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MOVEMENT OF SEA-RUN SEA LAMPREYS, *PETROMYZON MARINUS*, DURING THE SPAWNING MIGRATION IN THE CONNECTICUT RIVER[1]

Adult sea lampreys, *Petromyzon marinus*, first enter New England rivers in late March and early April (Bigelow and Schroeder 1953). The only information on river water temperatures during the migration were collected in 1974 from the St. John River, New Brunswick, where Beamish and Potter (1975) captured the first prespawning adults in a fish lift at Mactaquac Dam (river km 140) at 13°C in mid-June and the run peaked at 17°-19°C. Because thousands of sea lampreys are annually passed upstream of Holyoke Dam (river km 140) on the Connecticut River, the passage records provide an ideal opportunity to characterize the run relative to temperature. River flow was partially or totally controlled by the hydroelectric facilities at the dam, so we did not examine the effects of flow on the run.

The behavior and rate of movement of landlocked sea lampreys in the Great Lakes was determined using mark and recapture of adults at stream weirs (Applegate 1950; Applegate and Smith 1950; Smith and Elliot 1952; Moore et al. 1974). The only estimate of the rate of movement of sea-run sea lampreys was done by Beamish (1979) who used the energy expended during an upstream movement to estimate the distance traveled and the rate of movement of adults in the St. John River. Because this estimate of the rate of movement was not verified by direct observations on fish in the field, we believed that additional study was necessary. We selected radio telemetry to determine the rate of movement and diel behavior of sea lampreys. The abundance, size, and sex ratio of the Connecticut River population were reported by Stier and Kynard (1986).

Methods

Radio-tagged sea lampreys were observed in the 46 km stretch of the Connecticut River from Brunelle's Marina to Cabot Station, a hydroelectric facility located 4.5 km below Turners Falls Dam (Fig. 1). The downstream half of this stretch flows slowly, creating a deep channel and shoals; the upstream half flows swiftly with pools and riffles. Major spawning areas are in the upper main-stem near Cabot Station, Russelville Brook, and the Fort, Mill, Sawmill, and Deerfield Rivers (Fig. 1).

The number of sea lampreys passed daily by the fish lifts from 1980 to 1983 were counted by personnel of the Massachusetts Cooperative Fishery Research Unit. Daily maximum river temperature was recorded at Holyoke Dam.

Sea lampreys were captured in the trap at the fish lifts during May and June 1982, measured for total length, and held for <24 h in a 1,325 L circular tank supplied with river water. We anesthetized fish with MS-222 (1:20,000) and tagged them first with a Floy tag inserted through the posterior dorsal fin, and second with a transmitter placed on the left side of the body along the first dorsal fin. Sex could not be accurately determined visually.

Cylindrical radio transmitters were constructed from the design of Knight (1975) and operated at a frequency of 30.05-30.25 MHz. Tags measured 34 × 10 mm, weighed 3.5-4.5 g in air, and transmitted for about 20 d. Each fish was identified by frequency and pulse rate. We located fish to within about 10 m, using receivers equipped with an omnidirectional, 1/8-wave antenna and a directional, tuned-loop antenna.

We released two to six sea lampreys at a time and observed them continuously for ≥6 h or until darkness. Subsequently, sea lampreys were located each day until they reached Cabot Station or entered a tributary. During all surveys, we noted the locations of fish to the nearest river kilometer. Diel movement was monitored for five 24-h periods. Additional fish were released during the day for this study.

Results and Discussion

The water temperatures, and the year in parentheses, when sea lampreys first entered the fish lifts were 12.5°C (1980), 10.5°C (1981), 12.5°C (1982), and 15.5°C (1983) (Fig. 2). The lifts sampled the en-

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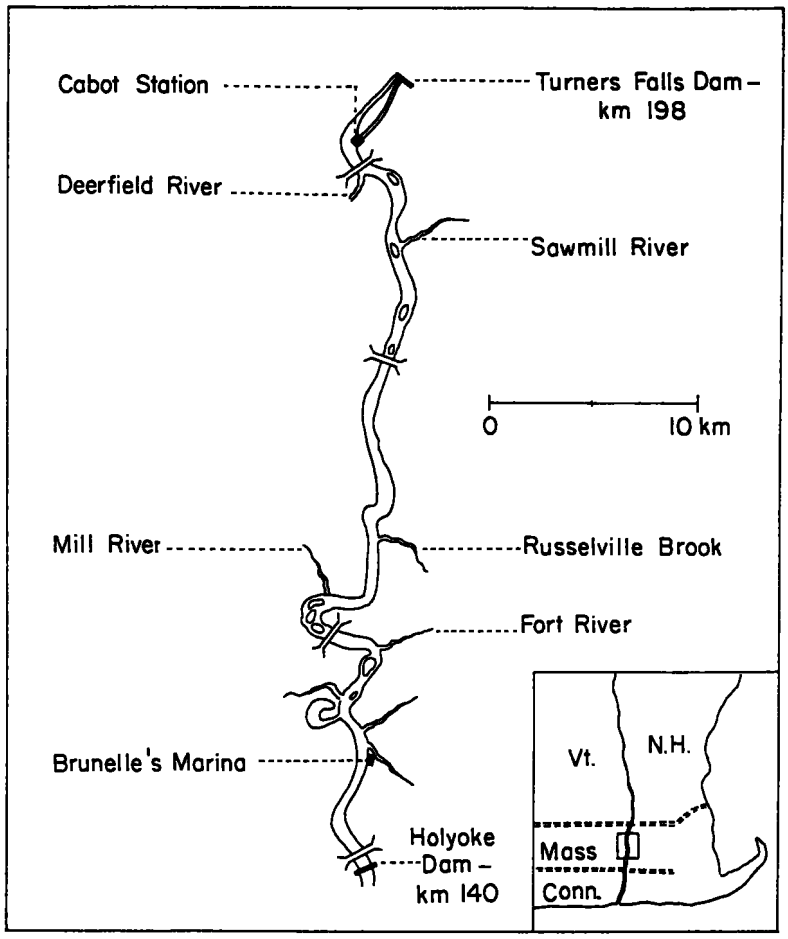

FIGURE 1.—Section of the Connecticut River from river km 140 to 198, showing the locations of the Holyoke and Turners Falls Dams, the release site for radio-tagged sea lampreys at Brunelle's Marina, and the major spawning tributaries between the two dams.

tire run each year except in 1981 when sea lampreys were present in the first lifts of the year (the lifts began operating on 29 or 30 April of each year). During the peak 7 d, the temperature ranges, and year in parentheses, were 16°-19°C (1980), 17°-19°C (1981), 16°-17°C (1982), and 17°-21°C (1983). Movement into the fish lift ceased at 24°C in 1983 and at 21°-22°C in the other years (Fig. 2).

Information on the maximum daily temperature during the migration of landlocked sea lampreys in a large river comes from the Ocqueoc River (Lake Huron drainage) which for some years supported an annual run of 25,000-40,000 (Applegate 1950; Applegate and Smith 1950). The temperatures, and date in parentheses, when the first sea lampreys entered a weir near the mouth of the river were 10°C (27 April 1949) and 6°C (11 May 1950); and the run peaked at 14°-17°C (first week of May 1949) and 18°-20°C (third week of May 1950). Most movement at the weir ceased at 21°C (about 11 July), but during both years one or two sea lampreys per day continued to enter the weir throughout the summer at 22°-26°C.

The temperature regimes in the Ocqueoc and Connecticut Rivers during the peak and at the end of the principal migration were in general agreement. Runs peaked at 14°-20°C in the Ocqueoc River and 16°-21°C in the Connecticut River; most of the run ceased at 21°C in the Ocqueoc River and at 21°-24°C in the Connecticut River. The migrations differed because a few adults in the Ocqueoc River continued to migrate throughout the summer, whereas none were captured after 25 June during 3 yr in the Connecticut River. Therefore, even

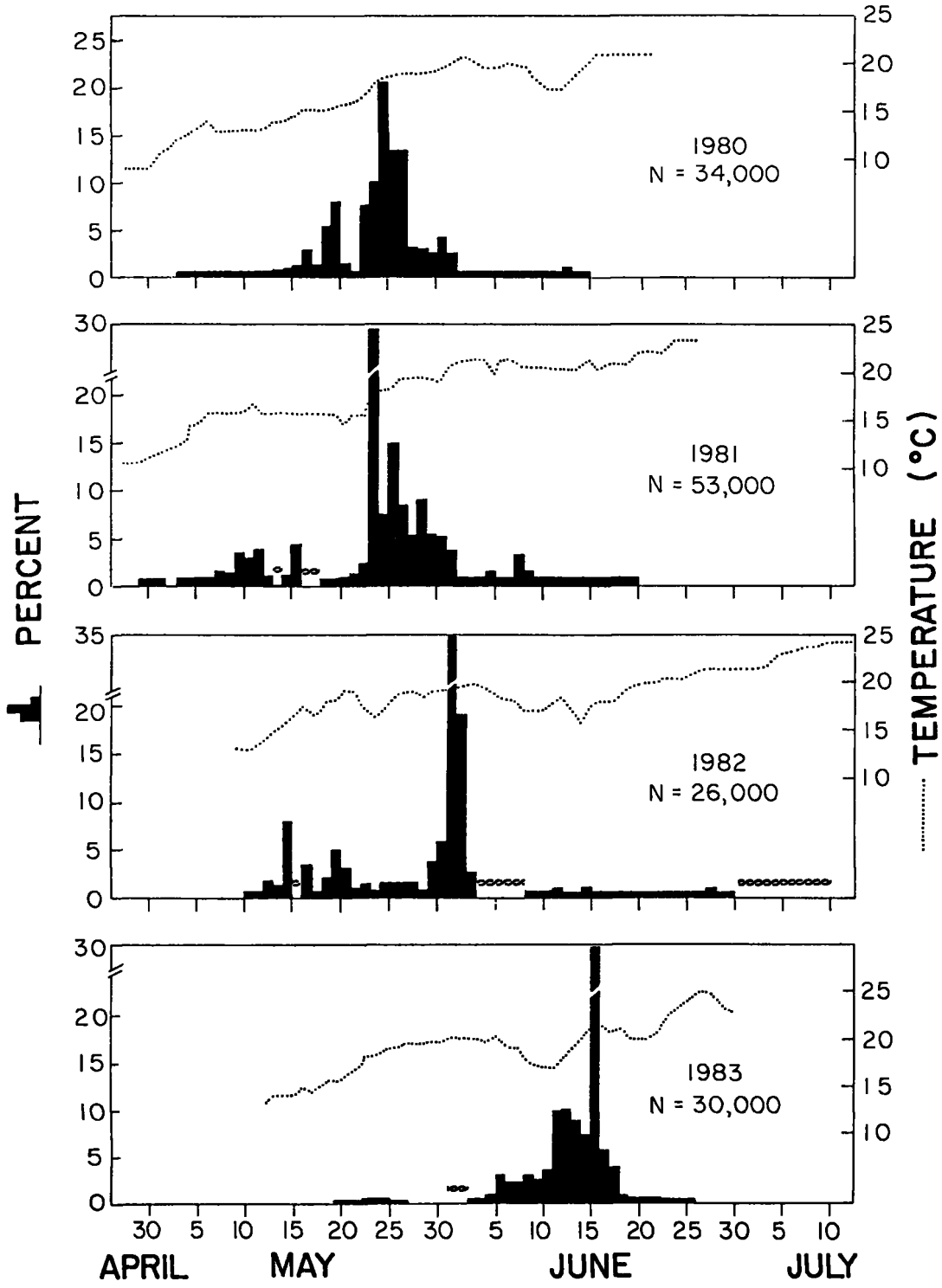

FIGURE 2.—Daily percent of total sea lampreys lifted at the Holyoke fish lifts each year, 1980-83. Temperatures are the daily maximum river temperatures. The lifts began operating about 1 May in all years and ceased about 15 July. Wavy line near the base of each panel identifies days on which the lifts were not operated.

though the data from the two runs differed greatly in time and space, the general migration pattern in relation to river temperature was remarkably similar.

The behavior of the sea lampreys in the St. Johns and Connecticut Rivers also appeared similar. In 1974, the first migrants were collected at 13°C at the Mactaquac fish lift (Beamish and Potter 1975), and from 1980 to 1983 the first migrants were passed in the Holyoke fish lift at 10.5°-15.5°C. The peak of the run was also similar—17°-19°C in the St. Johns River and 16°-21°C in the Connecticut River.

Mean length of the 45 sea lampreys tagged was 73.2 cm (range, 63.0-80.0 cm). Five were not relocated either because the tag failed or the fish moved downstream over the dam. No tagged sea lamprey died during the study. The remaining 40 fish were followed for a total of 224 h during 24 d (12 May-4 June; Fig. 3). Since sea lampreys migrated upstream at Holyoke until 30 June 1982 (Fig. 2), for the most part we observed the movement of early migrants. During the study, water temperature increased from 13° to 22°C; river discharge gradually decreased from 60.4 m^3/s on 12 May to 50.9 m^3/s on 31 May. Twenty sea lampreys moved >23 km and 4 reached Cabot Station. Nineteen were last located near the mouths of the Fort or Mill Rivers or Russelville Brook (Fig. 1). Spawning of tagged fish was verified in the tributaries—an indication that normal behavior resumed after the sea lampreys were tagged.

Sea lampreys moved upstream at ground speeds of 0.1-3.5 km/h. The daily mean rate of movement including rest periods was 1.01 km/h ± 0.75 (mean ± SD; range, 0.1-2.7 km/h; N = 40) or 0.4 body length/s. The mean rate, excluding rest periods, was 1.51 km/h ± 0.53 (range, 0.1-3.5 km/h; N = 39) or 0.6 body length/s. Early migrants moved a mean of 0.1-1.2 km/h; and three migrants that were observed during the peak passage at the fish lift on 2 June had the fastest mean daily rate of 2 km/h (Fig. 3).

Among landlocked sea lampreys, early migrants have a slower rate of movement than peak migrants because they rest more (Applegate 1950; Skidmore 1959; Larsen 1980). Our observations during the peak period after 30 June did not indicate a sustained increase in the rate of movement (Fig. 3). Because we only observed a few peak migrants, additional study is necessary to compare the rates of movement between early and peak migrants.

The movement rates of sea lampreys in the Connecticut River were the highest reported for the species. Landlocked sea lampreys moved at much lower rates of 0.02-0.21 km/h (Applegate and Smith 1950; Skidmore 1959; Wigley 1959). Beamish (1974) found a maximum swimming speed of 1.08 km/h (30 cm/s) for landlocked adults in the laboratory. Using the energetics of adult sea-run sea lampreys during a 35-d upstream move into the fish lift at Mactaquac Dam on the St. John River, Beamish (1979) estimated the rate to be 0.23 km/h for males and 0.26 km/h for females, or 0.1 body length/s for both. This rate was similar to that of the landlocked form. Because the sea-run adults are much larger than landlocked adults, they should swim faster. Our results suggest that the 0.2 km/h rate which was estimated for the St. John River adults may be incorrect, possibly because the fish were delayed

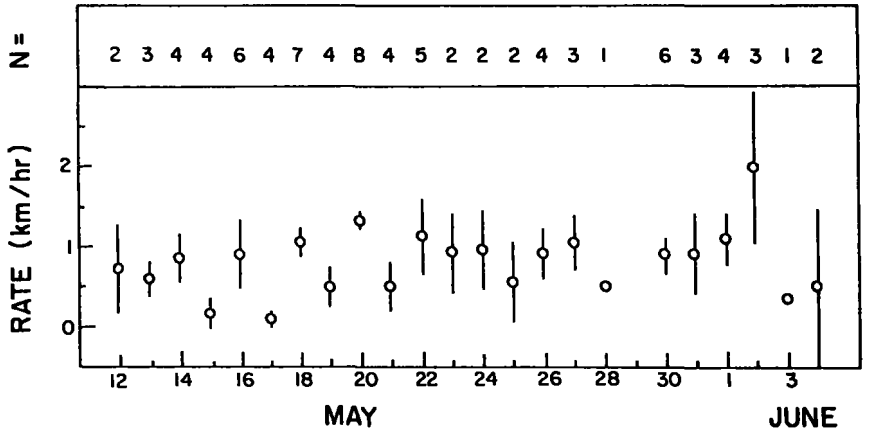

FIGURE 3.—Daily mean rates of movement of radio-tagged sea lampreys (open circles). (Vertical lines show standard errors; numbers of lampreys monitored are shown above each mean.)

several days before finding the entrance to the fish lift at Mactaquac Dam.

Diel movement rates were monitored on 13 and 17 May (early migrants) and 26 and 30 May and 1 June (peak migrants). Movement was slowest from 1200 to 1700 h (Fig. 4). Nocturnal behavior was strongest among the early migrants; peak migrants had a higher rate of movement because they also moved during the day (mornings only). A similar pattern for landlocked adults was found by Kleerekoper et al. (1961).

In summary, except for the longer summer migration and the slower rate of upstream movement, the behavior of sea-run sea lampreys in the Connecticut and St. Johns Rivers was similar to that of the landlocked sea lampreys in the Ocqueoc River. The timing of the runs in relation to temperature and the diel movement patterns appears very stable, probably with important survival or reproductive advantages.

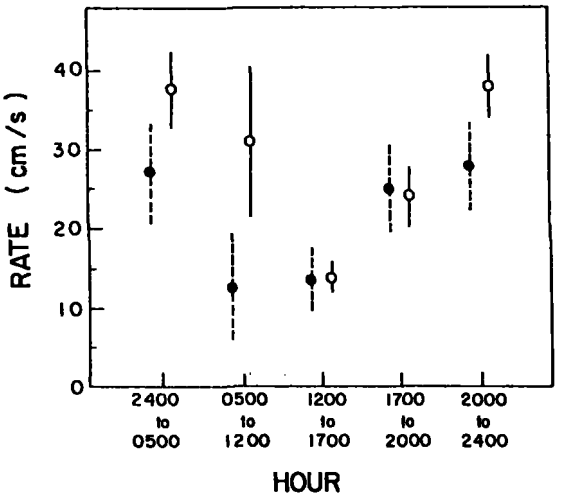

FIGURE 4.—Mean movement rates of early migrants (solid circles) monitored 13 and 17 May (N = 13), and peak migrants (open circles) monitored 26 and 30 May and 1 June 1982 (N = 7). (Vertical lines show standard errors.)

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Literature Cited

APPLEGATE, V. C.
1950. Natural history of the sea lamprey, *Petromyzon marinus*, in Michigan. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 55, 237 p.

APPLEGATE, V. C., AND B. R. SMITH.
1950. Sea lamprey spawning runs in the Great Lakes in 1950. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 61, 49 p.

BEAMISH, F. W. H.
1974. Swimming performance of adult sea lamprey, *Petromyzon marinus*, in relation to weight and temperature. Trans. Am. Fish. Soc. 103:355-358.
1979. Migration and spawning energetics of the anadromous sea lamprey, *Petromyzon marinus*. Environ. Biol. Fishes 4:3-7.

BEAMISH, F. W. H., AND I. C. POTTER.
1975. The biology of the anadromous sea lamprey (*Petromyzon marinus*) in New Brunswick. J. Zool. (Lond.) 177: 57-72.

BIGELOW, H. B., AND W. C. SCHROEDER.
1953. Fishes of the Gulf of Maine. U.S. Fish Wildl. Serv., Fish. Bull. 53:1-577.

KLEEREKOPER, H., G. TAYLOR, AND R. WILTON.
1961. Diurnal periodicity in the activity of *Petromyzon marinus* and the effects of chemical stimulation. Trans. Am. Fish. Soc. 90:73-78.

KNIGHT, A. E.
1975. A tuned-antenna radio telemetry tag for fish. Underwater Telem. Newsl. 5:13-16.

LARSEN, L. O.
1980. Physiology for adult lampreys, with special regard to natural starvation, reproduction, and death after spawning. Can. J. Fish. Aquat. Sci. 37:1762-1779.

MOORE, H. H., F. H. DAHL, AND A. K. LAMSA.
1974. Movement and recapture of parasitic phase sea lampreys (*Petromyzon marinus*) tagged in the St. Marys River and Lakes Huron and Michigan, 1963-67. Great Lakes Fish. Comm. Tech. Rep. 27, 19 p.

SKIDMORE, J. F.
1959. Biology of spawning-run sea lampreys (*Petromyzon marinus*) in the Pancake River, Ontario. M.S. Thesis, Univ. Western Ontario, London, Ont., 87 p.

SMITH, B. R., AND O. R. ELLIOTT.
1952. Movement of parasitic-phase sea lampreys in Lakes Huron and Michigan. Trans. Am. Fish. Soc. 82:123-128.

STIER, K., AND B. KYNARD.
1986. Abundance, size, and sex ratio of adult sea-run sea lamprey, *Petromyzon marinus*, in the Connecticut River. Fish. Bull., U.S. 84:476-480.

WIGLEY, R. L.
1959. Life history of the sea lamprey of Cayuga Lake, New York. U.S. Fish Wildl. Serv., Fish. Bull. 59:559-617.

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