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 Fishery Commission

TECHNICAL REPORT No. 27

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MOVEMENT AND RECAPTURE OF PARASITIC-PHASE SEA LAMPREYS (*PETROMYZON MARINUS*) TAGGED IN THE ST. MARYS RIVER AND LAKES HURON AND MICHIGAN, 1963-67

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by

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ABSTRACT

Recoveries of 477 (11.8%) of 4,048 tagged parasitic-phase sea lampreys showed that lampreys moved extensively and that interchange between the Great Lakes was common. Of 93 recoveries from 2,265 tagged lampreys released below the navigation locks in the St. Marys River, 80 were in Lake Huron, 12 in Lake Superior, and 1 in Lake Erie; of 3.59 recaptures from 1,666 released in northern Lake Huron, 331 were in Lake Huron, 25 in Lake Michigan, and 3 in the St. Marys River; and of 25 recaptures from 117 released in Lake Michigan, 21 were in Lake Michigan and 4 in Lake Huron.

Of the 477 sea lampreys recovered, 209 (44%) were captured more than 15 km from the locality of release; 42 had traveled 160-628 km (average, 275 km) before they were recaptured.

Among recaptures from sea lampreys released in northern Lake Huron, 240 (67%) were recovered within 15 km of the release point in less than 50 days after release; only 12 were recaptured within this radius after 50 or more days of liberty.

Probability of recapture was not influenced by size among sea lampreys longer than 205 mm (total length), but the lampreys recaptured at the greater distances from the tagging localities tended to be large. All of 34 lampreys recaptured more than 150 km from the point of release were longer than 254 mm (average, 418 mm) when tagged and 9 recaptured more than 300 km away were longer than 354 mm (average, 441 mm).

Four sea lampreys 345-445 mm long when tagged in November or early December were recovered in mid-September of the following year, at least 2 months after the end of the normal spawning season. Suggested possible reasons for this unusual occurrence are the extension of the parasitic phase of the life cycle beyond the usual 12 to 20 months, late-season maturation of the gonads, disease, or deleterious effects of the tags.

INTRODUCTION

Information on the movement of sea lampreys in the Great Lakes during the parasitic phase of their life cycle is limited almost entirely to that from

1 Contribution 484 of the Great Lakes Fishery Laboratory, U.S. Fish and Wildlife Service, Ann Arbor, Michigan 48107. This study, which is part of a program conducted by the Service and the Canadian Department of the Environment under contract with the Great Lakes Fishery Commission, was completed while the first and second authors were on the staff of the Laboratory.

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two studies. Smith and Elliott (1953) who reported on the movement of 38 lampreys from 219 parasitic-phase lampreys tagged and released in Lake Huron near Cheboygan, Michigan, found no distinct pattern of migration. One lamprey was recovered in Lake Michigan, and two were recovered more than 325 km from the tagging locality. Applegate and Smith (1951), who reported on the dispersion of a spawning run of sea lampreys partly obstructed from entry into the upper Cheboygan River, a tributary of Lake Huron, found that the diverted lampreys moved in all directions from the tagging site. Most followed the Lake Huron and Lake Michigan shoreline of the Lower Peninsula of Michigan. One lamprey was recovered about 240 km from the place of release.

In the present study, we tagged 4,048 sea lampreys in the St. Marys River, northern Lake Huron, and Lake Michigan to gain further insight into the distances and directions and other characteristics of their movement, and to evaluate the implications of the findings for sea lamprey control.

MATERIALS AND METHODS

The 4,048 sea lampreys tagged and released in Lakes Huron and Michigan in August-December 1963-66 were collected in several localities (Table 1, Figs. 1 and 2) and by several methods. In the St. Marys River, lampreys were collected below the navigation locks at Sault Ste. Marie, after they had been attracted to the turbulence created by a slowly moving boat powered by an outboard motor (Dahl 1968); 2,012 were caught in a surface tow net, 139 in dip nets, and 114 in an electrified otter trawl. In other areas lampreys were taken while feeding on fish captured in gill nets (1,382), trap nets (395) or pound nets (6). Most of the feeding lampreys were taken at three State of Michigan localities in northern Lake Huron: 1,000 off St. Ignace from gill nets fished for lake whitefish (Coregonus *clupeaformis); 300* off De Tour from trap nets fished for lake whitefish; and 308 off Port Dolomite from gill nets fished primarily for lake herring *(Coregonus artedii)* and lake whitefish. The numbers of lampreys removed for tagging from various prey species caught in nets were as follows: lake whitefish, 1,416; lake herring, 240; walleye *(Stizostedion* V. *vitreum),* 51; yellow perch (Perca *flavescens),* 38; round whitefish *(Prosopium cylindraceum),* 27; and deepwater ciscoes (Coregonus spp.), 11.

Tagging procedures were closely similar to those described by Applegate and Smith (1951). The sea lampreys were anesthetized with a 75-ppm solution of tricaine methanesulfonate (M.S. 222), measured (total length in millimeters), weighed (in grams), tagged with Petersen tags, and released near the locality of capture. Lampreys caught in experimental gear were marked almost immediately after capture; those from the commercial fisheries were held in live cages until they were tagged (usually within 1 week). The inscription on the plastic discs requested that the tags be forwarded to the U.S. Fish and Wildlife Service, Great Lakes Fishery Laboratory, Ann Arbor, Michigan (one series of tags), or to the Service's Biological Station at Marquette, Michigan (a second series). No reward was offered for return of tags in 1963-65, but $1 per tag was paid near the end of the study (beginning November 1, 1966).

Table, 1. Number of sea lampreys tagged and released at different localities in the St. Marys River and Lakes Huron and Michigan between August 1 and December 20, 1963-66, and (in parentheses) the number recovered in 1963-67. (1)

Locality*	Year 1965	Year 1966	Total' Number tagged	Total' Recoveries Number	Total' Recoveries Percentage
St. Marys River	826 (41)	877 (32)	2,265	93	4.1
Northern Lake Huron					
De Tour	300 (38)	-	300	38	
Port Dolomite	202 (40)	106 (17)	308	57	
St. Ignace	279 (121)	721 (134)	1,000	255	
Cheboygan	51 (9)	-	51	9	
Oscoda	7 (0)		7	0	
Subtotal, Lake Huron	839 (208)	827 (151)	1,666	359	21.5
Lake Michigan					
North Shore					
Brevort	8 (2)	21 (4)	29	6	
Epoufette	15 (4)	10 (4)	25	8	
Naubinway	14 (4)	5 (0)	19	4	
Manistique	3 (1)	-	3	1	
West Shore					
Menominee	2 (0)		2	0	
Baileys Harbor	13 (1)	-	13	1	
Past Shore					
Ludington	24 (4)	2 (1)	26		
Subtotal, Lake Michigan	79 (16)	38 (9)	117	2:	21.4
Grand total	1,744 (265)	1,742 (192)	4,048	477	11.8

[1] Not listed in separate columns of the table, but included in the totals, are 159 lampreys tagged in the St. Marys River in 1963 (6 recovered) and 403 in 1964 (14 recovered). Three lampreys in 1966 were not marked within the August l-December 20 period: one was tagged in the St. Marys River in March and two at St. Ignace in April. In the St. Marys River, 655 recoveries (including each recapture, for lampreys recovered more than once) made in tow nets, trawls, or dip nets during the period when lampreys were collected for tagging are not included here (see Table 6).

[2] See Figures 1 and 2 for locations.

Most of the tags were recovered during personal visits to commercial fishermen--primarily those in the general vicinity of the various tagging localities. The number of unreported recoveries is not known.

SIZE OF TAGGED SEA LAMPREYS

The average length and weight of sea lampreys marked varied with tagging date and among areas. In each tagging area, both measurements increased progressively (with few exceptions) in successive semimonthly periods from August to December. Inasmuch as year-to-year differences in average size were relatively small for given semimonthly periods in the major

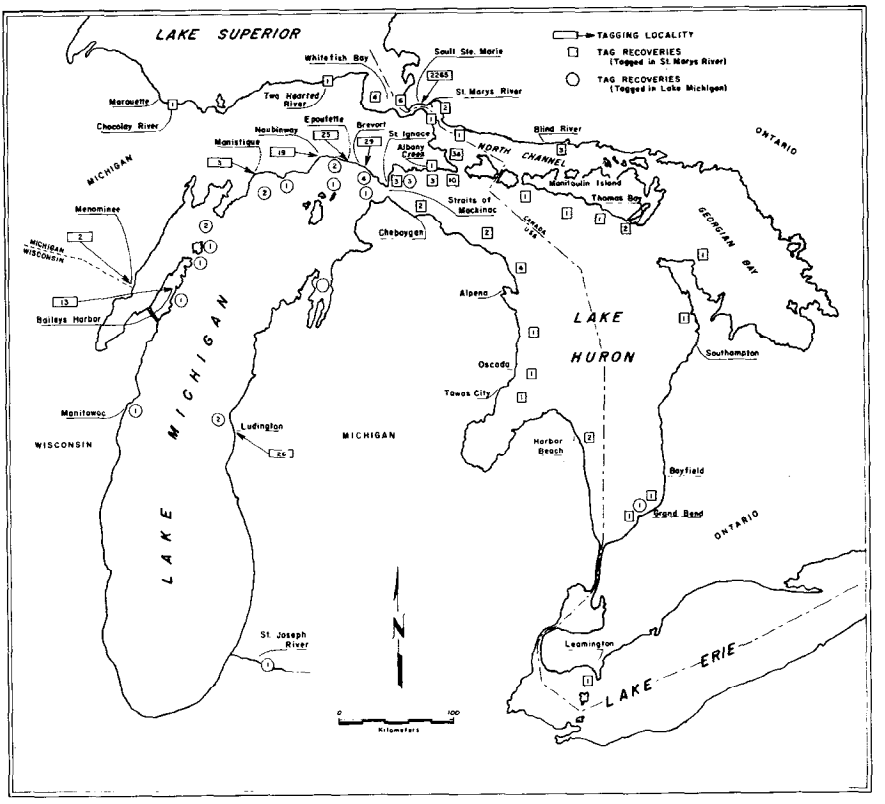

Fig. 1. Localities of release (rectangles with arrows) and recovery (squares and circles) for sea lampreys tagged in St. Marys River and Lake Michigan, 1963-67. Numbers released or recovered are shown inside the rectangles or squares.

tagging localities (Table 2), all length and weight data were combined within the different areas (Table 3).

Lampreys tagged in the St. Marys River were considerably larger than those marked in other areas in each of the semimonthly periods; the only exceptions were those marked in Lake Michigan November l-15 and December I-15. The simple average of the mean lengths (in millimeters), by area, for the periods September 16-30 through October 16-31, for example, were (in order of decreasing length): St. Marys River, 445; Lake Michigan, 398; St. Ignace, 389; Port Dolomite, 346; Cheboygan, 345; and De Tour, 326 (Table 4). Comparisons of average lengths for other combinations of 2- or 4-week periods common to two or more areas did not change this rank.

It is not known whether the differences in size of sea lampreys between areas were related to discreteness of populations, gear selectivity, differences in movements related to size, differences in availability of food, or other factors.

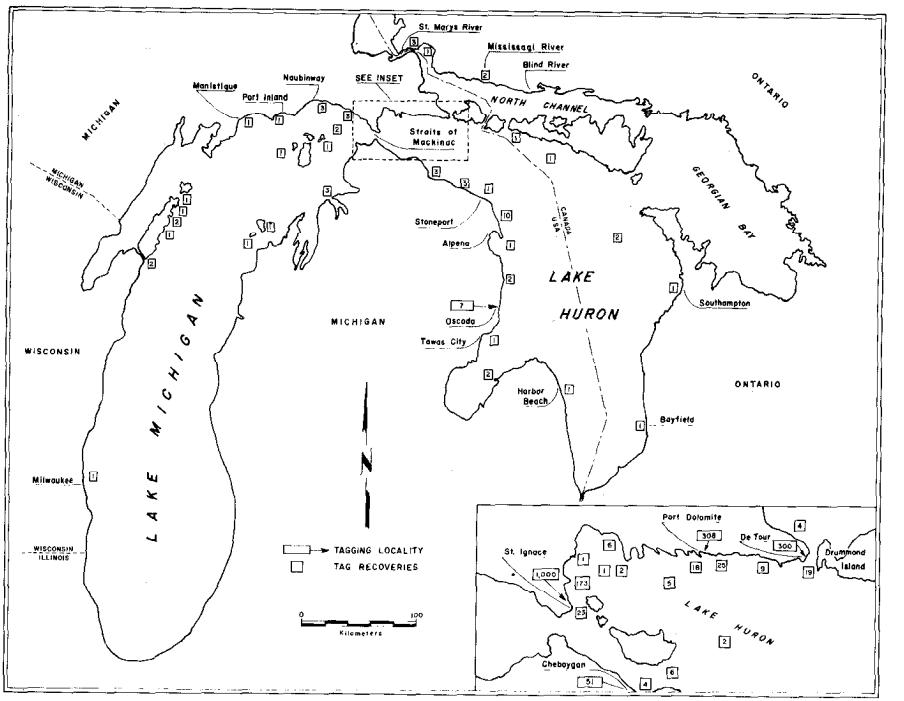

Fig. 2. Localities of release (rectangles with arrows; see inset at lower right) and recovery (squares) for sea lampreys tagged in northern Lake Huron, 1965-67. Numbers released or recovered are shown inside the rectangles or squares. Inset shows recoveries in northwestern Lake Huron.

MOVEMENT OF TAGGED SEA LAMPREYS

The localities of recovery of the 477 sea lampreys recaptured indicated that movement was extensive (Figs. 1 and 2; Table 5). A considerable number of lampreys had traveled long distances, and movement across political boundaries and between lakes was common.

Not included in the following description of the dispersal of sea lampreys from the individual tagging localities are 655 recoveries in experimental gear during the tagging periods in the St. Marys River. The degree of attraction to the boat, propeller turbulence, or both, was demonstrated by the large number of multiple recaptures (Table 6). (Multiple recaptures were possible because all but 16 of the recovered lampreys were released after the tag number, date of recapture, and length were recorded.) The time from tagging to first recapture was O-67 days; from first to second recapture, O-48 days; from second to third, 1-49 days; and from third to fourth, 9-51 days. One lamprey was captured five times within 13 days.

Although some sea lampreys traveled long distances in a relatively short time, the recaptures in the St. Marys River showed that others remained in a

Table 2. Total lengths of sea lampreys tagged during semimonthly periods of different years in the St. Marys River, 1963-66, and at two localities in northern Lake Huron, 1965-66

Tagging locality, period, and year	Number of lampreys	Length (mm)		
		Mean	Range	Standard error
St. Marys River				
Oct. 1-15				
1965	87	429	285-635	6.0
1966	47	460	360-530	6.3
Oct. 16-31				
1963	1.59	423	310-560	4.1
1964	71	445	345-535	5.5
1965	398	443	290-565	2.3
1966	492	447	340-570	2.0
Nov. 1-15				
1964	308	452	290-585	3.0
1965	126	450	340-580	4.6
1966	167	471	370-570	3.0
Nov. 16-30				
1965	133	474	365-600	4.3
1966	115	415	360-590	4.5
St. Ignace				
Sept. 16-30				
1965	21	340	260-435	9.7
1966	90	317	255-520	5.5
Oct. 1-15				
1965	6	391	260-485	23.1
1966	86	390	270-520	5.9
Oct. 16-31				
1965	23	400	215-555	13.4
1966	250	407	260-565	3.7
Dec. 1-15				
1965	220	417	290-580	4.1
1966	92	415	330-545	4.6
Port Dolomite				
Oct. 16-31				
1965	27	361	256-454	3.7
1966	92	394	290-520	4.9
Nov. 1-15				
1965	58	389	310-515	6.2
1966	l	368	-	-
Nov. 16-30				
1965	54	378	280-520	8.4
1966	7	363	307-414	19.8

Table 3. Mean length (mm) and weight (g) of tagged sea lampreys released in the St. Marys River and various areas of Lakes Huron and Michigan, by semimonthly periods, 1963-66.[1]

[Number of sea lampreys in parentheses.]

Period	St. Marys River		Northern Lake Huron							Lake Michigan (all areas)	
			St. Ignace		Port Dolomite		De Tour		Cheboygan[2]		
	Length	Weight	Length	Weight	Length	Weight	Length	Weight	Length	Length	Weight
Aug. 1-15	-	-	300 (33)	53 (13) 51	-	-	-		-	226 (9)	-
Aug. 16-31	411 (1)	-	315 (75)	(37) 43	-	-	-		-	335 (8)	127 (2)
Sept. 1-15	-	-	338 (102)	(11)	312 (32)	(2)	308 (26)	47 (26)	320 (12)	391 (12)	185 (1)
Sept. 16-30	450 (6)	-	371 (111)	87 (73)	310 (16)	44 (16)	312 (89)	(2)	328 (13)	406 (9)	185 (1)
Oct. 1-15	440 (134)	130 (39)	391 (92)	101 (92)	343 (16)	53 (9)	328 (96)	(2)	351 (15)	396 (21)	121 (2)
Oct. 16-31[3]	445	143	406	107	386	91 (1 95	338	63 (50)	355 (11)	391 (7)	-
Nov. 1-15	455 (601)	155 (285)	-	-	389 (59)	(45) 96	-	-	-	490 (5)	195 (5)
Nov. 16-30	474 (248)	172 (179)	-	-	376 (61)	(58) 90	-	-	-	467 (27)	172 (27)
Dec. 1-15		169 (121)	416 (312)	123 (312)	386 (5)	(5)	-	-	-	495 (19)	206 (19)
Dec. 16-20	485 (32)	183 (32)	-	-	-	-	-	-	-	-	-

1 Four lampreys included in Table 1 are excluded here because they were not measured.

2 Lampreys tagged at Cheboygan were not weighed.

[3]Mean length of seven sea lampreys released in Lake Huron at Oscoda, Michigan, Oct. 16-31, was 307 mm.

Table 4. Average lengths (mm) of sea lampreys in different combinations of semimonthly tagging periods (from Table 3) that were common to two or more tagging localities.

Periods compared	Number of periods	Locality					
		St. Marys River	Lake Michigan	Northern Lake Huron			
				St. Ignace	Port Dolomite	Cheboygan	De Tour
Sept. 16-30 to Oct. 16-31	3	445	398	389	346	345	326
Sept. 1-15 to Oct. 16-31	4	-	396	376	338	338	322
Sept. 16-30 to Dec. 1-15	6	456	441	-	365	-	-
Aug. l-l.5 to Oct. 16-31 plus Dec. 1-15	7	-	377	362	-	-	-
Sept. 1-15 to Dec. 1-15	7	-	434	-	357	-	-

Table 5. Locality of release of tagged sea lampreys, number recaptured in different Great Lakes waters, and total percentage recaptured, 1963-67.

Tagging location	Number released	Area of recapture						
		Lake Superior	St. Marys River	Lake Huron	Lake Michigan	Lake Erie	Recaptures Total	Percentage
St. Marys River	2,265	12	0[1]	80	0	1	93	4.1
Northern Lake Huron	1,666	0	3	331	25	0	359	21.5
Lake Michigan	117	0	0	4	21	0	25	21.4
Total	4,048	12	3	415	46	1	477	11.8

1 For the St. Marys River, 655 recoveries (including each recapture, for lampreys recovered more than once) made in tow nets, trawls, or dip nets during the period when lampreys were collected for tagging are not included here (see Table 6).

Table 6. Numbers of sea lampreys recovered at the tagging locality in tow nets, trawls, or dip nets in the St. Marys River, 1963-66.

Year tagged	Number released	Number of times recaptured					Total
		1	2	3	4	5	
1963	159	8	1	-	-	-	9
1964	403	62	5	-1	-	-	68
1965	826	194	42	8	5	1	250
1966	877	260	52	14	2	-	328
Total	2,265	524	100	23	7	1	655
Percentage recaptured	-	23.1	4.4	1.0	0.3	<0.1	28.9

single locality (or returned to it) over relatively long periods. The time between first and last recapture at the tagging site exceeded 30 days for 16 lampreys, and was as long as 67 days.

St. Marys River

(Of 2,265 sea lampreys tagged and released below the locks in the St. Marys River at Sault Ste. Marie in 1963-66, 93 were recovered-80 in widely scattered localities of Lake Huron, 12 in southeastern Lake Superior, and 1 in western Lake Erie.

The Lake Huron recoveries comprised 10 off De Tour, 34 near Lime Island north of De Tour, 7 in North Channel, 1 in Georgian Bay, and 28 scattered throughout the open lake. Two of these recoveries were near the south end of Lake Huron, off Grand Bend, Ontario, some 420 km from the place of release.

Sea lampreys moved readily from the St. Marys River into Lake Superior. Five were recaptured in Lake Superior within 5 to 10 days after release in the river and three others within 25 days. Ten of the 12 recoveries were made within 60 km of the navigational locks at Sault Ste. Marie and 2 were made in sea lamprey weirs during the spawning season-l at the Two Hearted River (April 8, 1966) and 1 at the Chocolay River (June 21, 1965) near Marquette, 240 km west of the locality of release.

The lamprey recaptured in Lake Erie was caught near Leamington, Ontario, 628 km from the place of release, 153 days after it was tagged.

Dispersal of sea lampreys from the St. Marys River was thus primarily (87%) downstream and extended over a total distance of at least 868 km-628 km to the south and 240 km to the west. Although three lampreys were recovered near the Straits of Mackinac, none were recaptured in Lake Michigan.

Northern Lake Huron

Of 359 recoveries from 1,666 tagged sea lampreys released in northern Lake Huron, 83% were captured in the St. Ignace-De Tour area and the rest were widely scattered (Fig. 2). Of the 298 recoveries in the St. Ignace-De Tour area, 173 were taken 6 km north of St. Ignace, in Lake Huron. Of the recoveries in Lake Huron outside the St. Ignace-De Tour area, 10 lampreys were caught near Alpena, Michigan, 3 in the North Channel, 3 (released at De Tour) in the St. Marys River, and 20 at various points throughout the open lake. Twenty-four lampreys tagged in Lake Huron were recaptured at widely scattered localities in northern Lake Michigan and one was taken in the central western part of the lake, off Milwaukee, Wisconsin, 426 km from the tagging site.

Dispersal of sea lampreys from tagging sites in northern Lake Huron thus covered a range about as great as that from the St. Marys River: 426 km to the southwest (off Milwaukee), 69 km to the north (to the St. Marys River), and 357 km to the southeast (off Bayfield, Ontario).

Lake Michigan

Twenty-five sea lampreys recovered after being tagged in Lake Michigan in 1965-66 had moved in all directions from the release sites (Fig. 1). Recaptures in Lake Michigan were confined to the northern half of the lake except for one, tagged at Ludington, that was taken in the St. Joseph River, near Benton Harbor, Michigan, 240 km from the tagging site. Three of the lampreys that entered Lake Huron were captured near St. Ignace and one was taken off Grand Bend, Ontario, 450 km from the place of release.

The distance traveled by sea lampreys tagged in northern Lake Michigan was as great as 298 km to the south (off Manitowoc, Wisconsin) and 450 km to the southeast (Grand Bend, Ontario).

Distances moved in relation to days at liberty and length at time of tagging

Of the 477 sea lampreys recaptured, 209 (44%) had moved more than 15 km from the point of release, and 42 of these had traveled 160 to 628 km (Table 7).

Dispersal from the tagging area was rapid and extensive for lampreys tagged in northern Lake Huron, which provided by far the largest group of returns from a single tagging area (Table 8). The days between tagging and recapture ranged from 1 to 290. About 72% of the recaptures were made within 15 km of the place of release and 83% were made within 50 days. Only 12 lampreys were recovered within 15 km of the release point after 50 or more days at liberty (for all tagging localities combined this number was 16).

Sea lampreys recaptured at the greater distances from the tagging localities tended to be large (Table 9). The average length at tagging of groups of lampreys recovered at different distances from the tagging site were: 1-75 km, 393 mm; 76-300 km, 419 mm; and 301-628 km, 441 mm. All lampreys recovered more than 300 km from the place of release were longer than 354 mm at the time of tagging. For length groups represented by more than four recoveries, the percentages of the total recoveries that were taken

Table 7. Numbers of tagged sea lampreys recovered at various distances from the area of release.

Area of release	Distance (km)								Total
	<15	15-79	80-159	160-239	240-319	320-399	400-479	628	
St. Marys River	21[1]	55	18	7	6	2	2	1	93
Northern Lake Huron	260	59	19	12	6	2	1	0	359
Lake Michigan	6	11	5	0	2	0	1	0	25
Total	268	125	42	19	14	4	4	1	417
Percentage of total recaptured	56.3	26.2	8.8	4.0	2.9	0.8	0.8	0.2	100.0

[1] Recaptures in experimental gear excluded.

Table 8. Numbers of sea lampreys recaptured after different periods of liberty, following release in northern Lake Huron.

Distance traveled (km)	Days at liberty				Total recaptured	
	1-49	so-99	100-149	150-290	Number	Percentage
<15	240	7	1	4	252	12.0
15-39	23	3	1	1	28	8.0
40-79	19	6	3	2	30	8.6
80-119	3	3	4	1	11	3.1
120-159	2	3	1	2	8	2.3
>159	3	5	8	5	21	6.0
Total	290	27	18	15	350 [1]	-
Percentage of total recaptured	82.9	7.7	5.1	4.3	-	-

[1] No data on days at liberty for nine lampreys.

Table 9. Percentages of lampreys of different length groups (at tagging) recovered at various distances from tagging localities in the St. Marys River and Lakes Huron and Michigan, 1963-67.

Total length at tagging (mm)	Number tagged	Number recovered	Distance traveled (km)			
			1-75	76-150	151-300	301-628
155-204	6	0	-		-	
205-254	26	4		—		
255-304	252	49	93.8 75.0	25.0	2.1 -	-
305-354	472	78	85.9	6.4	7.7	
355-404	850	125	85.6	6.4	5.6	2.4
405-4154	1,140	110	80.0	8.2	9.1	2.7
455-504	917	82	79.3	12.2	7.3	1.2
505-554	328	26	57.7	19.2	15.4	7.7
555-604	52	3	100.0	-	-	-
605-654	1	0	-	-	-	-
Not measured	4	0	-	-	-	-
Total	4,048	477	-	-	-	
Average length (mm)	-	-	393	420	418	441

more than 75 km from the tagging locality increased progressively (one exception), from 6.2 for lampreys 255-304 mm long to 42.3 for those 505-554 mm long.

Rate of movement

Although the true rate of travel of sea lampreys between localities of tagging and recapture could not be determined because the routes traversed and times of arrival at the recapture localities were not known, some evidence was gleaned about the minimum rates of movement. The fastest rate recorded

for a lamprey that had traveled more than 15 km between release and recapture was 11.1 km per day, for a lamprey tagged at St. Ignace on December 3, 1966, and recovered at Middle Island near Alpena 13 days later. Eight lampreys tagged in Lake Huron that were recovered 80 to 194 km from the place of release within' 49 days (Table 8) had moved at an average minimum rate of 4.7 km per day (range, 2.8-11.1 km). The lamprey that moved the farthest-628 km, from the St. Marys River to Lake Erie-traveled at a minimum rate of 4.1 km per day.

RECAPTURE OF TAGGED SEA LAMPREYS

Sources of recaptures

At least 335 (87%) of the tagged sea lampreys recovered after release in Lakes Huron and Michigan were caught in gill nets of the commercial fishery (Table 10); 3 were recaptured in other fishing gear; and 8 were taken in tributary streams of the two lakes (method of recovery is not known for 38). Gill nets set for whitefish were by far the most productive source of lampreys for tagging (62% of the total) and of recaptures (72% of the number for which method of recapture is known).

Of the tagged lampreys recovered after release in the St. Marys River, 61 were caught in gill nets and 5 in tributary streams; method of recovery is not known for 27.

Gill nets are especially effective in recovering lampreys or other fish tagged with Petersen tags because the projecting buttons and pin readily

Table 10. Numbers of tagged sea lampreys released in Lakes Huron and Michigan that were recaptured in commercial fishing gear.

[Number of sea lampreys taken in different gears for tagging and release is ***given in*** parentheses.]

Principal species sought by fishery	Gear			
	Gill net	Pound net	Trap net	All gear
Lake whitefish	244 (1,104)	1 (0)	(312)	247 (1,416)
Lake herring	26 (240)	-	-	26 (240)
Deepwater ciscoes	59 (11)	-	-	(11)
Yellow perch	1 (0)	(6)	0 (32)	1 (38)
Walleye	-	-	0 (51)	0 (51)
Round whitefish	5 (27)	-	-	5 (27)
Total	335 (1,382)	1 (6)	(395)	338 (1,783)

become entangled in the twine (e.g., see Buettner 1961). Presumably some lampreys were recovered while feeding on fish entangled in the nets, however, since all or nearly all of the lampreys collected for tagging in the two lakes were caught while attached to fish, rather than by entanglement in the nets.

Only I 1 tags were recovered from 55,221 sea lampreys examined during the sea lamprey spawning migrations in 1964-67, mainly at electric barriers operated to intercept spawning runs on 24 tributaries of Lake Superior (16 along the United States shore and 8 along the Canadian shore) and 10 tributaries of Lake Huron (9 in Canada and 1 in the United States). Two were recovered at barriers in tributaries of Lake Superior and five in tributaries of Lake Huron. Three tagged lampreys were captured on spawning grounds in streams-one in Albany Creek, 50 km east of St. Ignace, and two in the Mississagi River, which flows into the North Channel-and one was killed during treatment of the St. Joseph River, Lake Michigan, with a sea lamprey larvicide.

Depth of recaptures

A total of 222 (60%) of the 367 recaptured sea lampreys for which depth of recapture is known were taken at depths less than 20 m (Table 11)-the depths at which most commercial fishing for whitefish was done. The many recaptures at these depths confirmed the observation of Applegate (1951) that sea lampreys tend to enter shallow water in the fall.

Recaptures in relation to length at tagging

There was no evidence that rate of recapture of sea lampreys more than 205 mm long was influenced by length at time of tagging (Table 12) although the rate varied among areas. In comparison with the average length of all tagged lampreys released in each tagging area, the average lengths of those later recovered were (at the time of release) 9 mm longer in northern Lake Huron (381 and 372 mm), 2 mm shorter in the St. Marys River (443 and 445 mm), and 7 mm shorter in Lake Michigan (410 and 417 mm).

Table 11. Numbers of tagged sea lampreys recovered at different depths.
[Depth is not known for 110 recoveries.]

Area of release	Depth (m) 0-19	20-39	40-59	60-79	80-99	100-119	120-139	Total
St. Marys River	3[1]	25	3	7	3	0	1	42
Northern Lake Huron	208	45	5	26	12	9	3	308
Lake Michigan	11	2	1	1	0	2	0	17
Total	222	72	9	34	15	11	4	367
Percentage of total recaptured	60.5	19.6	2.4	9.3	4.1	3.0	1.1	100.0

[1] Recaptures in experimental gear excluded.

Table 12. Numbers of sea lampreys tagged at different lengths in the St. Marys River and various areas of Lakes Huron and Michigan, 1963-66, and percentages recovered, 1963-67.

Total length at tagging (mm)	St. Marys River		Northern Lake Huron		Lake Michigan		Total	
	Number tagged	Percentage recovered	Number tagged	Percentage recovered	Number tagged	Percentage recovered	Number tagged	Percentage recovered
155-204	-	-	4	0.0	2	0.0	6	0.0
205-254	-	-	19	15.8	7	14.3	26	15.4
255-304	4	0.0	246	19.5	2	50.0	252	19.4
305-354	48	6.2	412	17.7	12	16.6	472	16.5
355-404	337	3.3	488	22.9	25	8.0	850	14.7
405-454	796	4.3	318	21.0	26	34.6	1,140	9.6
455-504	766	3.8	125	37.6	26	23.0	917	8.9
SOS-554	266	5.3	49	18.4	13	23.0	328	1.9
555-604	45	4.4	3	0.0	4	25.0	52	5.8
605-654	1	0.0	-	-	-	-	1	0.0
Not measured	2	0.0	2	0.0	-	-	4	0.0
Total	2,265	4.1	1,666	21.5	117	21.4	4,048	11.8

Recaptures in relation to dates of tagging and of recapture

No consistent relation existed between the date of tagging of sea lampreys in the St. Marys River-northern Lake Huron region and the likelihood of later recapture (Table 13). This result was unexpected, since the sea lampreys tagged in August were subject to recapture about 4 months longer than those tagged in December. In addition, the lampreys tagged early in each year of tagging were exposed to greater fishing pressure than those tagged late in that year-the fishery in northern Lake Huron, the source of most recoveries, was much more intensive in late summer and early fall than in other seasons.

This general pattern of the fishery was not reflected by the percentages of total recoveries of sea lampreys made in different months (Table 14). The recovery percentage was invariably highest during the month of tagging, and then usually decreased rather steadily during successive later months.

The number of recoveries had decreased sharply by July and was nil in August; however, four lampreys were recaptured in the open lake in mid-September (Table 15) at least 2 months after the end of the period in which they would have been expected to ascend a tributary, spawn, and die. These captures of large adult sea lampreys long after the spawning season were the first such records known to us for the Great Lakes or other natural waters. Three possible reasons for their occurrence are suggested: (1) If the lampreys had not been caught, duration of their parasitic life might have lasted a full season longer than the usual 12 to 20 months. Parker and Lennon (1956) reported that 3 of 22 sea lampreys reared in the laboratory failed to mature at the end of the usual parasitic cycle, and one of these (a specimen smaller

Table 13. Percentage recapture of sea lampreys tagged during different periods in the St. Marys River and three localities in northern Lake Huron, 1963-66.

Tagging period	St. Marys River		St. Ignace		Port Dolomite		De Tour	
	Number tagged[1]	Percentage recaptured	Number tagged[2]	Percentage recaptured	Number tagged	Percentage recaptured	Number tagged	Percentage recaptured
August 1-15	-	-	33	39.4	-	-	-	-
August 16-31	1	0.0	75	26.1	-	-	-	-
September 1-15	-	-	102	46.1	32	9.4	26	11.5
September 16-30	6	0.0	111	23.4	16	37.5	89	7.9
October 1-15	134	3.7	92	20.7	16	31.3	96	11.5
October 16-31	1,120	3.6	273	25.6	119	18.5	89	19.1
November 1-15	602	4.0		-	59	18.6	-	-
November 16-30	248	4.4	-	-	61	16.4	-	-
December l-l 5	121	9.9	312	19.2	5	0.0	-	
December 16-20	32	3.1	-	-	-	-	-	-
Total tagged, and percentage recaptured	2,264	4.1	998	25.6	308	18.5	300	12.1

[1] One lamprey tagged in March 1966 is not included here.
[2] Two lampreys tagged in April 1966 are not included here.

Table 14. Percentage of total recoveries in different months of sea lampreys tagged in the St. Marys River and Lakes Huron and Michigan, 1963-66.

Month of recovery	Month tagged, and total number recovered					Total
	August 36	September 94	October 195	November 70	December 79	4741
August	55.5	-	-	-	-	4.2
September	30.5	62.7	-	-	-	14.8
October	5.6	23.4	47.2	-	-	24.5
November	2.8	5.3	21.7	28.5	-	17.1
December		3.2	1.2	18.5	55.6	15.9
January	-	2.1	6.2	12.9	5.1	5.1
February	-	1.1	5.2	12.9	8.9	5.7
March	-	1.1	1.5	5.7	5.1	2.5
April	-	1.1	1.5	4.3	13.9	3.8
May	-	-	1.5	7.1	2.5	2.1
June	-	-	2.0	4.3	5.1	2.3
July	-	-	-	2.9	1.3	0.6
August	-	-	-	-	-	-
September	-	-	-	2.9	2.5	0.8

[1] No data on month of recovery for three lampreys.

Table 15. Data on release and recovery of four lampreys recaptured in Lake Huron in September, 2 months after the end of the spawning season.

Release				Recovery		
Date	Locality	Length (mm)	Weight (g)	Date	Locality	Days at liberty
Nov. 13, 1964	St. Marys River	345	-	Sept. 15, 1965	Stoneport	306
Nov. 13, 1964	St. Marys River	390	-	Sept. 15, 1965	South of Tawas City	306
Dec. 3, 1965	St. Ignace	445	126	Sept. 20, 1966	St. Ignace	290
Dec. 6, 1965	St. Ignace	381	80	Sept. 19, 1966	St. Ignace	287

than the others) was still immature when sacrificed after 26 months of parasitic life. (2) The lampreys may have been unusually late spawners. Smith and Braem (1973) reported that sea lampreys spawned in the Rock River, Lake Superior, on September 6, 1972-much later than they have been previously observed in the Great Lakes. (3) Disease, or deleterious effects of the Petersen tags, may have adversely affected maturation. Parker and Lennon (1956) suggested that unknown adverse conditions in the laboratory may have been responsible for the delay in maturity in their laboratory animals.

GROWTH OF TAGGED SEA LAMPREYS

Total length was obtained for 136 sea lampreys that had been recovered after varying intervals of freedom. The dependability of the measurements of sea lampreys at recapture no doubt varied among individual fishermen;

measurements were of freshly killed specimens, however, and should have been closely comparable with those made after the animals were anesthetized. On the average, their measurements closely paralleled those made by staff members, who measured 85 tagged lampreys at recapture. Of the tagged sea lampreys recovered, 25% apparently shrank, 35% showed no growth, and 40% increased in length (Table 16). A reduction in length was recorded for 57% of the sea lampreys that were at liberty more than 150 days.

The gradual shortening of sea lampreys during the spawning period may result from a cessation of feeding that precedes upstream migration (Berg 1948; Parker and Lennon 1956; Wigley 1959; Manion and McLain 1971). Most lampreys that were remeasured after more than 150 days of freedom were recaptured in weirs during the spawning period. Shrinkage was also recorded, however, for lampreys captured during the period when they would be expected to be actively feeding. Shrinkage of lampreys during this period might be attributable to the paucity of large prey fishes in Lakes Huron and Michigan, which would curtail their opportunity to feed, or to the presence of the tag:, which could reduce feeding efficiency or impair growth.

Table 16. Change in length of tagged sea lampreys by days at liberty, Lakes Huron and Michigan, 1963-66.

Increment of total length (mm)	Number recaptured by days at liberty					
	1-49	50-99	100-149	150-199	200-299	300-306
150 to 159	1	-	-	-	-	-
130 to 139	-	-	1	-	-	-
110 to 119	-	-	-	-	1	-
90 to 99	-	-	-	1	-	-
70 to 79	-	1	-	-	-	-
50 to 59	-	1	-	-	-	-
40 to 49	-	1	-	-	-	1
30 to 39	2	-	1	-	-	-
20 to 29	4	2	1	-	-	-
10 to 19	15	-	1	-	-	-
1 to 9	20	-	-	1		-
0	45	-	-	-	2	-
-1 to -9		-	-		-	-
-10 to -19	9	-	-	3	-	-
-20 to -29	2	2	1	-	-	-
-30 to -39	-	-	3	1	-	-
-40 to -49	1	-	1	-	2	-
-50 to -59	-	-	-	2	-	-
Increase	42	5	4	2	1	1
No change	45	-	-	-	2	-
Decrease	19	2	5	6	2	-
Total	106	7	9	8	5	1

IMPLICATIONS OF WIDESPREAD MOVEMENT IN SEA LAMPREY CONTROL

The general conclusion clearly warranted by the observations reported here-that large parasitic-phase sea lampreys move long distances (sometimes rapidly) in almost all directions throughout the four upper Great Lakes-emphasizes the international, interstate, and interlake nature of sea lamprey control. Although the application of selective lampricides (Applegate et al. 1961; Howell et al. 1964) in the tributaries of a single lake has been markedly effective in reducing sea lamprey populations within a few years (e.g., Lake Superior, in 1958-61) and although even local control operations may be beneficial, control throughout at least the three upper Great Lakes is obviously required to ensure continued long-term improvement in effectiveness.

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