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DURATION OF LARVAL LIFE AND MIGRATION OF SEA LAMPREY AMMOCOETES IN THE CARP LAKE RIVER, EMMET COUNTY

By

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An inclined-plane trap has been operated in the Carp Lake River, Emmet County, Michigan since October 1948. This trap, located about 1,500 feet above the stream mouth, blocks or traps upstream-migrating mature sea lampreys (Petromyzon marinus) and traps downstream-migrating ammocoetes and newly transformed adults (Applegate and Brynildson, 1952). Collections from the downstream trap in 1948-1959 and related studies in 1955-1959 have provided information on the downstream migration and duration of larval life of sea lampreys in the Carp Lake River. Some of the earlier observations were reported by Applegate and Brynildson (1952) and Stauffer (1956); more recent data are summarized in the present report. The evidence to date indicates strongly that the larval life of sea lampreys in the Carp Lake River is longer than the 4 or 5 years commonly assigned to it.

Methods

Information on the movement and duration of larval life of sea lamprey ammocoetes in the Carp Lake River was obtained by operation of the inclined-plane trap near the mouth of the river; collection of ammocoetes in the stream by electrofishing; inspection of the stream for lamprey redds; operation of a two-way weir in the river near its source in Lake Paradise (formerly Carp Lake); and by the marking of sea lamprey ammocoetes in the river and later recapture in the inclined-plane trap.

The annual downstream migration of newly transformed adult sea lampreys typically extended from late October to mid-April and usually reached its peak in late March and early April. Most ammocoetes were taken somewhat later, in April and May, although a few were trapped in nearly every month of the year (Applegate and Brynildson, 1952). Continuous operation of the inclined trap was attempted during the major migration periods, but spring flood conditions (frequently coinciding with the peaks of downstream movement) resulted in the loss of unknown numbers (probably large) of newly transformed adults and/or ammocoetes during all migration seasons[1] except 1958. Even though the inclined trap was out of operation during certain periods, the structure presumably was effective in blocking all upstream migration. Large samples (9 to 100 percent) of the catch of ammocoetes from the 1956 to 1959 migration seasons were preserved and later identified by Institute for Fisheries Research staff members. Of the ammocoetes in these four samples, 95 to 96 percent were sea lampreys (4 to 5 percent were Lampetra lamottei and Ichthyomyzon spp.).

In early summer and/or fall of 1955 through 1959, ammocoetes were collected with a direct-current shocker from three sampling areas (225 to 825 feet in length) in the Carp Lake River above the inclined trap (Figure 1). Stations designated "S-A" and "S-B" were in areas heavily populated by sea lamprey ammocoetes, while station "S-C" was in a less densely populated area near the upstream limit of the population. Although the same locations were sampled in all four years (1955-1959), Stauffer and Hansen (1958) showed that "shocked out" areas are quickly repopulated by ammocoetes. Therefore, the removal of earlier samples is not believed to have appreciably reduced the number of ammocoetes in subsequent samples from the same area.

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[1] A migration season was considered to extend from October to June; in this report the calendar year assigned to a given migration season was the one during which the major portion of the migration occurred. For example, the 1958 season extended from October 1, 1957 to June 30, 1958.

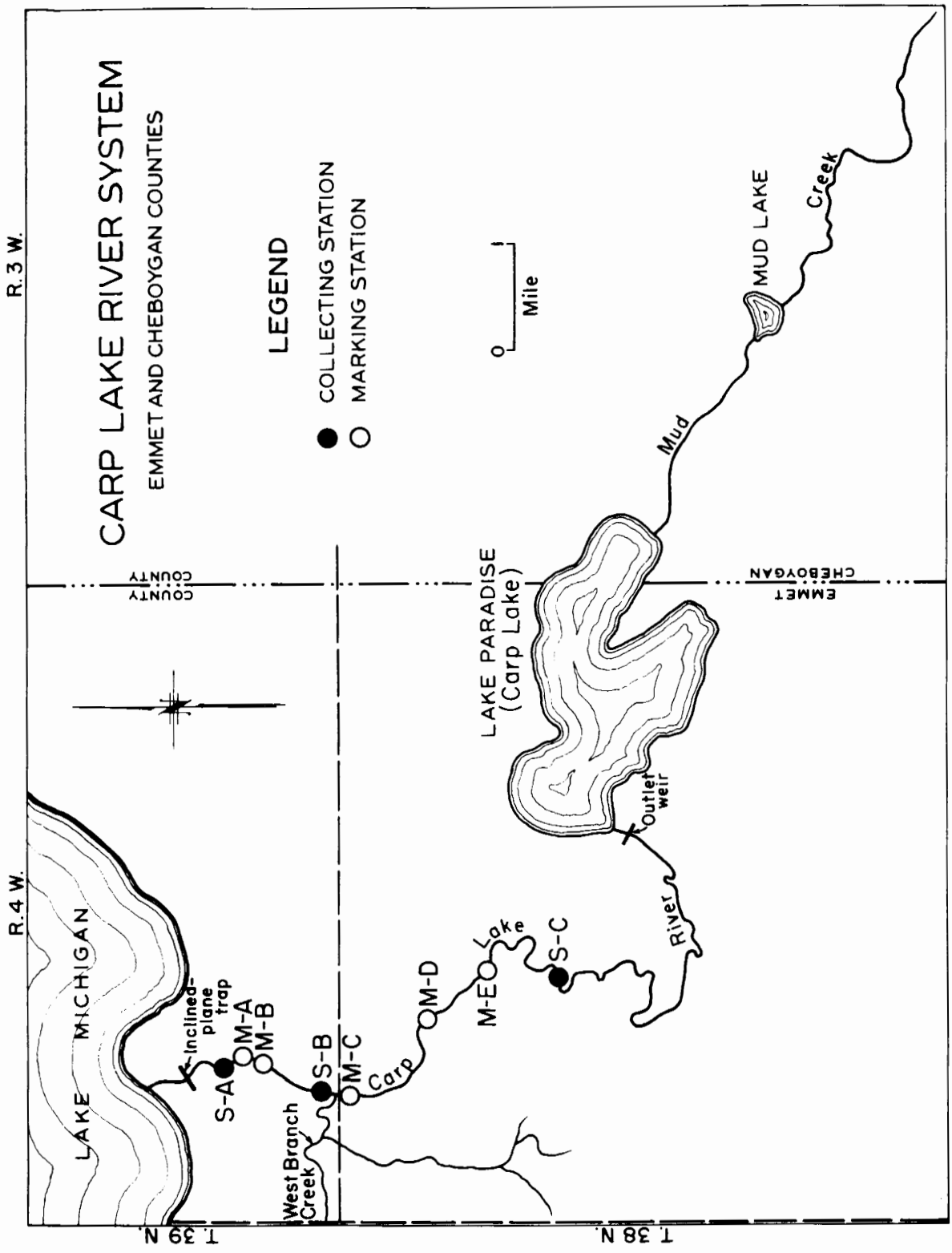

Figure 1.--The Carp Lake River System, showing stations where sea lamprey ammocoetes were collected in 1955-1958 (solid circles) and where marked ammocoetes were released in 1958 (open circles).

In late June or early July of 1955-1959, the entire stream above the inclined trap was inspected for sea lamprey redds. In general, two trained observers walked along or in the stream when it was low and clear. Any redd-like formation noted was then inspected by a third observer.

A second weir with an upstream and downstream trap was operated during portions of four consecutive migration seasons (1956-1959) near the source of Carp Lake River (Figure 1), to determine if any sea lampreys (mature adults, newly transformed adults, or ammocoetes) moved between the stream and lake. The screen size used was 1/8-inch during the season when most recently transformed adults and ammocoetes were being caught in the inclined-plane trap (near the mouth), and either 1/2- or 1/8-inch mesh during the period of migration of mature adults. As determined by the catch of the inclined trap near the mouth of the Carp Lake River, the operation of the outlet weir coincided with: (1) the major portions of the upstream spawning migrations of adults, (2) most of the downstream migrations of newly transformed adults (excluding the 1956 season), and (3) about 50 to 100 percent of the seasons (except 1956) during which downstream migrations of ammocoetes occurred.

A total of 2,187 sea lamprey ammocoetes in Carp Lake River were marked by subcutaneous injections of cadmium sulfide or mercuric sulfide (Wigley, 1952) in June and July 1958.[2] In this study, sea lamprey ammocoetes were collected with a direct-current shocker at five different locations (M-A to M-E in Figure 1),

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[2] The dye mark has persisted on ammocoetes held in aquaria for 20 months (experiment still in progress). The dye injection apparently did not cause extensive mortality, since the numbers recovered (33 and 38), from releases of 313 dye-marked and 311 tail-clipped ammocoetes (collected and released in the same area in Carp Lake River), with a direct-current shocker (3 collections in a 3 1/2-month period) were not significantly different at the 5 percent level. Although two types of marks, both of which may have caused some mortality, are being compared here, tail-clipping, a seemingly less injurious process, is not believed to cause appreciable mortality.

marked (differently at each station), and released near the point of capture. Within the limits imposed by accessibility and the availability of large numbers of sea lamprey ammocoetes for marking, an attempt was made to distribute the marking sites uniformly through the area of stream inhabited by ammocoetes. Marked specimens were recovered (as newly transformed adults or ammocoetes) in the inclined trap during the 1959 migration season (three marked ammocoetes were recovered during the direct-current shocker collections). All sea lamprey ammocoetes and recently transformed adults, that were caught after release of the marked ammocoetes, were examined for dye marks by Wilbert Wagner and the author. Although the dye mark was readily visible on many specimens, it was barely discernible on others. Some (probably few) marked specimens may have been overlooked. A random sample of 114 specimens was taken from an inclined-trap collection (from which the normal inspection had already removed 13 marked individuals) of 584 newly transformed adult sea lampreys and cross-sectioned to determine if the dye mark was concealed by the skin and/or pigment. A random sample of 143 specimens was also taken from a collection (from which the normal inspection had removed 5 marked specimens) of 722 sea lamprey ammocoetes, and similarly examined. None of the sectioned adults or ammocoetes were marked, indicating, at the 95-percent confidence level, that the number of marked specimens which might have been missed did not exceed 1 percent of the total collection.

Duration of larval life

There has been no known upstream escapement of adult sea lampreys at the inclined trap since 1949. However, since no examination was made of the spawning area or ammocoete population above the inclined trap in 1950-1954, the possibility of contamination during this period cannot be positively excluded. A second possible source of recruitment was Lake Paradise and its inlet, Mud Creek, which are in the headwaters of Carp Lake River. Although no sexually

mature sea lampreys have been reported from these waters since 1947 and no ammocoetes of any species were found in Mud Creek (4 collections), small (7- to 10-inch) feeding lampreys (tentatively identified as sea lampreys by C. T. Yoder) were reported caught in Lake Paradise during the spring of 1955, and three immature feeding adult sea lampreys were caught in the lake in the spring of 1956.[3] These observations suggested that sea lampreys may complete at least a portion of the parasitic phase of their life cycle in the lake. No sea lampreys were taken in the outlet weir, however, when it was operated in 1956-1959.

The belief that the sea lamprey did not reproduce in Carp Lake River during 1955-1959 was supported by observations on the spawning grounds between June 26 and July 14 each year (after the upstream migration of adults was essentially complete) and by the size distribution of sea lamprey ammocoetes collected from this stream by electrofishing. The inspections of the spawning grounds revealed no sea lamprey redds. No sea lamprey ammocoetes less than 2.1 inches long were caught in shocker collections in 1955-1959 (Table 1), although such specimens have been taken commonly in streams where spawning runs are not obstructed; furthermore, smaller ammocoetes of other species were encountered frequently in the Carp Lake River collections. Wigley (1953) found that modes of length-frequency distributions of age-group 0 and I sea lamprey ammocoetes, from July collections in Cayuga Lake Inlet, New York, were 0.5 and 1.5 inches, respectively; Applegate (1950) found modes at 1.0 and 1.9-2.1 inches in October in the Ocqueoc River, Michigan. (There is good agreement between the two studies as to the identities of sea lamprey ammocoetes of age-groups 0 and I if growth between July and October is considered.) Assuming a comparable early growth rate in the Carp Lake River, young-of-the-year

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[3] The sea lampreys were caught during sucker-removal operations. I verified the identification of one of the lampreys caught in 1956. C. Troy Yoder reported the 1955 captures and Jack Hammond reported those taken in 1956 (personal communications).

Table 1.--The total number, catch per hour, and length of sea lamprey ammocoetes collected in Carp Lake River with a direct-current shocker, 1955-1959

Station, and date of collection	Number of ammocoetes collected (all species)	Sea lamprey ammocoetes				
		Number collected	Percentage of sea lamprey ammocoetes in collection	Number caught per hour of shocking	Total length (inches)[1]	
					Minimum	Average
S-A						
July 10, 1955	713	562	79	336	2.2	4.0
October 2, 1955	335	218	65	109	2.9	4.2
June 26, 1956	358	147	41	37	2.1	4.2
October 11, 1956	437	137	31	68	3.1	4.2
July 9, 1957	246	87	35	23	3.3	4.8
November 6, 1957	195	79	40	45	3.6	5.0
July 1, 1958	282	167	59	84	3.8	5.1
October 17, 1958	179	92	51	48	3.3	5.2
June 30, 1959	264	106	40	51	3.5	4.9
November 23, 1959	300	162	54	78	3.4	5.1
S-B						
July 8, 1955	260	118	45	118	2.6	3.6
June 27, 1956	310	175	56	88	2.9	3.7
July 8, 1957	206	97	47	39	3.3	3.9
November 7, 1957	292	139	48	93	3.3	4.1
July 3, 1958	318	158	50	79	2.9	4.7
October 17, 1958	86	37	43	37	4.0	4.9
June 30, 1959	105	27	26	23	4.4	5.0
November 25, 1959	111	21	19	10	4.4	5.6
S-C						
July 7, 1955	175	51	29	47	3.2	4.2
July 9, 1957	217	22	10	7	3.9	4.8
November 7, 1957	303	42	14	39	3.6	4.7
July 1, 1958	449	36	8	31	4.0	4.9
October 16, 1958	402	45	11	36	4.1	5.0
June 29, 1959	150	2	1	1	4.8	4.8
November 24, 1959	38	0	0	0	...	...

[1] All sea lamprey ammocoetes were measured, except for five specimens in the collection at Station S-A in June, 1956.

ammocoetes were not present in the Carp Lake River collections of 1955-1959. Furthermore, the length-frequency distribution of the 1955 collections seems also to preclude the possibility of spawning having occurred in 1954. If an extremely slow rate of growth of a few individuals in the population accounted for the 2.1-inch ammocoete taken by electrofishing in June 1956 and the 2.3-inch specimen taken in the inclined-plane trap during the 1957 migration season, the conclusion is that the minimum age of ammocoetes still in Carp Lake River in 1960 is surely not less than 6 years (1954 year class), probably not under 7 years (1953 year class), and may be 11 years or more (1949 or earlier year classes).

On the basis of recovery of marked sea lampreys (recovered as ammocoetes or recently transformed adults) in the downstream trap of the inclined-plane trap, the population of sea lamprey ammocoetes remaining in Carp Lake River in 1958 was estimated as 166,755, using the Petersen method. Since the various size groups (0.1-inch) differed in their susceptibility to recapture (see below), separate estimates (Table 2) were made for each size group to obviate some of the underestimation that occurs if groups of specimens are combined which are different in their susceptibility to recapture (Cooper and Lagler, 1956). However, such stratification into small groups may result in an overestimation where the number of recaptures for certain size classes is small. To reduce this overestimation, the recaptures for each size group were reapportioned by running averages of three as outlined by Latta (1959).

A certain amount of underestimation due to variation (0.5-9.9 percent) in percentages of recapture from the different marking sites (see below), could not be avoided.

Although a large population of sea lamprey ammocoetes still remained in 1958, the shocker collections (Table 1) suggested that an appreciable decline was underway in 1959. Even though the catch of sea lamprey ammocoetes per hour

Table 2.--An estimate of the population of sea lampreys in the Carp Lake River, above the weir, in July 1958

Length (inches)	Number marked (M)	Number recaptured (R)[1]	R/M as percentage[2]	Adjusted R	Population estimate[3]
2.9-4.4	269	1	...	1	39,274
4.5	106	3	1.6	2	5,671
4.6	131	4	2.6	3	6,070
4.7	141	3	2.6	4	7,402
4.8	145	4	3.2	5	7,888
4.9	177	8	4.3	8	8,076
5.0	165	9	4.7	8	10,911
5.1	165	7	5.9	10	11,517
5.2	142	12	6.2	9	11,881
5.3	160	10	10.0	16	8,930
5.4	147	23	10.5	15	9,457
5.5	122	12	13.0	16	7,701
5.6	91	12	10.9	10	8,181
5.7	63	6	10.3	6	8,600
5.8	69	5	9.8	7	6,131
5.9	32	5	13.4	4	4,096
6.0	26	7	21.4	6	1,894
6.1	12	3	21.6	3	1,028
6.2	13	1	20.0	3	789
6.3	5	2	20.8	1	550
6.4-6.8	6	2	...	2	708
Total	2,187	139		139	166,755

[1] Recaptures were from the Carp Lake River inclined plane trap during the 1959 migration season.

[2] A weighted moving average of three of R and M was used to determine the percentage.

[3] Based on the adjusted number of recoveries for each size class.

with the shocker was not a sensitive index of abundance (due to several variables), the unusually low catch per hour at Station S-C in June, 1959 and the failure to collect any at this station in November, 1959 indicates that the population must be much reduced in the upper portion of the stream where, because of downstream migration (see below), reduction in numbers might first be expected. To a lesser degree, the catch per hour at the middle station (S-B) was also low in both 1959 collections, but no decline in catch occurred at the lowermost station (S-A). In addition to sea lampreys, other species of ammocoetes were found in the Carp Lake River collections. Since reproduction of these species was presumably uninhibited, the percentage of sea lamprey ammocoetes in the collections should decrease progressively if sea lamprey reproduction has been prevented. However, the percentage of sea lamprey ammocoetes in the catch did not change appreciably in 1955-1958. In 1959, on the other hand, the relatively low percentages (1, 0 and 26, 19) of sea lamprey ammocoetes in the collections from S-C and S-B supported the view that the population of sea lamprey ammocoetes has been markedly reduced in the upper portion of the stream.

Downstream migration of sea lamprey ammocoetes

The inclined-trap catches (1950-1957 migration seasons) and other instances of sea lamprey ammocoete migration, were described in some detail by Stauffer and Hansen (1958). The inclined trap on Carp Lake River continued to take large numbers of ammocoetes migrating downstream in the 1958-1959 migration seasons (Table 3). Over a period of 11 migration seasons, the catch of sea lamprey ammocoetes (estimated as about 74,000) nearly equalled the catch of newly transformed adults (Table 3). The marking study (Table 4) indicated that 2.4 percent of the total number of marked sea lamprey ammocoetes migrated downstream to the inclined trap before transformation (an additional 4.0 percent migrated as

Table 3.--Number of newly-transformed adult sea lampreys, number of ammocoetes, and size of sea lamprey ammocoetes caught in the Carp Lake River inclined-plane trap, 1949-1959 migration seasons

Migration season[1]	Number of recently transformed adult sea lampreys	Number of ammocoetes[2] (all species)	Sea lamprey ammocoetes		
			Number measured	Total length (inches) Range	Average
1949	7,969	492	...	...	...
1950	16,235	8,403	...	...	...
1951	15,103	12,647	...	...	...
1952	4,069	1,414	...	...	...
1953	6,861	2,838	...	...	...
1954	10,238	14,827	...	...	...
1955	3,893	3,725	...	...	...
1956	2,401	22,822	2,141	2.7-6.1	4.6
1957	2,640	4,884	3,875	2.3-6.9	4.8
1958	4,796	561	530	3.7-6.4	5.2
1959	4,796	5,640	5,365	3.7-6.8	5.2
Totals	79,001	78,253	...	...	...

[1] A migration season extended from October to June. The calendar year assigned to each was the one during which the major portion of the migration occurred. For example, the 1949 season extended from October 1, 1948 to June 30, 1949.

[2] Sea lampreys are believed to represent 95 to 96 percent of the total, based on identification of representative samples of ammocoetes in 1956-1959.

Table 4.--Number of marked sea lampreys recovered in the inclined trap, Carp Lake River, 1959 migration season

Marking station	Distance above inclined trap (miles)	Ammocoetes marked		Number recaptured as:			
		Number	Average length (inches)	Adults		Ammocoetes	
				Number	Percentage	Number	Percentage
M-A	1/2	616	4.9	11	1.8	32	5.2
M-B	1/2-2/3	313	4.7	4	1.3	14	4.5
M-C	2	516	5.2	47	9.1	4	0.8
M-D	3	540	5.2	25	4.6	1	0.2
M-E	3 1/2	202	4.9	0	...	1	0.5
Totals		2,187	5.0	87	4.0	52	2.4

newly transformed adults) in a single migration season. Thus both the marking study and the catch of the inclined trap demonstrated that downstream migration before transformation is of considerable consequence in Carp Lake River.

Average length (inches) of sea lamprey ammocoetes collected with the shocker in the fall before each migration season, and (in parentheses) average length of sea lamprey ammocoetes in the subsequent migration, were as follows: 1955, 4.2 (4.6); 1956, 4.2 (4.8); 1957, 4.5 (5.2); and 1958, 5.1 (5.2). The consistently larger average size of sea lamprey ammocoetes taken in the inclined trap strongly suggests that larger sea lamprey ammocoetes are more likely to migrate downstream, although individuals of all sizes present in the stream also appeared in the inclined-trap catch.

The annual downstream migration of sea lamprey ammocoetes does not appear to involve long distances. The percentage of marked specimens recovered in the inclined trap as ammocoetes decreased progressively as the distance of the marking site from the inclined trap increased (Table 3), indicating that migrations of short distances (1/2 to 2/3 mile) were more likely to occur than migrations of relatively longer distances (2 to 3 1/2 miles). Among the size groups marked, the distance of the marking sites from the inclined trap appeared to influence the recovery rate more than did the tendency of larger ammocoetes to move downstream.

Literature cited

Applegate, Vernon C.

1950. Natural history of the sea lamprey (Petromyzon marinus) in Michigan. U. S. Dept. Int., Fish and Wildlife Serv., Spec. Sci. Rept.: Fish. No. 55, 237 pp.

Applegate, Vernon C., and Clifford L. Brynildson

1952. Downstream movement of recently transformed sea lampreys (Petromyzon marinus) in the Carp Lake River, Michigan. Trans. Am. Fish. Soc., Vol. 81 (1951), pp. 275-290.

Cooper, Gerald P., and Karl F. Lagler

1956. Appraisal of methods of fish population study - Part III. The measurement of fish population size. Trans. 21st. N. A. Wildlife Conf., pp. 281-297.

Latta, William C.

1958. Significance of trap-net selectivity in estimating fish population statistics. Pap. Mich. Acad. Sci., Arts, and Let., Vol. XLIV pp. 123-137.

Stauffer, Thomas M.

1956. An investigation of the continued capture of downstream migrating recently transformed sea lampreys in the downstream trap of a weir on Carp Lake River. Mich. Dept. Cons., Inst. Fish. Res. Report No. 1474 (unpublished).

Stauffer, Thomas M. and Martin J. Hansen

1958. A preliminary report on the migration of sea lamprey ammocoetes in Michigan. Mich. Dept. Cons., Inst. Fish. Res. Report No. 1535 (unpublished).

Wigley, Roland L.

1952. A method of marking larval lampreys. Copeia, 1952, No. 3, pp. 203-204.

1959. The life history of the sea lamprey of Cayuga Lake, New York. Bull. U. S. Dept. Int., Fish and Wildlife Serv., Vol. 59, No. 154, pp. 561-617.

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References Cited

Ricker, W. E. 1958. Handbook of computations for biological statistics of fish populations. Bull. Fish. Res. Bd. Canada, 119: 300 pp.

Schumacher, F. X., and R. W. Eschmeyer, 1943. The estimate of fish population in lakes or ponds. Jour. Tenn. Acad. Sci., 18 (3): 228-249.

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