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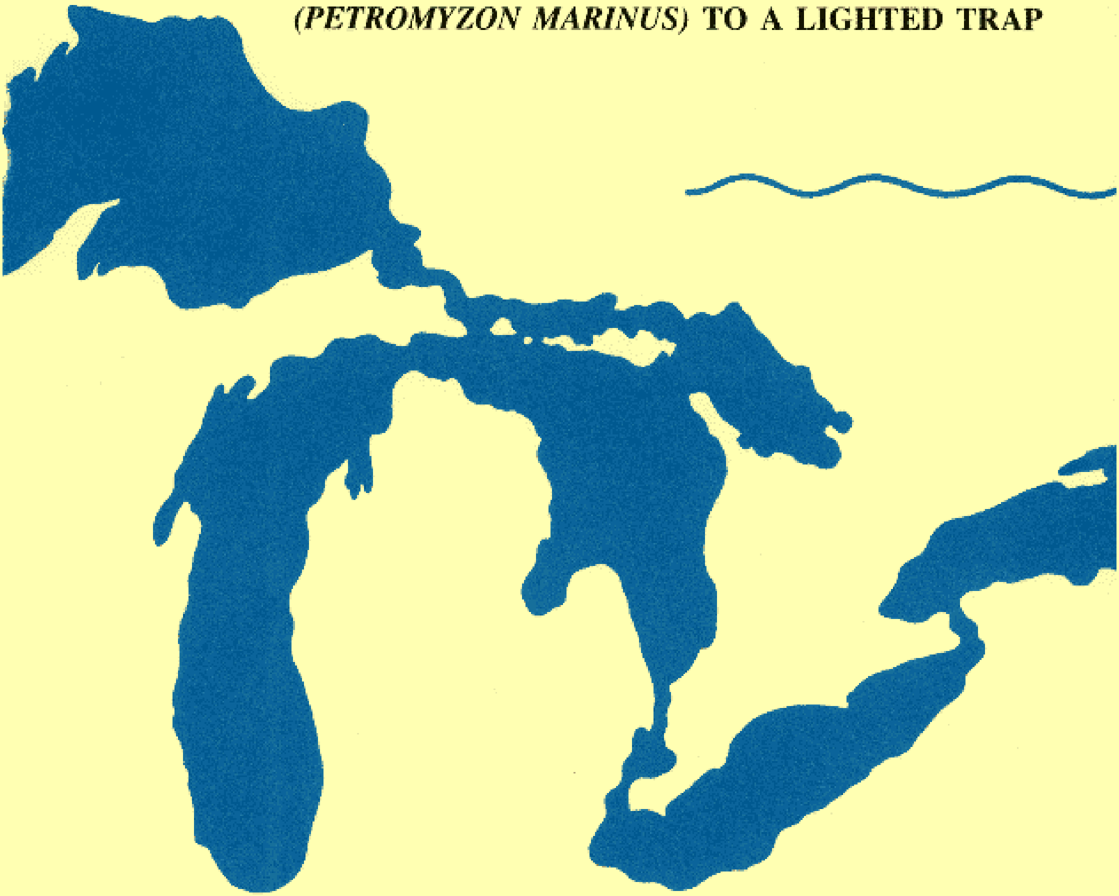
RESPONSE OF SPAWNING-PHASE SEA LAMPREYS *(PETROMYZON MARINUS)* TO A LIGHTED TRAP



Great Lakes Fishery Commission

TECHNICAL REPORT No. 42

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(PETROMYZON MARINUS)

MARKED IN NORTHERN LAKE HURON, 1981-82

by

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MOVEMENT AND CAPTURE OF SEA LAMPREYS *(PETROMYZON MARINUS)* MARKED IN NORTHERN LAKE HURON, 1981-82[1]

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ABSTRACT

A total of 830 parasitic-phase sea lampreys *(Petromyzon marinus)* were marked and released during May-October 1981 in two areas of northern Lake Huron--398 in a north area and 432 in a south area. Of these, 101 were recaptured--9 as parasitic adults in commercial nets in 1981, and 92 as spawning adults in sea lamprey traps in three tributaries of Lake Huron and five tributaries of Lake Michigan in 1982. Most recaptures in 1982 were in the Cheboygan (48) and St. Marys (15) rivers on Lake Huron and in the Manistique (14) and Carp Lake (9) rivers on Lake Michigan. Although a few marked sea lampreys moved long distances (maximum, 534 km), 78% of the recoveries were taken within 100 km of release. A high proportion of those recaptured in the St. Marys River had been marked in the north area, and of those taken in the Cheboygan River, a high proportion were from the south. Growth of sea lampreys in both release areas was linear in 1981, but lampreys in the north were longer at the start of the study and remained longer from May through October than those in the south. An estimated 250,000 spawning-phase sea lampreys were present in northern Lake Huron in 1982.

INTRODUCTION

The life cycle of the sea lamprey *(Petromyzon marinus)* after hatching consists of three stages: the

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1 This study was part of a program conducted by the U.S. Fish and Wildlife Service under contract with the Great Lakes Fishery Commission.

larval, parasitic or lake-dwelling, and spawning adult. Treatments with 3-trifluoromethyl-4-nitrophenol (TFM), a selective lampricide (Howell et al. 1964), have reduced significantly the numbers of sea lamprey larvae in tributaries and parasitic adults in most areas of the Great Lakes. Because parasitic-phase sea lampreys are difficult to obtain for study and observe in their natural habitat, the stage is the least understood in the life cycle of this Great Lakes invader.

Previous mark and recapture studies in northern Lake Huron showed that movement of parasitic sea lampreys was extensive, often interchanging among the lakes, but with no apparent pattern of migration (Smith and Elliott 1953; Moore et al. 1974). Although electric barriers to capture spawning-run sea lampreys were operated in many rivers at that time, few of the marked lampreys were recovered in streams; most were recaptured in the lakes (Petersen disc tags were used to mark the lampreys and became entangled in commercial fishery nets). These studies were conducted when lake trout was virtually extinct in Lake Huron and before completion of the first round of lampricide treatments in 1967 (Smith 1968).

Since the earlier studies, conditions have changed. Massive numbers of lake trout have been planted in Lake Huron annually beginning in 1973 (Great Lakes Fishery Commission 1983) and sea lampreys have been reduced through periodic applications of TFM.

Knowledge of the movements of parasitic-phase sea lampreys until spawning is essential to formulate new control methods aimed at further reducing the populations. We describe the marking of parasitic-phase sea lampreys over a 22-week period in two areas of northern Lake Huron and their subsequent recapture in Lakes Huron and Michigan. Information is included on the growth of lampreys during the parasitic stage.

MARKING OF SEA LAMPREYS

The sea lampreys used in the present study were captured by commercial trap net fishermen in statistical district NH-1 (Smith et al. 1961) of northern Lake Huron in May-October 1981. Although lake whitefish *(Coregonus* *clupeaformis)* was the target species of the fishery, most sea lampreys were attached to lake trout *(Salvelinus namaycush)* captured incidentally in the nets. The commercial operators worked out of three ports in Michigan--DeTour, Mackinaw City, and Rogers City. Areas fished by operators out of Mackinaw City and DeTour overlapped and were combined into one area (north) covering about 1,677 km^2 of Lake Huron between the two ports (Fig. 1). The fisherman out of Rogers City worked from Hammond Bay to 13 km southeast of Rogers City, an area about 611 km^2 (south).

A total of 830 sea lampreys were marked and released, 398 in the north area and 432 in the south area (Fig. 1). Sea lampreys were marked by injecting rose and kelly green pigments into the posterior dorsal fin (Hanson 1972). From two to five stripes of pigment were injected into each dorsal fin: the color and number of marks identified the area and time of release in 11 2-week periods (beginning 24 May-6 June and ending 11-24 October). Rose pigment is more visible than kelly green and was always used in at least one of the stripes. Most lampreys were marked and then immediately released near the point of capture by the following procedure: after removal from the trap net they were anesthetized in a 75-μg/L solution of tricaine methanesulfonate, measured (total length in millimeters), injected with dye, revived in fresh water, and released. Lampreys that could not be marked immediately were transported in an insulated 48.5-L container, held at dockside in a wire mesh cage, marked during the evening, then transported and released near the pint of capture the next morning.

METHODS OF ANALYSIS

Marked sea lampreys were recovered in 1981 as parasitic adults in commercial fishing gear, and in 1982 as spawning adults in portable lamprey traps (Schuldt and Heinrich 1982) and large mechanical traps similar to those used at electrical weirs (McLain et al. 1965). Sampling of the commercial fishery from select ports and the operation of assessment traps on selected streams are used as methods to monitor the annual

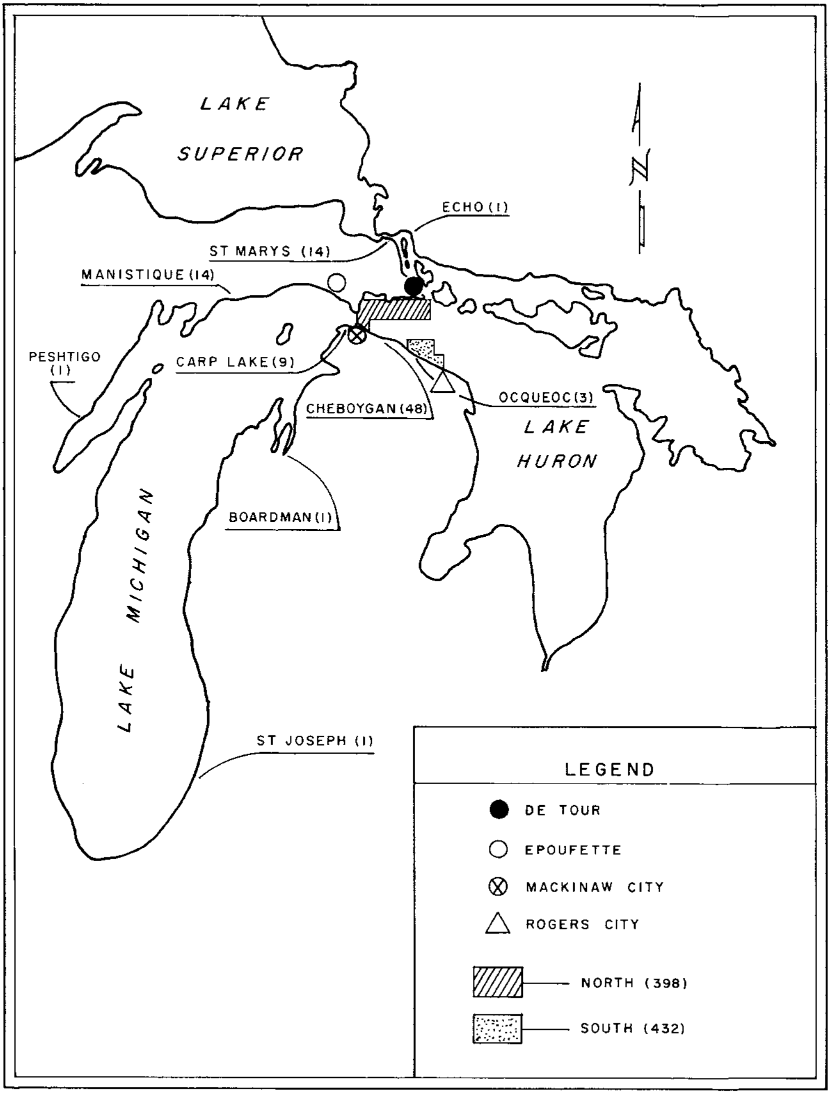

Figure 1. Areas of northern Lake Huron in which 830 parasitic-phase sea lampreys were marked and released in 1981, and the tributaries of Lakes Huron and Michigan where 92 marked lampreys were recaptured as spawning adults in 1982. The number marked in each area and the number recaptured in each tributary are in parentheses.

changes in the relative abundance of sea lampreys in the Great Lakes. A total of 2,169 parasitic-phase sea lampreys from 47 ports were examined for marks in 1981, and 39,969 spawning-phase adults from 41 tributary streams were examined in 1982. Chi-square distribution (X^2) was used to test differences between sampling and theoretical distributions for the following data combinations: all marked sea lampreys recaptured in 1982 (marking areas separated by north and south and then combined) by stream and by lake basin in proportion to the assessment trap catch of unmarked lampreys by stream and by lake basin. Distance from release to recapture was measured in kilometers from the geographic center of the marking area to the point of recapture.

Growth rates of the parasitic-phase sea lampreys were estimated by measuring total length of 830 lampreys over 22 weeks in 1981 (from 24-30 May to 18-24 October). The average growth in length for the entire period was estimated by the regression equation:

$$y = a + bx$$

where y = length in millimeters, and x = time in weeks. Regressions were plotted separately for lampreys from each area and for areas combined, then were tested to determine if data could be pooled (Ostle 1963).

Total lengths (in millimeters) were measured of all marked sea lampreys recaptured in 1982, but these lengths were not fitted into the regressions.

RECOVERY AND MOVEMENT OF MARKED SEA LAMPREYS

Of the 830 sea lampreys marked, 101 (12.2%) were recaptured. Other investigators reported recovery rates of 10.2% for a blocked spawning run of migrant sea lampreys (Applegate and Smith 1951), 17.2% (Smith and Elliott 1953) and 11.8% (Moore et al. 1974) for lampreys marked as feeding adults and recaptured in the parasitic and spawning phases, and 0.1% (1963-68) and 2.9% (1978-79) for lampreys marked in the newly transformed stage and recovered as spawning adults (L. H. Hanson, U. S. Fish and Wildlife Service, Millersburg, Michigan, personal communication).

AREAS OF RECOVERY

Although collections of sea lampreys were examined in all the Great Lakes, marked individuals were recovered only in watersheds of Lakes Huron and Michigan. Commercial fishermen recaptured nine marked parasitic-phase lampreys during the tagging period in 1981. Of these, eight were recaptured in the areas in which they were released (three in the north area and five in the south). The other was taken by a fisherman in northern Lake Michigan from Epoufette, Michigan, and had been released in the north area.

A total of 1,758 parasitic-phase sea lampreys from Lakes Michigan and Huron were examined for marks in 1981. Commercial fishermen captured 207 from 12 Lake Michigan ports (between Epoufette, Michigan, south to Sheboygan, Wisconsin) and 1,551 from 14 Lake Huron ports (DeTour, Michigan, south to Bayport, Michigan, and Blind River, Ontario, south to Southampton, Ontario).

In 1982, 92 of the marked sea lampreys were recovered as spawning adults in eight rivers of Lakes Huron and Michigan (Table 1, Fig. 1). Most of the marked sea lampreys, (66; 72%), were recaptured in three Lake Huron streams (Cheboygan, Ocqueoc, and St. Marys rivers), but 26 (28%) were taken in five tributaries of Lake Michigan (Manistique, Carp Lake, Peshtigo, Boardman, and St. Joseph rivers).

A total of 33,240 spawning-phase sea lampreys were examined for marks in the eight streams where marked lampreys were recovered. An additional 1,466 sea lampreys were examined from 10 other tributaries of Lakes Michigan (7) and Huron (3).

DISTANCES TRAVELED

Most recaptured sea lampreys apparently had not traveled widely, but were found near the area of release. Eight of the nine sea lampreys recaptured in 1981 were within the areas of release, but one lamprey from the north area had traveled about 90 km west into Lake Michigan. The time from release to recovery of the nine sea lampreys averaged 5 weeks (range 1-14 weeks).

Of the 92 lampreys recaptured in 1982, 70 (76%) were taken less than 100 km from the release area; 22 (24%) were found more than 100 km away. Distance from the north and south areas of release to the Cheboygan River, where 48 of the marked sea lampreys were recaptured, was about 50 km from each release area. Distances from the north and south areas to the recapture points on the St. Marys, Carp Lake, and Manistique rivers were 90 and 125, 61 and 87, and 164 and 190 km, respectively. The shortest distance traveled by a sea lamprey from release area to stream of recovery was about 18 km, from the south area to the Ocqueoc River. A few lampreys were found far from release areas. A sea lamprey marked in the north area traveled about 302 km to the dam on the Peshtigo River at Peshtigo, Wisconsin (released during the period 16-29 August 1981 and recaptured on 15 May 1982). Of those marked in the south area, one sea lamprey was recovered in the St. Joseph River at Berrien Springs, Michigan, 534 km from point of release (released during the period 19 July-1 August 1981, and recaptured on 3 May 1982). Average time from release to recovery of the 92 spawning-phase lampreys was 43 weeks (range 31-59 weeks).

RELATION OF AREA OF RELEASE TO POINT OF RECAPTURE

The percentage of the total number of sea lampreys marked and released in each of the two areas of northern Lake Huron in 1981 was similar to the percentage recaptured from each area in 1982. Of the 830 lampreys marked in 1981, 48% were released in the north area and 52% were in the south area, whereas of the 92 recovered in 1982, 46% had been marked in the north and 54% were from the south.

More than half of the marked sea lampreys taken in 1982 were trapped in the Cheboygan River (48), and of these, 33 had been marked in the south area and 15 in the north (Table 1). Fifteen marked sea lampreys were recovered from the St. Marys River, but here twice as many were collected from the north area (10) than from the south area (5). In other streams where assessment traps were operated, 14 marked sea lampreys were taken

Table 1. Number of marked sea lampreys recaptured in assesment traps
Lake Huron in Michigan (N = Mackinaw City east to DeTour, 39

(Total catch of sea lampreys [marked and unmarked] in a

Lake and river	Period, area (Nor S), and number									
	May 24-Jun 6		Jun 7-20		Jun 21-Jul 4		Jul. 5-18		Jul 19-Aug 1	
		S	N	S	N	S	N	S	N	S
	52	64	60	33	60	47	32	49	53	44
									Number	
Lake Huron										
Cheboygan (14,584)	1	5	3	5	1	7	2	2	2	2
St. Marys (3,868)[a]	2	–	1	-	1	1	1	2	3	–
Ocqueoc (1,794)	-	–	1	-	-	-	-	1		–
Total (20,246)	3	5	5	5	2	8	3	5	5	2
Lake Michigan										
Manistique (11,417)	1	1	2	1	1	1	-	2	3	–
Carp Lake (575)[b]	-	2	1[b]	-	1[b]	-	1	-	2	–
Peshtigo (475)		–	-	-	-	-	-	-		–
Boardman (172)		–	-	-	-	1	-	-		–
St. Joseph (355)		–	-	-	-	-	-	-		1
Total (12,994)	1	3	3	1	2	2	1	2	5	1
Grand Total (33,240)	4	8	8	6	4	10	4	7	10	3

[a]Includes 16 (1 marked) sea lampreys from a trap in the Echo River, a tri

[b]Not included in the assessment trap catch is about 300 lampreys incident
bank; of the 9 marked lampreys, 3 were found on the bank.

in 1982 of 830 released in 2-week periods in two areas of northern
8; S = Hammond Bay south to Rogers City, 432) in 1981.

Assessesmt traps in 1982 is given in parentheses.)

of marked sea lampreys released in 1981													
Aug 2-15		Aug 16-29		Aug 30-Sep 12		Sep 13-26		Sep 27-Oct 10		Oct 11-24			
N	S	N	S	N	S	N	S	N	S	N	N	S	Total
18	91	42	39	18	16	38	19	17	30	8			
Recaptured in 1982													
2	3	1	6	2	-	1	-	-	3		15	33	48
-	1	-	1	1[a]	-	-	-	1	-		10	5	15
-	-	-	-	1	-	-	-	-	-		2	1	3
2	4	1	7	4	-	1	-	1	3		27	39	66
1				-	-	-	1	-	-		8	6	14
-	-	1	1[b]	-	-	-	-	-	-		6	3	9
-		1	-	-	-	-	-	-	-		1	-	1
-	-	-	-	-	-	-	-	-	-		-	1	1
-	-	-	-	-	-	-	-	-	-		-	1	1
1		2	1	-	-	-	1	-	-		15	11	26
3	4	3	8	4	-	1	1	1	3		42	50	92

butary of the St. Marys River in Canada.

ally captured by rainbow smelt fishermen and discarded on the stream in the Manistique River (8 released in the north and 6 in the south); 9 from the Carp Lake River (6 released in the north and 3 in the south) of which 3 were among about 300 sea lampreys that had been discarded on the river bank by fishermen netting rainbow smelt *(Osmerus mordax);* and 3 from the Ocqueoc River (2 released in the north and 1 in the south). In addition, one marked sea lamprey was recaptured in each of the Peshtigo (released in north), Boardman (released in south), and St. Joseph (released in south) rivers.

On the basis of the total number of marked sea lampreys recaptured and the total assessment trap catches in 1982 (Table 1), significantly more marked lampreys were recovered in streams of Lake Huron than Lake Michigan ($X^2_{0.01} = 6.676$). (The catch in the Carp Lake River was-adjusted from 575 to 875 to include those lampreys examined for marks but not captured in traps.) By area of marking, the difference remained significant for the south ($x^2_{0.0} = 8.398$), but for sea lampreys marked in the north, the proportion recovered in Lake Michigan streams was within the expected range. The north release area is closer to Lake Michigan streams than the south one.

A comparison of the number of marked and unmarked (assessment trap catch) sea lampreys captured in each stream with the combined totals of marked and unmarked sea lampreys taken in the eight tributaries of Lakes Huron and Michigan showed non-random distribution of the recoveries in some streams. The number of marked sea lampreys recovered in the Carp Lake River was significantly more than expected ($X^2_{0.01} = 15.525$). The Carp Lake River is nearer the boundary of the two lakes than the Manistique River. More of those marked in the north area were recaptured in the St. Marys River ($X^2_{0.01} = 5.739$), and of those from the south, more were taken in the Cheboygan River ($X^2_{0.01} = 9.82$). The St. Marys River is closer to the north area, but the Cheboygan River is about equal distance from both areas. Distributions of various data combinations from all other streams were within expected ranges.

GROWTH OF SEA LAMPREYS

Sea lampreys in the north release area of Lake Huron were longer at the start of the study, and remained longer through October 1981, than those lampreys in the south area. Growth was linear in both areas ($P < 0.01$), but the regressions differed significantly ($F_{[2,832;\ 0.95]} = 2.485$) and could not be combined. The average growth of sea lampreys marked in the north area (N = 398) for the entire 22 weeks was estimated by the equation:

$$y = 228.2 + 9.5x; \ (r = 0.701)$$

The growth of lampreys in the south area (N = 432) was estimated as:

$$y = 211.7 + 9.2x; \ (r = 0.686)$$

Average length at the time of spawning of the recaptured sea lampreys was 458 mm (N = 42) for those marked in the north area and 440 mm (N = 50) for those marked in the south.

UNRECOVERED MARKED SEA LAMPREYS

Although the fate of those marked sea lampreys that were not recaptured could not be determined, we believe some indirect information suggests most of these lampreys remained within northern Lake Huron. Although more marked sea lampreys were captured in assessment traps in the Cheboygan River than in the St. Marys River, the rate of capture of marked to unmarked lampreys was about the same in each river, 3.3/1,000 and 3.6/1,000, respectively. Efficiency of assessment traps are not equal in these two streams; from 60% to 80% of the spawning run is trapped in the Cheboygan River, whereas only 10% to 25% in the St. Marys River (Marquette Biological Station, unpublished data). Simple ratios suggest that 60 to 80 marked lampreys may have been present in the spawning population in the Cheboygan River and 60 to 150 in the St. Marys River. Undetected marked sea lampreys were likely present in the other rivers where marked lampreys were recaptured, although probably not to the extent suggested in the Cheboygan and St. Marys rivers.

Marked sea lampreys likely migrated into other streams in northern Lake Huron where the spawning runs of adults are not monitored. Major river systems in the upper Peninsula of Michigan, such as the Carp and Pine rivers, are not trapped for sea lampreys because of the absence of suitable sites for the installation of devices. Surveys and chemical treatments of these rivers, however, indicate an abundance of larvae and suggest thousands of adult lampreys may be present in the spawning runs of each.

Mortality of the marked sea lampreys during the parasitic stage may have accounted for some of the other unrecovered specimens. The percentages of lampreys recovered that were marked in the newly transformed stage (0.1% and 2.9%: L. H. Hanson, U. S. Fish and Wildlife Service, Millersburg, Michigan, personal communication) compared to returns of those marked as feeding adults (12.2%; present study), indicate mortality is probably significant during the transition to first parasitic feeding. The rate of return from each of the 2-week periods in our study was about the same (Table 1), so any mortality would appear to have been uniform throughout May-October 1981.

POPULATION ESTIMATE

Although the present study was not designed to yield an estimate of a population of sea lampreys nor were the data collected in a manner consistent with an estimate model, we believe the information can supply some inferences into the size of the population of sea lampreys in northern Lake Huron. A major problem in most population estimates is defining the effects of bias created by immigration and emigration of marked and unmarked animals to and from a study area. All lampreys were marked in northern Lake Huron, but lampreys were examined for marks from tributaries of all the Great Lakes and some marked lampreys were recaptured in Lake Michigan. It would be difficult to define the geographical boundaries of the population if all of the available numbers were used. To minimize the effects of these factors, we considered only that information collected in northern Lake Huron. A simple proportion using the number of sea lampreys marked in 1981 (830) and the number recaptured in the Cheboygan, St. Marys, and Ocqueoc rivers in 1982 (66) with the number examined for marks in these three streams (20,246), suggests a population of about 250,000 spawning-phase sea lampreys in northern Lake Huron in 1982.

CONCLUSION

We suggest that some form of discreteness may exist in the sea lampreys of northern Lake Huron. Although past mark and recapture studies in northern Lake Huron showed sea lampreys moved extensively and that interchange among the Great Lakes was common, lampreys in this study not only remained in the lake but also near the geographical area in which they were marked. When they sought a stream in which to spawn, they tended to enter rivers near where they had fed. We speculate the sea lampreys remained in northern Lake Huron because prey species are more abundant than during the earlier studies. The reasons for the apparent segregation between lampreys in the two marking areas are less clear, but probably relate to environmental factors and not genetics. Further, the lampreys in the two marking areas differed in length throughout that portion of their parasitic life included in our study. Slight differences in abundance or size of prey again may be contributing factors for these differences.

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RESPONSE OF SPAWNING PHASE SEA LAMPREYS (PETROMYZON MARINUS) TO A LIGHTED TRAP[1]

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ABSTRACT

The response of upstream migrating adult sea lampreys *(Petromyzon marinus)* to light was tested in a two-compartment trap. Illuminated traps collected about five times as many sea lampreys (5,766 of 6,983, or 83%) as did dark traps: the difference was highly significant ($P < 0.01$). Comparisons between catches when both traps were either lit or dark, as well as when one was lit and the other dark, showed that illuminated traps caught significantly more lampreys ($P < 0.05$). The position of the trap in relation to the river bank also affected the catch of sea lampreys: trap 1 which was farthest from the bank captured 85% (5,919) of the sea lampreys. Although sea lampreys responded strongly to trap position, this response was modified by selected lighting arrangements. Illumination of traps could play a prominent role in the assessment and control of sea lampreys under a program of integrated sea lamprey management.

INTRODUCTION

Lampreys have been reported to exhibit negative responses to artificial light. As early as 1911, the negative reaction of lampreys to light was investigated, and much later, experiments with underwater lamps and electrofishing took advantage of this negative response to guide migrant Pacific and Arctic lampreys into nets

1 This study was part of a program conducted by the U.S. Fish and Wildlife Service under contract with the Great Lakes Fishery Commission.

and traps (Ben-Yami 1976). Most movements of migrant spawning sea lampreys occur at night, which also implies a natural aversion to light. An extreme avoidance of light was reported by Tuunainen et al. (1980) for the European river lamprey *(Lampetra fluviatilis)*. They reported bright street lights on a newly constructed bridge prevented lampreys from migrating upstream above the bridge. Sterba (1962) described European river lampreys as behaving photonegatively until the development of secondary sexual characteristics (2 weeks before the spawning period) and then remaining photo-positive during the breeding period.

Observations of sea lampreys *(Petromyzon marinus)* during spawning migrations throughout the Great Lakes did not indicate any particular attraction to artificial lights. Nighttime observations with flashlights of migrant lampreys below electrical weirs, dams, and natural barriers showed little reaction (either positive or negative) to the lights (H. H. Moore, U. S. Fish and Wildlife Service, Marquette Biological Station, personal communication).

Traps have been operated for many years to assess populations of spawning sea lampreys in tributaries of the Great Lakes (Smith and Tibbles 1980). Assessment traps captured about 40,000 sea lampreys in 43 U.S. and Canadian tributaries in 1982 (Daugherty et al. 1984). Observations at night in 1981 at a trap in the Cheboygan River, a tributary to northern Lake Huron near the Straits of Mackinac, indicated a flashlight beam apparently increased the number of lampreys entering the trap. These observations, along with results of a preliminary test, suggested a correlation between light and the capture of lampreys. Our study describes the response of sea lampreys to an artificial light placed in a two-compartment trap.

MATERIALS AND METHODS

A circular current created by a dam about 2 km upstream of the mouth of the Cheboygan River attracts large numbers of spawning-phase sea lampreys (Fig. 1). A trap was placed along the east bank of the river to intercept lampreys as they swam against the current.

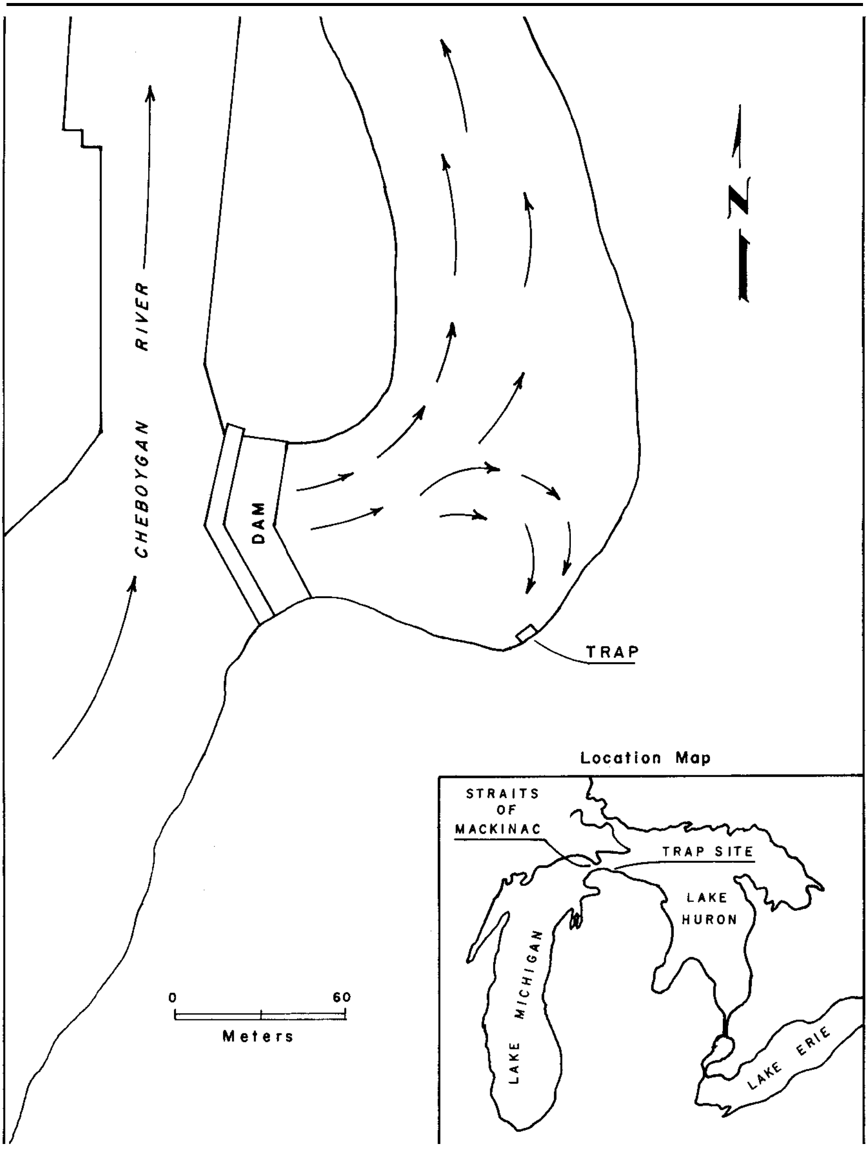

Figure 1. Location and position of test trap in the Cheboygan River, Lake Huron.

The trap, 182 x 182 x 122 cm, was divided into two equal compartments by placing a light-proof partition lengthwise in the trap (Fig. 2). The compartments were designated trap 1 (riverside) and trap 2 (shoreside). The trap was constructed of a wood frame covered with 6-mm galvanized wire screen. Tapered funnels extended into the trap 76 cm and terminated in a 13- x 15-cm opening. A 6-mm galvanized screen, 182 cm long x 122 cm high, extended into the river at a 45° angle to help guide lampreys toward the traps. Because sea lampreys migrate at night, all tests were conducted after darkness and ware begun 1/2 hour after sunset rather than at a set prescribed time. Thus, tests began at 9:50 p.m. EM' on the first day (18 May) and at 10:09 p.m. on the last day (6 June).

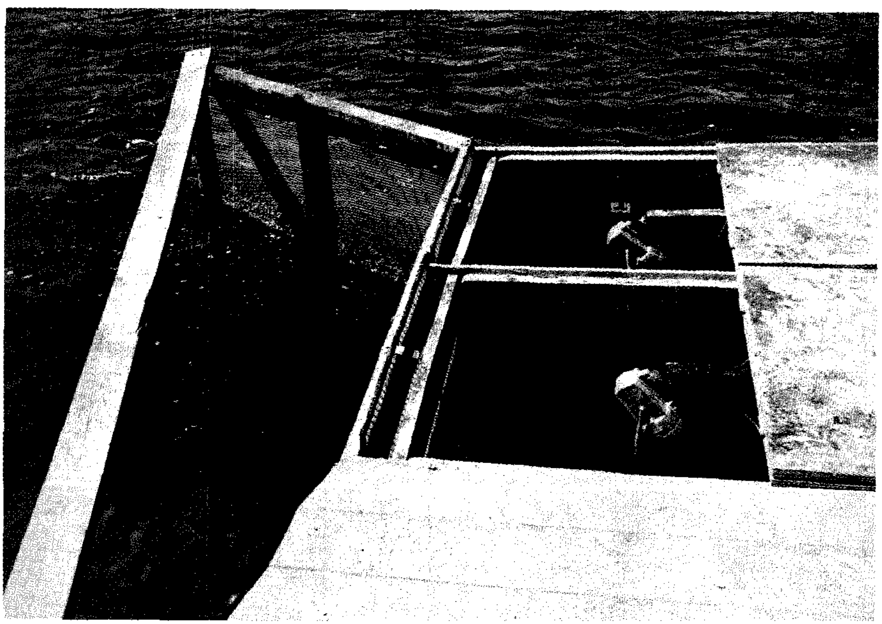

Figure 2. Test trap with lights used to determine the response of sea lampreys (Petromyzon marinus) to light in the Cheboygan River. (Trap 1, riverside: trap 2, shoreside.)

The light source used during preliminary tests in 1981 was an ordinary flashlight, powered by six dry cell, D batteries, with a 10-cm polished reflector, which produced 93,000 candlepower. For this experiment, the lighting system was modified slightly because dry cells are expensive, short-lived, and unreliable over long periods of usage. Instead, a Westinghouse PR 16, 12.5-volt bulb[2] and a 12-volt motorcycle battery were substituted. The light was suspended from the top of the trap and projected a narrow beam of light 75 mm in front of the funnel opening.

Tests were designed to determine the response of lampreys to light and position of the traps. Each evening for 20 nights the traps were operated during four 45-minute test periods; 30 minutes were allowed between each test to remove the lampreys and record the data (Table 1). Each 4-day sequence was tested five times. This schedule reduced biases from such factors as time of night, trap position, day of test, water temperature, and water level.

Table 1. Lighting schedule for a two-compartment trap in the Cheboygan River, Lake Huron.

(L indicates trap lit; D indicates trap dark. Each test period was 45 minutes, and the schedule was repeated every 4 days for 20 days.)

Evening test period	Day 1		Day 2		Day 3		Day 4	
	Trap 1	Trap 2	Trap 1	Trap 2	Trap 1	Trap 2	Trap 1	Trap 2
1	L	L	L	D	D	D	D	L
2	D	D	D	L	L	L	L	D
3	L	D	L	L	D	L	D	D
4	D	L	D	D	L	D	L	L

[2]Mention of a trade name does not constitute recommendation or endorsement by the U.S. Government.

Statistical analyses used to evaluate the data included Student's t-tests, paired Student's t-tests, and linear regressions. The significance level was established at $P = 0.05$.

RESPONSE OF SEA LAMPREYS TO LIGHT

Sea lampreys responded positively to a light placed inside the trap. A total of 6,983 adult sea lampreys were captured in the double compartment trap over the 20-day period. Overall, about five times as many lampreys were collected when traps were illuminated (5,766) than when dark (1,217); the difference was highly significant ($P < 0.01$). Every comparison, including both traps lit or dark and one lit and the other dark, demonstrated that illuminated traps consistently caught significantly more lampreys.

The strongest response of sea lampreys to light was in Test A where trap 1 was lit and trap 2 dark (Table 2). When presented with this choice, 3,218 of 3,365 (96%) sea lampreys selected the illuminated trap. A comparison of the catches in Test A with Test B (no lights) shows about 4.6 times more lampreys (3,365 versus 734) were taken in Test A than Test B.

Surprisingly, fewer sea lampreys were captured in Test C (both traps lit) than in Test A. About 36% fewer lampreys responded to Test C in which both traps were lit, compared with Test A in which only trap 1 was lit. Perhaps the presence of both lights created a threshold for photophobia which was not reached with one light and lampreys did not enter either trap. For whatever reason, about 56% more lampreys were captured in Test A. A comparison of the catches between Test B and Test C shows that traps caught about three times as many lampreys when both were illuminated as when both were dark.

Results of Test D (trap 1 dark, trap 2 lit) also showed a strong response of sea lampreys to light. In Test D, sea lampreys overcame the prominent light-independent effect of trap position shown in Tests B and C, and selected trap 2 over trap 1. In Tests B and C, 82% (2,365 of 2,890) of the lampreys were captured in trap 1. The ratio of lampreys in trap 1 versus trap 2

Table 2. Response of sea lampreys to four 45-minute tests at night in a two-compartment trap in the Cheboygan River, Lake Huron, from 18 May to 6 June 1982.

(Traps were illuminated with a 12.5-volt bulb; position of trap 1 was riverside and trap 2 was shoreside.)

	Number of sea lampreys captured								
	Test A		Test B		Test C		Test D		
Date	Trap 1 (light)	Trap 2 (dark)	Trap 1 (dark)	Trap 2 (dark)	Trap 1 (light)	Trap 2 (light)	Trap 1 (dark)	Trap 2 (light)	Total
May 18	100	2	56	5	63	6	9	10	251
19	511	15	147	29	297	129	51	42	1,221
20	60	0	10	1	133	23	30	13	270
21	536	12	51	14	125	74	29	47	888
22	50	8	44	6	17	8	22	22	177
23	12	0	4	0	24	2	1	18	61
24	156	10	9	2	243	40	7	2	469
25	124	53	84	8	222	50	24	42	1,207
26	482	42	137	25	173	31	108	130	1,128
27	22	0	8	3	91	4	9	10	147
28	65	0	0	0	29	4	4	9	111
29	99	0	6	1	87	8	6	1	208
30	240	3	10	1	12	3	21	21	311
31	17	0	47	0	4	0	1	4	73
June 1	33	0	0	0	62	3	4	7	109
2	15	0	2	0	30	2	0	0	49
	54	0	1	1	8	1	2	6	73
4	5	1	4	4	48	16	4	3	85
5	8	0	3	0	49	8	2	2	72
6	29	1	5	6	20	7	2	3	73
Trap total	3,218	147	628	106	1.737	419	336	392	6,983
Test total	3,365		734		2,156		728		6,983

was 6:1 and 4:1 in Tests B and C, respectively. When lampreys were presented with the choice of trap 1 dark and trap 2 lit, 54% of the lampreys selected trap 2 for a corresponding ratio of 0.86:1.

Daily catches from Test D compared with those in Tests A-C also showed that the response to light was stronger than the position effect of trap 1. On a daily basis, trap 2 equaled or exceeded trap 1 on 15 of 20 days (75%) in Test D, as compared with only 1 day in Test B. In Tests A and C, the catch in trap 2 never exceeded the catch in trap 1. Thus in Test D, light apparently caused lampreys to overcame bias for position of trap 1.

The positive response of lampreys to light was especially evident in Test A in the last 10 days of the study. In this test, when lampreys were presented with the choice of trap 1 lit or trap 2 dark, 565 of 570 (99%), or a ratio of 113:1 lampreys, selected trap 1. During the first 10 days of the study, the ratio of lampreys selecting trap 1 was 19:1 (2,653 to 142). Because of the large daily variation in the catches of lampreys, these differences were not statistically significant. Lampreys migrating later in the run appear to respond at a much higher rate to the lighted trap than earlier migrants because of greater sexual maturity.

The position of the trap (position effect) contributed significantly to the catch rates. Trap 1 caught about five times as many lampreys as trap 2 (5,919 to 1,064); the difference was highly significant ($P < 0.01$). We anticipated that trap 1 would catch more lampreys because the flow of water in trap 1 was stronger than in trap 2, and trap 1 was adjacent to the leading wing. Both of these factors probably contributed to the strong preference of lampreys for trap 1. The number of lampreys captured in Test B, in which both traps were dark, showed sea lampreys selected trap 1 over trap 2 in a ratio of about 6:1 (628 to 106). When both traps were lit (Test C), the ratio of lampreys selecting trap 1 was about 4:1 (1,737 to 419). The ratios were not significantly different between Tests B and C. In Test A (trap 1 lit and trap 2 dark), sea lampreys responded to trap 1 at a ratio of 22:1 (3,218 to 147). The strong response of lampreys to trap 1 in

Test A appears to be due to the combined effects of trap position and light. The results of Tests A-C showed sea lampreys responded strongly to the position effect, but in Test D the light was strong enough to overcome the position effect.

DISCUSSION

The Great Lakes Fishery Commission, which is responsible for sea lamprey control, is committed to a program of integrated sea lamprey management (Smith and Tibbles 1980). The concept involves the application of physical, chemical, and biological techniques to exert optimum impact on a target organism. In addition to the present method of selective toxicants (Applegate et al. 1961; Howell et al. 1964), other methods considered feasible in sea lamprey management include the sterile male technique (Hanson and Manion 1980), pheromone attractants (Teeter 1980), and barrier dams and traps (Hunn and Youngs 1980). Barrier dams, with accompanying traps, contribute to sea lamprey management in several ways. For example, the barriers can greatly reduce the spawning habitat available to lampreys, and effective and efficient traps can reduce the number of lampreys available for spawning. In addition, traps located at barriers to migration and positioned to intercept lampreys on their spawning runs can provide a source of live specimens for the sterilemale technique.

Although our study demonstrates a strong response of lampreys to light, we do not believe sea lampreys can be attracted from a great distance with an artificial light source. Rather than a true or direct attraction to light, we believe the study demonstrates the "light at the end of the tunnel" effect. Tests with sockeye salmon *(Oncorhynchus nerka)* showed the highest percentage (88) of fingerling salmon were induced to pass through a tunnel by a combination of water velocity and a downstream light (Blahm 1963). The percentage of sea lampreys captured in Test A in the present study showed similar results.

The response and behavior of fish (lampreys, in particular) toward artificial light is not well understood. For those fish species that demonstrate phototaxis, response may vary significantly according to *age, sex,* spawning condition, and season. The effectiveness of light on attraction of fish may be affected by transparency of the water, power and color of the light, weather, temperature, phase of the moon, and diverse reaction of individual fish within the same species (Ben-Yami 1976).

Present control and management of sea lamprey populations rely on the selective lampricide, 3-trifluoromethyl-4-nitrophenol (TFM), and any control measure to supplement TFM treatments would be of great benefit to the program. We believe the results of this study point out the need for additional investigation of the response of sea lampreys to light and of the feasibility of using light as a method of attracting *or* repelling sea lampreys.

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