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Evidence for Lack of Homing by Sea Lampreys

ROGER A. BERGSTEDT AND JAMES G. SEELYE

***National Biological Service, Great Lakes Science Center, Lake Huron Biological Station
11188 Ray Road, Millersburg, Michigan 49759, USA***

Abstract.-Recently metamorphosed sea lampreys *Petromyzon marinus* were captured in the Devil River, a tributary to Lake Huron, during summer and autumn 1990. They were tagged with a coded wire tag and returned to the river to continue their migration to Lake Huron to begin the parasitic (juvenile) phase of their life. During the spawning run in spring 1992 when the tagged animals were expected to mature and return to spawn, sea lampreys were trapped in nine tributaries to Lake Huron, including the Devil River; 47,946 animals were examined for coded wire tags, and 41 tagged animals were recovered. None of the 45 mature sea lampreys captured in the Devil River in 1992 were tagged, a proportion (0%) significantly lower than the proportion of the recently metamorphosed sea lampreys tagged in 1990. The distribution of tag recoveries among streams lakewide, however, was proportional to catch. Tagged sea lampreys did not appear to home, but instead seemed to select spawning streams through innate attraction to other sensory cues.

Control of sea lampreys *Petromyzon marinus* in the Great Lakes is founded on knowledge of their life cycle and behavior. One fundamental aspect of their behavior that is not understood (Beamish 1980) is whether sea lampreys tend to return to their natal streams (homing behavior), as do other anadromous species. The rapid spread of sea lampreys across the Great Lakes (Smith and Tibbles 1980) suggests that strict homing is unlikely. Several authors have suggested that sea lampreys do not home, based on movements of animals during the spawning migration. At least 9% of sea lampreys marked during the spawning run in the Cheboygan River (Applegate and Smith 1951) left the river and entered other rivers. Sea lampreys captured and marked during the spawning run in the Pancake River (Skidmore 1959) and the Humber River (Purvis and McDonald 1987) did not consistently return to the stream of capture when released in the lake. However, these observations are not conclusive because neither the natal streams of the marked animals nor the streams they would have selected for spawning if not captured are known. Better evidence about homing tendencies is needed if stream selection by spawning adults is to be understood and if the most effective control methods are to be devised.

Other authors have noted the lack of direct evidence for homing by sea lampreys in the Great Lakes and have suggested that stream attributes such as discharge, temperature, substrate, or cues provided by existing larval populations govern the distribution of sea lampreys among streams (Moore and Schleen 1980; Morman et al. 1980; Teeter 1980; Young et al. 1990). Only about 8% of the tributaries to the Great Lakes have supported populations of sea lamprey larvae (Morman et al. 1980). Production of sea lampreys in such a limited subset of streams may reflect the unsuitability of some streams for hatching and nurturing larvae and the selection by sea lampreys of only certain streams for spawning. The latter possibility is suggested because as sea lamprey numbers were reduced by chemical control (Smith and Tibbles 1980), the number of streams with larvae declined (Torblaa and Westman 1980). As numbers of spawning sea lampreys decreased, too few animals selected these streams to allow recolonization. If stream selection occurs, the two most likely causes are homing to the natal stream, as described for Pacific salmon *Oncorhynchus* spp. (Hasler 1966) or innate attraction to sensory cues such as pheromones (Nordeng 1971) or odors associated with suitable habitat, as described for migrating elvers of the American eel *Anguilla rostrata* (Miles 1968; Sorensen 1986).

Planning procedures within the sea lamprey control program require predicting how control efforts will affect future production in a lake or region of a lake. Parasitic (juvenile) sea lampreys escaping from a stream spend one growing season in the Great Lakes and spawn the next spring, 12 to 18 months after migration to the lake (Applegate 1950; Bergstedt and Swink, in press). Current methods for projecting patterns of stream repopulation, and thereby projecting future control efforts, are based on the assumption that sea lampreys do not home. Reproductive potential is instead apportioned among streams, based on stream attributes and historical patterns. However, the assumption of no homing remains unproven.

The objective of this study was to test whether

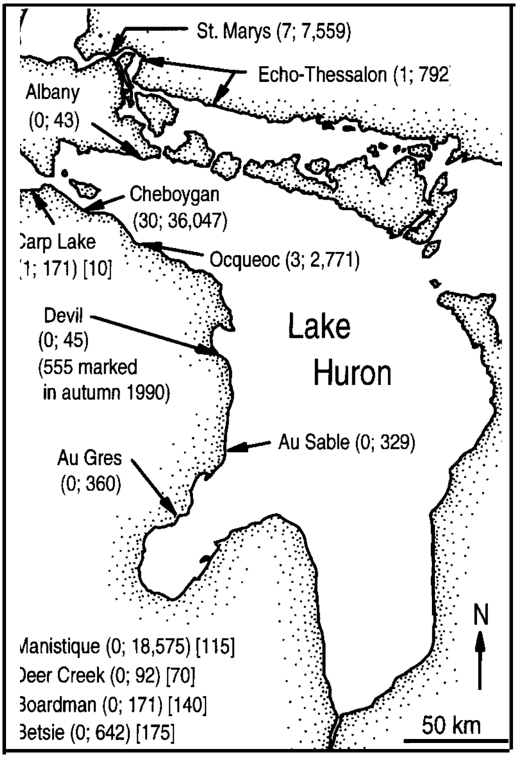

FIGURE 1. Locations of nine tributaries to Lake Huron and one tributary to Lake Michigan where mature sea lampreys were examined for tags during the 1992 spawning run. Tags had been injected into 555 recently metamorphosed sea lampreys in the Devil River in 1990. Numbers in parentheses are the number of tagged animals recovered and number of animals examined in each river, Four other Lake Michigan tributaries where animals were examined for tags are listed in the lower left of the figure. For Lake Michigan tributaries, the distance (km) from Lake Huron is given in brackets.

or not sea lampreys return (home) to their natal stream to spawn. We chose the Devil River, a tributary to Lake Huron, as our study site. Some of the sea lampreys that metamorphosed there during summer 1990 were tagged with coded wire tags and allowed to migrate naturally to Lake Huron. We used tag recovery from mature animals during the spawning run in spring 1992 to evaluate homing.

Methods

We collected recently metamorphosed sea lampreys from the Devil River, Michigan (Figure l), using two techniques. First, sea lampreys were collected with backpack electrofishing gear (Weisser and Klar 1990) during 22-26 August and 26-29 September 1990. We tagged those animals with coded wire tags injected in the epaxial muscle mass near the insertion of the dorsal fin. Tag loss from that site was probably less than 1% (Bergstedt et al. 1993). Anesthetic was not used, and tagged animals were immediately returned to the stream. To avoid retagging animals, we first examined them with a magnetic field detector. Although we did not monitor their movement, migration of metamorphosed sea lampreys to the lake typically occurs between mid-October and the following May (Applegate 1950). Consequently, recently metamorphosed sea lampreys were also collected with fyke nets during the downstream migration from 13 October to 20 December 1990. The nets were set facing upstream in the first riffle upstream of the river mouth. Animals captured in the fyke nets were examined for tags with a magnetic field detector. Animals containing a tag injected during August-September were recorded as recaptures, and untagged animals were tagged. All tagged animals were returned to the river downstream of the nets to continue their migration to Lake Huron. The tagged animals were expected to spend 1991 as parasites on fish in Lake Huron and to spawn in spring 1992 (Applegate 1950; Bergstedt and Swink, in press).

Recaptures of tagged animals in the fyke nets were used to estimate the population of recently metamorphosed sea lampreys in the Devil River. A population estimate and 95% confidence interval were calculated with Chapman's modification of the Schnabel method (Ricker 1975, equation 3.17). Recently metamorphosed sea lampreys are not randomly distributed within a stream system, and those we marked were captured in the lower half of the stream where we could collect sufficient numbers through electrofishing. There was some effort in the upper half of the stream but none were caught there. In making the population estimate, we assumed that our fyke nets took a random sample of the downstream migrants and that the probability of tagged, recently metamorphosed sea lampreys migrating to the lake in autumn was not different from that of untagged specimens.

Mature sea lampreys were trapped during the upstream spawning migration in spring 1992 as part of annual assessment activities. Each year, traps or fyke nets are used to assess the number of mature sea lampreys in streams that routinely attract spawning migrations. Animals were examined with magnetic field detectors for coded wire tags on nine tributaries to Lake Huron (including the Devil River) and on five tributaries to northern Lake Michigan (Figure 1). Animals collected from the Echo and Thessalon rivers were mixed by field crews before inspection for tags, and data for those two rivers were combined. Tags were removed and read to verify that the animal's stream of origin was the Devil River. To estimate collection efficiency on the Devil River, we captured animals during spring 1993, marked them with a fin clip, and released them downstream of the net site. We estimated efficiency from the proportion of clipped animals recovered. A confidence interval for the estimated efficiency was calculated from the binomial distribution.

We evaluated two hypotheses describing selection of spawning streams by sea lampreys. If there is a strong tendency to home, most animals would return to their natal stream, and the proportion of tagged animals in the 1992 spawning run in the Devil River should reflect the proportion of animals tagged in 1990. We used the chi-square test to examine the null hypothesis that those proportions were the same. The expected proportion was calculated from the number we tagged and the estimated population for recently metamorphosed sea lampreys in the Devil River in 1990.

If sea lampreys do not home, there are two other potential hypotheses to explain their distribution among spawning streams; we test only one of those here. The first hypothesis is that they do not select spawning streams and are randomly distributed among streams in the Great Lakes basin. We rejected that hypothesis, based on the small proportion of streams in the Great Lakes where sea lampreys reproduce (433 of 5,747, 8%; Morman 1980). The second hypothesis is that they do select spawning streams based on innate attraction to other unspecified criteria. According to that hypothesis, tagged animals from the Devil River would be distributed among selected streams in the same way as the total Lake Huron population, with recoveries by stream proportional to the number of animals examined. We used the chi-square test to examine this hypothesis and calculated the expected recoveries by multiplying the lakewide proportion of tagged animals in Lake Huron by the catch in each stream. Catches from the Echo, Thessalon, Au Gres, Au Sable, Devil, and Albany rivers (Figure 1) were combined to produce an expected catch of at least one (Snedecor and Cochran 1989).

Results

We tagged and released 555 recently metamorphosed sea lampreys in the Devil River during August-December 1990. Of those, 292 had been captured by electrofishing and tagged before the downstream migration. Of 355 animals captured in fyke nets during the downstream migration, 29 were already tagged. We then tagged 263 of the untagged animals collected by fyke nets, bringing to 555 the number of tagged sea lampreys released to migrate to Lake Huron. The remaining 63 animals captured in the fyke nets were not tagged and were removed from the population. A Schnabe1 estimate of the number of sea lampreys that metamorphosed in the Devil River in 1990 was 3,455 (95% confidence interval, 2,433-5,081). Given that 555 animals were tagged in the Devil River during 1990 and that 63 untagged animals were removed from the population, the estimated proportion of tagged sea lampreys migrating to Lake Huron was 16% (95% confidence interval, 11-23%). If equal mortality of tagged and untagged animals is assumed, the expected lower limit to the proportion of tagged animals to be recovered in spring 1992 is 11%.

We recaptured 42 (8%) of the tagged sea lampreys as adults during the spring spawning migration in 1992. In Lake Huron, 41 of the 47,946 sea lampreys examined were tagged, but in Lake Michigan, only 1 of the 19,651 sea lampreys examined was tagged (Figure 1). That animal was recovered from the Carp Lake River, about 10 km west of Lake Huron through the Straits of Mackinac (Figure 1). Because movement to Lake Michigan appeared to be minimal, the following analyses are based only on the 41 recaptures from Lake Huron tributaries.

The distribution of tag recoveries among streams was not consistent with the hypothesis of homing by sea lampreys, but it was consistent with the hypothesis that innate attraction to other factors governs selection of spawning streams. Only 45 mature sea lampreys were captured in the Devil River in spring 1992. Capture efficiency for marked mature sea lampreys released below the net site in the Devil River in spring 1993 was estimated at 24% (95% confidence interval, 16-32%), indicating that the spawning run in 1992 was probably less than 300. None of the 45 mature sea lampreys (0%; upper 95% confidence limit, 6%; Louis 1981) captured in 1992 was tagged. Under the null hypothesis, the proportion of tagged upstream migrants in the Devil River in spring 1992 should have been about 16% but no less than 11% (the lower 95% confidence limit for the proportion tagged there in 1990). The observed recoveries of 0 tagged and 45 untagged animals differed significantly from the expected numbers if 11% of the population had been tagged (x^2 = 5.56, df = 1, P = 0.02). Under the hypothesis of innate attraction to unspecified stream attributes, the distribution of tagged animals among Lake Huron tributaries was expected to be proportional to the total number migrating into each stream, in which case the number of tags recovered should be proportional to the number examined in each stream. The distribution of tag recoveries was not significantly different from expected (x^2 = 0.32, df = 2, P = 0.85), with one tag recovered for about every 1,170 animals examined lakewide (Figure 1).

Discussion

The recovery of tagged animals only outside their natal stream strongly suggests that sea lampreys do not rely on homing but choose spawning streams for other reasons. We recovered no tags from the natal stream, and the proportion of tagged animals (0%) was significantly less than expected. Furthermore, the distribution of tag recoveries among streams lakewide was proportional to catch and was consistent with the hypothesis that tagged animals from the Devil River would be distributed among streams in response to other factors. If we assume that sea lampreys actively select streams for spawning and do not disperse randomly, innately detectable factors probably exist that communicate the presence of suitable spawning or nursery areas. The distribution of tagged animals among streams in proportion to catch also suggests that a thorough mixing of sea lampreys occurs in Lake Huron during their parasitic phase.

Innately detectable factors could either emanate from the substrate and biota and be characteristic of suitable conditions (Miles 1968; Sorensen 1986) or be produced by conspecifics living successfully in the stream (Nordeng 1971). Morman et al. (1980) and Young et al. (1990) noted that stream characteristics such as flow, temperature, and substrate were related to selection of streams for spawning and to the occurrence and growth of larvae. If attraction is related to stream attributes, the odor produced by the substrate or biota in suitable streams may be more attractive than the actual stream characteristics to upstream-migrating sea lampreys. Other evidence shows that substances released by conspecifics may be more important. Moore and Schleen (1980) noted that spawning runs generally decrease in the spring following a treatment and speculated that existing sea lamprey larvae may provide an attractant. Teeter (1980) found that water in which larvae are held attracted migrating adults. More recent research suggests that the attractant may be a bile acid excreted by the larvae (P. Sorensen and W. Li, University of Minnesota, personal communications).

If further research can show that sea lampreys select streams by innately recognizing odorants, those odorants could be useful for control. The ability to either attract or repel sea lampreys could improve sea lamprey control in several ways: sea lampreys could be lured to traps either for removal or improved assessment; spawning sea lampreys could be lured into streams that are easily treated or have poor larval habitat; and spawning sea lampreys could be repelled from "problem" streams that are difficult or costly to treat.

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