

Sonic Tracking of Burbot in Lake Opeongo, Ontario

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Abstract.—The diel movements of seven adult burbot *Lota lota*, 55–67 cm in total length, were seasonally monitored with sonic tags in Lake Opeongo during 1989 and 1991 to determine patterns of activity and habitat use. Burbot were inactive during daylight hours, began moving near dusk, and moved throughout each night until dawn. In the summer, burbot moved more slowly and occupied deeper water than in the spring. Swimming speed appeared to increase in the fall. Burbot occupied the same local areas within seasons and between years. Burbot were sometimes active in 20°C water for extended periods at night but moved to cooler water during the day. Burbot seemed to use an area-restricted searching pattern. None of the burbot were located in water less than 2 m deep.

The burbot *Lota lota* is a benthic predator common in oligotrophic lakes of the northern temperate areas of North America and Eurasia (Scott and Crossman 1973). Little is known of the burbot's movement patterns, habitat requirements, or role in the benthic community. Early telemetric work by Poddubnyi et al. (1971) and Malinin (1972a, 1972b) indicated burbot were fairly sedentary throughout the day and night. However, the transmitters used in these studies lasted less than 4 d, and the behavior reported may have been an artifact of the tagging procedure. Hudd and Lehtonen (1987) tagged nearly 3,000 burbot in the Gulf of Bothnia off the coast of Finland and found that the fish homed after displacement and occasionally migrated more than 20 km. Breeser et al. (1988) noted movements of up to 125 km for radio-tagged burbot in an Alaskan river system. Bergersen et al. (1993) implanted sonic transmitters in eight adult burbot from an impoundment and found that the fish rarely moved in winter and early spring. Edsall et al. (1993) observed that burbot were stationary during daylight hours in Lake Michigan during August.

As part of a study examining the interactions of burbot and a sympatric competitor and predator, the lake trout *Salvelinus namaycush* (Carl 1992), individual burbot implanted with sonic transmitters were followed from spring through fall to determine patterns of activity and habitat use.

Methods

This study was based on seven burbot captured in trap nets in 1988–1989 in the East Arm of Lake Opeongo in southern Ontario (45°42'N, 78°22'W; Figure 1). Each of these fish was measured (cm; total length, TL), weighed (kg), anaesthetized,

tagged with a numbered tube tag, and surgically implanted with a sonic transmitter. Each fish was held for 1–6 d after surgery and then released near its capture site. The sonic tags (Sonotronics Co., Tucson, Arizona) were 60 mm long and 16 mm in diameter, and weighed 8 g in water. A Sonotronics USR-5B receiver was used to locate the tagged fish. The location of a fish was assumed to be fixed when the signal from the hydrophone was strongest immediately below the boat. This method was confirmed by a diver who picked up a sonic tag from a dead fish within 1 m of the hydrophone fix in about 7 m of water. Because the burbot is benthic (Scott and Crossman 1973; Edsall et al. 1993), fish were assumed to be on the bottom when located. The water depth recorded for each location fix was the depth sounder reading at that location. Swimming speed was estimated by dividing the distance between two consecutive fixes by the time interval between those fixes. This estimate of swimming speed was divided by body length to obtain speed in body lengths per unit time.

To examine variation in swimming speed, depth of occurrence, and water temperature at occurrence among fish and between spring, summer (when a firm thermocline was present), and fall, fish were tracked for several 12–24-h periods in each of the three seasons. Because preliminary tracking in 1988 had indicated that burbot moved primarily at night, most tracking was done at night. During each tracking, one fish was located every 20–30 min (mean interval, 25 min) from dusk until dawn. Each time the fish was located at night a numbered float was anchored at the fix location. Compass bearings were taken at each float the following morning and plotted on Universal Transverse Mercator maps. Locations for each fish were also re-

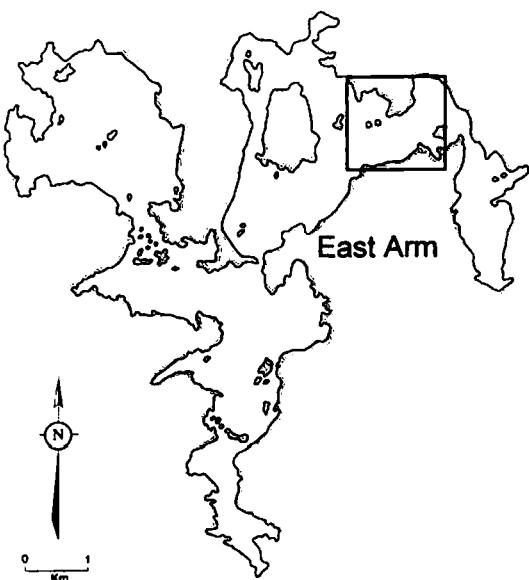


FIGURE 1.—Map of Lake Opeongo showing study area (inset) on the East Arm.

corded 1–4 times per week during the day in the spring and summer of 1989. During the summer of 1991, two of the seven study fish were tracked again to check for year-to-year differences in behavior. All data were classed as day (sunrise to sunset) or night (sunset to sunrise), based on the time of sunset and sunrise at 45°40'N latitude on the day of the fix. Bottom water temperature at each fix was estimated from water temperature-depth profiles taken in the study area on 13 d during 1989. Linear interpolation from the two closest profiles was used for those dates on which no temperature profile was recorded.

Analysis of the night tracking data indicated significant deviation from a normal distribution for swimming speed, depth, and bottom water temperature. A suitable transformation that normalized the data was not found. Therefore, a Friedman two-way nonparametric analysis of variance (ANOVA) was used to test three hypotheses: (1) Swimming speed was different among different thermal regimes and fish; (2) depth of occurrence was different among different thermal regimes and fish; and (3) speed was different between fish and between the years 1989 and 1991. For bottom water temperature, a Kruskall-Wallis one-way nonparametric ANOVA for fish by water temperature was performed for the summer (period of thermal stratification). Spring and fall data were not included because bottom water temperature was

TABLE 1.—Tagging, size, and tracking data for seven burbot followed in Lake Opeongo, 1988–1991.

Fish	Date tagged	Total length (cm)	Weight (kg)	Duration of tracking (months)
A	Feb 9, 1988	55		18
B	May 18, 1988	55		13
C	Feb 8, 1989	56	1.7	32
D	Feb 8, 1989	63	2.3	31
E	Feb 8, 1989	66	2.4	20
F	Feb 8, 1989	66	2.3	20
G	Jun 17, 1989	67		16

changing rapidly in these time periods and would have confounded the analysis.

Results and Discussion

The seven tagged burbot were 55–67-cm TL (mean, 61 cm) and weighed 1.7–2.4 kg (mean, 2.2 kg). Transmitters functioned for 13–32 months (mean, 21 months; Table 1). Swimming speed (*S*) and speed measured in body lengths per unit time (*B*) were highly correlated ($r = 0.995$) because of the similar size of the tracked fish; therefore, only absolute speed is reported. The regression describing the relationship is: $B = 0.0275S + 0.0005$.

Swimming speed was negatively correlated with the time interval between location fixes. However, the time interval explained only 2% of the variation in swimming speed and therefore was not taken into account in the analysis. There was no correlation between depth of occurrence or speed and time of night ($r = 0.05$ and 0.03; Sokal and Rohlf 1981). In general, burbot moved at night, a finding consistent with the results of Bergersen et al. (1993) and Edsall et al. (1993). Swimming speed for all fish was 1.4 m/min from sunrise to 1200 hours, 1.4 m/min from 1200 to 1800 hours, 2.3 m/min from 1800 hours to sunset, and 5.4 m/min from sunset to sunrise. Individual fish hit peaks of more than 20 m/min (mean speed), which was usually followed by periods of slow swimming (Figure 2).

I could detect no difference related to thermal regime or year of observation, or among different fish for the speed and depth data, possibly because a less powerful two-way nonparametric ANOVA was used ($P > 0.05$; Sokal and Rohlf 1981). However, burbot appeared to slow their movement and move deeper in the summer and to increase speed in the fall (Table 2). Fish C and E moved at night in the same localized areas during the spring and summer over the two years (generally less than 1 km; Figure 3). The speed of fish C and E was well

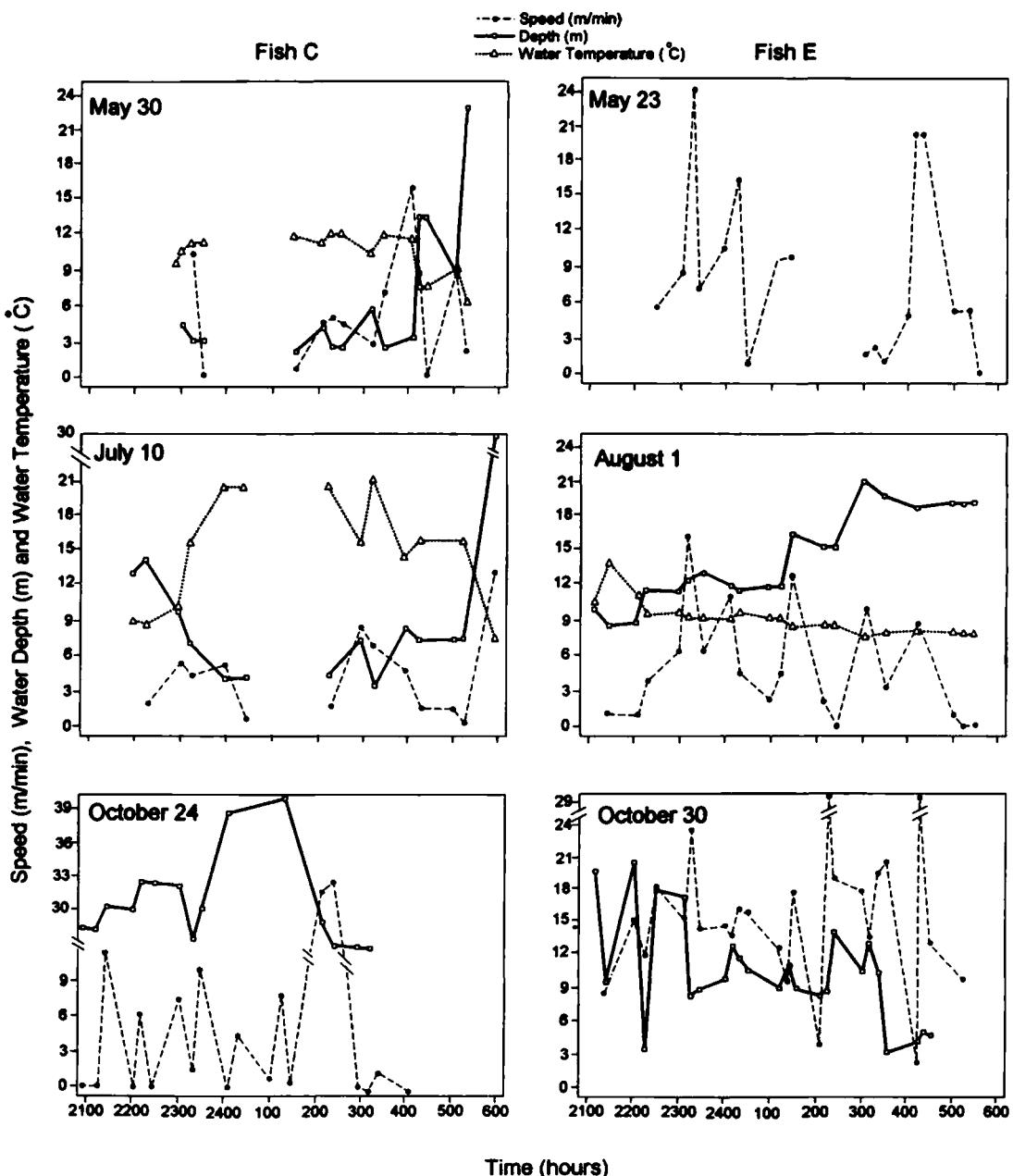


FIGURE 2.—Relation between swimming speed (m/min), water depth (m), temperature ($^{\circ}$ C), and time of day for burbot C and E (Table 2) on night tracks, June–October 1989.

within the speed range of burbot tracked in 1989. The other fish in the study (not shown due to space limitations) behaved in a similar manner. This suggests that the restricted activity area noted for these two fish was the normal pattern for adult burbot in Lake Opeongo and that in the summer, burbot may move to deeper water adjacent to the area

used in the spring. The fidelity to activity sites, the zig-zag patterns (Figure 3) and the abrupt changes in swimming speed (Figure 2) suggest that burbot use an area-restricted searching pattern. In this search pattern predators concentrate activity near where they have captured prey (Tinbergen et al. 1967; Smith 1974; Krebs 1978).

TABLE 2.—Movement of burbot at night, by season, in Lake Opeongo, 1989–1991.

Fish	Number of times tracked	Total number of fixes	Speed (m/min)	Night depth (m)		Bottom water tempera- ture (°C)
				Mean	Range	
Spring 1989						
B	2	32	7.4	10	3–25	9.7
C	2	24	6.0	5	2–14	10.7
D	4	59	5.7	8	3–13	9.0
E	1	16	9.1			
F	2	58	6.3	11	2–38	10.3
Mean				6.9	8	2–38
Summer 1989						
A	2	51	1.9	16	6–26	9.5
C	4	55	3.2	11	3–38	12.7
D	3	66	2.3	16	4–30	8.3
E	4	62	7.4	11	4–20	11.4
F	2	39	3.1	12	3–22	10.3
G	4	80	2.9	11		
Mean				3.5	13	3–38
Fall 1989						
C	1	25	4.9	23	20–33	
D	1	27	6.4	7	3–11	
E	2	37	12.3	11	4–21	
Mean				7.9	14	3–33
Summer 1991						
C	3	51	6.8	13	9–19	
D	3	42	3.8	16	10–26	
Mean				5.3	14	9–26

The mean depth occupied at night increased from 8 m before thermocline formation (when 70% of the observations were between 2 and 10 m) to a mean of 13 m after thermocline formation (when 30% of the observations were between 2 and 10 m; Table 2; Figure 4). The mean daytime depth was similar in spring (22.5 m; coefficient of variation [CV] = $100 \times \text{SD}/\text{mean} = 23.6\%$) and summer (20.8 m; CV = 32.3%). Depth at occurrence varied throughout the night. For example, on August 1, 1989, fish E gradually moved downslope. On October 30, 1989, fish E moved up the slope and then downslope relatively quickly, at one point moving from 21 m to 3 m in 20 min (Figure 2).

Bottom water temperature for each night fix increased from a mean of 9.4°C before thermocline formation to 10.5°C after, both temperatures well below the reported optimum of 15–18°C for burbot (Harkness and Fry 1940; Scott and Crossman 1973). The mean bottom temperature for daytime fix locations was 6.9°C before thermocline formation and 9.0°C after, whereas the mean

bottom temperature below 10 m was 7.6°C before thermocline formation and 8.6°C after, which indicates that burbot used the coolest water available to rest during the day. About 6% of the fixes after thermocline formation were recorded at temperatures greater than 20°C. The one-way ANOVA of water temperature indicated significant differences among fish during the time period when a strong thermocline was present ($P = 0.01$). Examination of individual night tracking data indicate that fish C occasionally spent 1–3 h at about 20°C followed by short periods in cooler water (Figure 2) and that it occupied warmer water than other fish in the study (Table 2). This may be because the area of localized activity of that fish was in shallower water, despite the warm water found there during the summer. On both May 30, 1989, and July 10, 1989, fish C was located in shallow water. During the July 10 track, it was moving slowly, without apparent consideration of water temperature above 20°C. Fish E foraged below the thermocline on August 1, 1989, and was in 8–10°C water most of the night (Figure 2). This suggests that, on a regular basis, burbot in Lake Opeongo operate above and below preferred temperatures in their local activity area even though preferred water temperatures are available. However, daytime resting temperatures during the spring and summer were near the lowest temperature available, which suggests that burbot seek cool water when resting, possibly to lower their metabolism.

None of the tagged burbot were located in water less than 2 m deep, even though forage fish and crayfish were present there (Figure 4). Because burbot in this study tolerated temperatures above their preferred temperature for extended time periods, the elevated summer temperature in the shallow nearshore habitat in Lake Opeongo would not exclude adult burbot. Other studies have shown that juvenile burbot up to 20–30 cm in length inhabit inshore areas (Scott and Crossman 1973; Eloranta 1985; Carl 1992; Ryder and Pesendorfer 1992). In Lake Opeongo there seems to be a discrete shift in habitat or ontogenetic niche from inshore areas for juvenile burbot to offshore benthic areas for adults. Several authors have shown a similar shift in other animals (Keast 1977; Polis 1984; Werner and Gilliam 1984).

The data in this study indicate burbot employ an area-restricted search pattern and use a small foraging area that may change little from year to year. During the summer, burbot move and presumably forage at night on the bottom, primarily

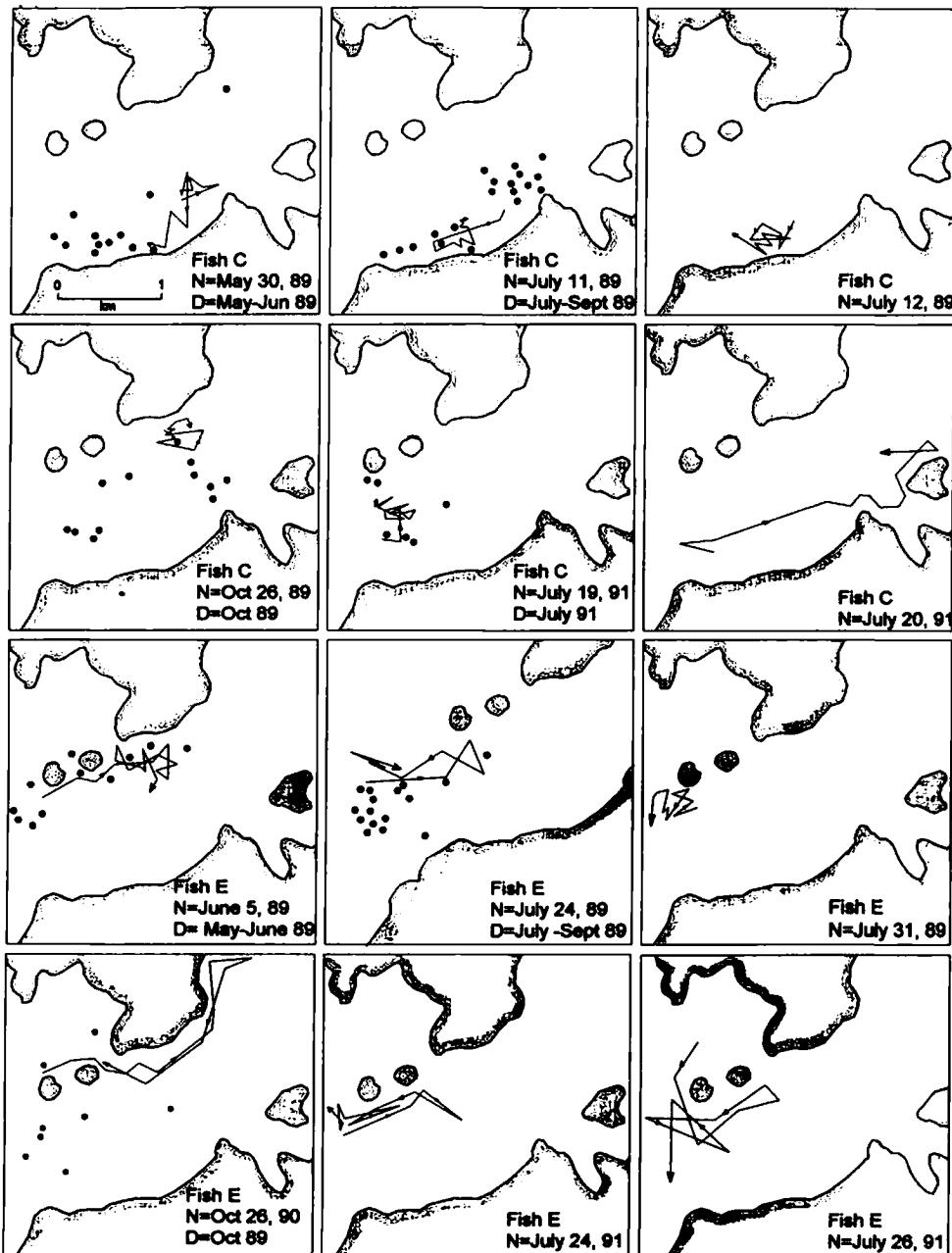


FIGURE 3.—Night tracks (N, lines) and daytime locations (D, dots) of burbot C and E (Table 2) in 1989 and 1991.

below the thermocline, although some movement occurs in shallow water above their preferred temperature. Carl (1992) suggested that burbot may prey on juvenile lake trout, and it appears that this is likely because juvenile lake trout inhabit these same areas during the summer (Evans et al. 1991).

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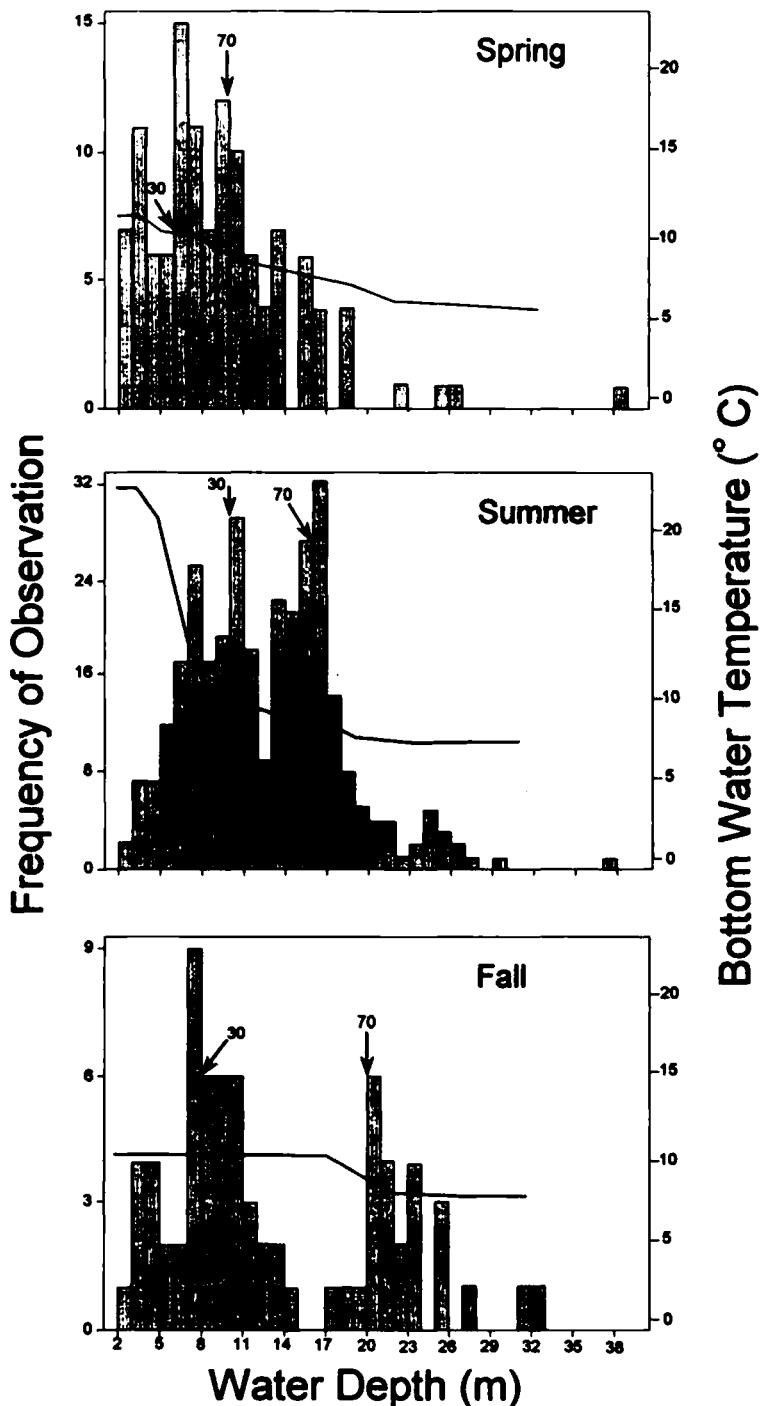


FIGURE 4.—Night distribution of burbot in relation to water depth (bars) and temperature (continuous lines) in spring (water temperature profile, WTP, on May 30, 1989), summer (WTP on August 3, 1989), and fall (WTP on October 11, 1989). The numbers 30 and 70 in each graph are the cumulative frequencies (%) for that season.

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