.005$; Table 1).

Juvenile lake trout appeared to move to shallower habitat at night. Highest densities were at 15–20 m during the day whereas greatest densities at night were at 5–10 m (Figure 1). For the summer surveys, the temperature ranges corresponding to these strata of maximum densities were 5.4–5.8°C and 10.0–18.0°C for day and night, respectively. For the fall survey, temperatures where greatest densities were observed were 5.4–6.0°C during the day and 10.1–10.7°C at night. These temperature ranges are similar to those inhabited by lake trout in other inland lakes (Rawson 1961; Evans et al. 1991).

Gill-Net Sampling

Most juvenile lake trout were caught within 0.3 m of the gill-net lead line (≤0.3 m 78%; ≤1.2 m, 88%). Relative densities of juvenile lake trout were 0.9 ± 0.1 lake trout/net-night for Lake Opeongo and 5.8 ± 0.4 lake trout/net-night for Source Lake (Table 2). Therefore, the catch ratio for Source Lake to Lake Opeongo for the gill-net samples was 6.4, similar to the ROV-obtained ratio of 5.0.

Discussion

The ROV was effective in sampling along the lake bottom. We were concerned that lake trout suspended higher than about 0.5 m would escape detection, so only a portion of the population would be sampled. However, juvenile lake trout were strongly associated with the lake bottom and exhibited solitary behavior. More than 95% of the lake trout encountered by the ROV were resting

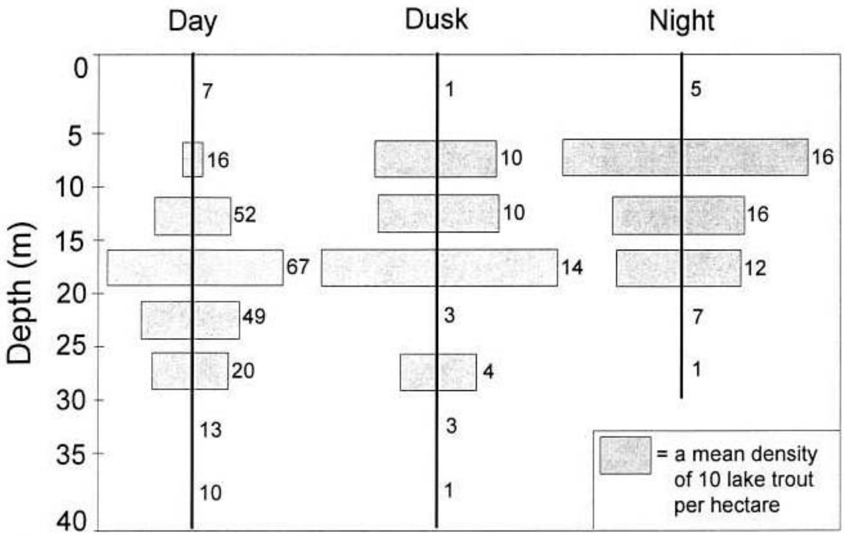

FIGURE 1.—Relative density (fish/ha) of juvenile lake trout at different depths determined by using a remotely operated vehicle in Source and Opeongo lakes, Ontario, during summer and fall 1993. Results are for pooled data from the three surveys. Time of day was divided as follows: day, 1 h after sunrise to 1 h before sunset; dusk, 1 h before sunset to 1 h after; and night, 1 h after sunset to 1 h before sunrise. The solid vertical lines show the depths that were sampled. Numbers of transects at each depth are to the right of the horizontal bars.

on or swimming slowly along the lake bottom when first observed. Also, almost 80% of juveniles collected by gill net were within 0.3 m of the lake bottom. Such benthic distribution has been suggested by trawling surveys (Elrod and Schneider 1987; Bronte et al. 1995).

Another concern was that lake trout may move away from the ROV before being recorded by the video camera. Again, most juvenile lake trout remained stationary or moved slowly when approached by the ROV, rarely exhibiting an avoidance response for the first 10 s of observation. We could approach within 1–2 m and make positive identifications. The low incidence of silt clouds suggested that few lake trout escaped detection. It is likely that some of the silt clouds were made by other species because lake trout made up less than half of our observations and rarely showed a prominent flight response.

TABLE 2.—Relative density (mean ± SE) measures of juvenile lake trout determined by small-mesh gill net in Opeongo (East Arm) and Source lakes, Ontario, during 1993. Relative densities were determined as catch per unit effort (CUE), where a unit of effort was an overnight set (16.0 ± 0.1 h; mean ± SE) of one net consisting of three panels of mesh (19, 25, and 38 mm, stretch measure). Combined mean CUEs for each lake are weighted by the surface area of the strata.

Lake	Depth strata (m)	Area of strata (ha)	Number of net-nights	Mean CUE/ net-night
Source	10–20	45.5	5	6.4 ± 2.1
	20–30	20.3	4	6.0 ± 0.4
	>30	6.2	3	1.0 ± 0.6
	Combined	72.0	12	5.8 ± 0.4
Opeongo	10–20	563.1	6	0.8 ± 0.3
	20–30	384.6	4	1.0 ± 0.4
	>30	174.6	2[a]	1.0 ± 1.0
	Combined	1,122.3	12	0.9 ± 0.1

[a] Only two nets were set in this depth stratum due to logistic constraints.

Both ROV and gill-net sampling indicated greater density of lake trout in Source Lake than in Lake Opeongo with similar relative differences in densities between the lakes. The major advantages of the ROV are that sampling with this device is nondestructive and provides a direct record of each fish and its associated habitat. In our subsequent research we have employed the line transect method (see Buckland et al. 1993), which has improved our density estimation of juvenile lake trout.

The ability of the operator to navigate the ROV increased with time, but we have no measure of operator efficiency. Operator proficiency must be addressed in future assessments of ROV technology for quantitative estimates of fish abundance. Similarly, standardization of ROV speed, distance above the substrate, illumination, visual field, and direction of travel are key factors for quantitative sampling.

We recommend the use of ROV technology for observation of juvenile lake trout. A high percentage of lake trout can be sampled this way, actual density estimates are possible, and detailed descriptions of the habitat can be made while obtaining a video record of everything observed. One of the main reasons that juvenile lake trout are difficult to study is their low density. Because of this, lethal sampling methods have the potential to severely damage small populations. In contrast, ROV sampling is nondestructive, thus allowing the high sampling intensity necessary to detect changes in recruitment or habitat use. In addition, this technology should have application for other species, especially those closely associated with benthic habitats. However, ROV investigation is intensive and relatively high in cost, which tend to limit its use. Our experience suggests that this cost disadvantage is outweighed by the benefits of direct visual observation and nondestructive sampling, in certain cases.

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