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1980 STUDY TO DETERMINE THE BURST SWIMMING SPEED OF SPAWNING-RUN SEA LAMPREYS (*PETROMYZON MARINUS*)

Research Completion Report

by

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Introduction

Sea lamprey control in the Great Lakes has been highly successful. The periodic treatment of sea lamprey producing streams with selective toxicants (Applegate et al. 1961; Howell et al. 1964; Manion 1969) has reduced the number of lampreys by approximately 90%.

Natural or man-made barriers prevent spawning-run lampreys from entering certain streams, or portions thereof, and thus reduce the numbers of streams that have to be treated. The Great Lakes Fishery Commission (GLFC) has, therefore, endorsed the installation of barriers as part of an integrated lamprey control program, and an assessment of the environmental impact of a barrier-dam program is being made. If the program is approved, barriers will be constructed on many sea lamprey producing streams tributary to the Great Lakes. Although the precise design of these barriers has yet to be determined, most will be low-head dams constructed of concrete or metal.

General design criteria are available for low-head barrier dams that will prevent the upstream movement of sea lampreys. According to Stauffer (1964), sea lampreys were able to surmount a dam (with a curved or straight lip) when a head of 20 inches or less was maintained, but were unable to pass over the dam when the head was increased to 26 inches. More recently, W. D. Youngs has shown that under certain conditions a drop of 12 inches (weir crest to pool surface) constitutes an effective barrier (Hunn and Youngs 1980).

Although low-head dams conforming to these criteria can be effective barriers to sea lampreys during periods of low or normal stream flow, they may permit lamprey passage if the head is reduced during periods of high stream flow. Because high stream flows are common in the spring during the spawning migration of the lamprey, consideration is being given by the GLFC to the design of low-head barrier dams that would maintain the necessary head during low and normal conditions of stream flow, and that would also create a velocity barrier to the upstream movement of spawning-run lampreys when high stream flow and flooding reduce the head.

The development of reliable engineering design criteria for velocity barriers to spawning-run sea lampreys is difficult because few observations are available on their burst swimming speed. Davis and Shera (1971) observed migrating lampreys at Denny's Dam on the Saugeen River and found sea lampreys could not move upstream past the dam when the water velocity exceeded 12.3 ft/s (375 cm/s) at 75.5 °F (24.2 °C). Experiments at the Great Lakes Fishery Laboratory (Bergstedt et al. 1977) indicated that the burst swimming speed of sea lampreys appears to lie within the range of 150-170 cm/s (4.9-5.6 ft/s) at 6 or 10 °C. Their report states, however, that the swimming chamber used (a 16-cm diameter tunnel respirometer) may have restricted the swimming movements of the lampreys. Hanson (1978) designed and constructed a test apparatus to determine the burst swimming speed of lampreys in a flume 30.5 cm wide. Twelve tests were conducted during June 1978 at water temperatures ranging from 16.5 to 25.0 °C and at water velocities of 4.5 to 13.6 ft/s. The study demonstrated that spawning-run sea lampreys have a burst swimming speed of over 13 ft/s. This study did not determine the duration of each swimming effort or the distance covered during each attempt

by each animal. In order to determine the duration of and distance swum during each swimming effort by individual lampreys, 19 tests were conducted in 1980.

Materials and Methods

Test Apparatus

A flow-through test apparatus, consisting of a head box (300-gal metal tank), flume (10 x 1 x 1 ft), and foot box (4 x 4 x 3 ft), was constructed and placed into operation at the lamprey weir site on the Ocqueoc River, Presque Isle County, Michigan (Fig. 1). River water was pumped through an 8-inch diameter pipe into the head box using a Model 55-B, Gorman Rupp[1/] irrigation pump powered by a Cummins V-6 diesel engine (Fig. 2). Water left the head box and entered the flume through an opening 6 inches high and 12 inches wide. A funnel made of 1/2-inch hardware cloth, with an opening 4 inches high and 6 inches wide, was placed over the opening in order to hinder the lampreys that entered the head box from going back into the flume. Water velocity in the flume was controlled by increasing or decreasing the velocity head in the head box by changing the speed of the pump.

The flume, made of 3/4-inch plywood, was attached to the openings in the head box and foot box. Water depth in the flume ranged between 5 and 6 inches. Water flowed from the flume into the foot box through a 1-ft square opening. Water depth in the foot box was 2 1/2 ft. A screen, made of 1/4-inch hardware cloth, extended all the way to the bottom on one side of the foot box. Water passed through the screen and out the overflow, and was

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1/ Mention of a trade name does not constitute recommendation or endorsement by the U.S. Government.

carried back to the river through wooden troughs.

Testing Procedure

Each of the 19 tests was started between 1600 and 1700 and terminated at 2400 h. After the desired velocity was established in the flume, lampreys that had been captured in the Ocqueoc River weir, or in traps fished in the Cheboygan River, were removed from a livebox and placed in the foot box. The number tested depended on how many were available. Some were used in as many as six tests in order to give us sufficient numbers to test. All lampreys were sexed, weighed to the nearest gram, and measured to the nearest mm (Table 1).

When a lamprey entered the flume, a net was placed over the opening into the foot box to prevent other lampreys from entering the flume and to capture the test lamprey if it failed in its attempt to swim the flume. The time the lamprey entered the flume, the duration of each swimming effort, the distance swum during each swimming effort, and the time spent attached to the side or bottom of the flume between swimming efforts was recorded. Lampreys that swam the flume or failed and were captured in the net at the downstream end of the flume were removed, weighed, measured, and sexed (Table 2). Lampreys attached to the sides or bottom of the flume between the 9- and 10-ft intervals were considered to have swum the flume. Those that tried to swim the flume (without success) for one hour were removed and considered to have failed. After dark, observations were made with the aid of blacklights suspended above the flume.

Measurements of the water velocity in the flume were taken with a current meter (Price Type AA) at 3- and 7-ft intervals (Fig. 3). Measurements were made at least every hour in order to detect any changes in velocity. The

height of the head in the head box and the speed of the diesel engine (as indicated on an rpm gauge) were checked at least every 15 min during the tests, since any changes in these readings indicated that a change in the water velocity in the flume had occurred.

Results

The swimming abilities of the test animals at various water velocities and temperatures are summarized in Table 3. Three tests were conducted at a water velocity of 5 ft/s. Only one lamprey attempted to swim the flume and it swam the entire length of the flume in one attempt. No other tests were conducted at this velocity after I had observed lampreys swimming the flume in one attempt at 9 ft/s.

Six tests were conducted at water velocities of 9 ft/s. Of the 53 lampreys that attempted to swim the flume at this velocity, 49 succeeded. Of these, 5 swam the entire length of the flume in one attempt. The swimming time for each attempt ranged from 0.3 to 6.0 s and averaged from 1.5 to 2.8 s for each test. The distance swam for each attempt ranged from -5.3 to 10.0 ft and averaged from 0.9 to 4.2 ft for each test. The rest period between swimming efforts ranged from 0.3 to 7.3 min and averaged from 2.9 to 3.2 min for each test.

One test was run at 10 ft/s and only one lamprey attempted to swim the flume. It succeeded in swimming the flume after six attempts.

Two tests were run at 11 ft/s. Of the 10 lampreys that attempted to swim the flume, 6 were successful, although none swam the entire length of the flume in one attempt. The swimming time for each attempt ranged from 0.5 to 5.0 s and averaged 1.6 and 2.3 s for each test. The distance

swam for each attempt ranged from -3.0 to 4.3 ft and averaged 0.1 and 1.0 ft for each test. The rest period between swimming efforts ranged from 0.3 to 6.5 min and averaged 3.9 and 3.5 min for each test.

Two tests were run at 12 ft/s. Of the 25 lampreys that attempted to swim the flume, 19 were successful, although none swam the entire length of the flume in one attempt. The swimming time for each attempt ranged from 0.3 to 4.0 s and averaged 2.0 and 2.1 s for each test. The distance swum for each attempt ranged from -4.5 to 6.0 ft and averaged 0.7 and 1.8 ft for each test. The rest period between swimming efforts ranged from 0.5 to 13.5 min and averaged 3.3 and 4.1 min for each test.

Five tests were conducted at 13 ft/s; the maximum velocity produced by the test apparatus. Of the 12 lampreys that attempted to swim the flume, none were successful, although all were able to swim the flume for various distances. Turbulence at the head of the flume at this velocity appeared to prevent them from swimming its entire length. The swimming time for each attempt at this velocity ranged from 0.5 to 5.0 s and averaged between 0.8 and 1.7 s for each test. The distance swum for each attempt ranged from -3.0 to 4.5 ft and averaged between 0.2 and 0.6 ft for each test. The rest period between swimming efforts ranged from 0.5 to 14.5 min and averaged between 3.3 and 6.0 min for each test.

Conclusions

The test animals made relatively few attempts to swim the flume when water temperatures were below 60 °F. Because of this, we still know relatively little about their swimming ability in colder water. As the water temperature increased, swimming activity also increased.

Most lampreys that attempted to swim the flume had little difficulty until the velocity was increased to approximately 10 ft/s. As the velocity was increased above this speed, swimming the flume became increasingly difficult for them. At the higher velocities, they usually did not swim as far during an attempt, although, in a few instances, they literally "flew" up the flume. In these particular cases, they swam at the surface of the water with only about the ventral third of their bodies submersed in the water. In this manner, they were able to avoid much of the onrushing water.

Burst speeds represent the highest velocities which fish can attain and can be maintained for periods of only a few seconds (Farlinger and Beamish 1977). All attempts to swim the flume were for periods of less than 6 s duration. At velocities of 5 and 9 ft/s, some lampreys were able to swim the flume in 4-6 s without attaching. As the velocity was increased, the lampreys attached more often, made less progress up the flume during each attempt, and the time of each attempt generally was of a shorter duration.

From these studies, I concluded that spawning-run sea lampreys of either sex are extremely good swimmers and that their burst swimming speed can exceed 13 ft/s. Not only were they able to maintain their position in the flume for short periods of time at this velocity, but, in some instances, were observed moving upstream against this current at approximately 1-2 ft/s; thus their actual burst speed is over 14-15 ft/s.

It has been suggested that if sea lampreys are not able to attach to the side of a velocity barrier of sufficient length, they may not be able to move upstream, even though their burst swimming speed is very high. However, the fact that some lampreys in the present study were able to swim 10 ft against a water velocity of 9 ft/s suggests that it would be very difficult to create

a velocity barrier on most streams. Moreover, since a velocity head of 1.25 ft is necessary to create a water velocity of 9 ft/s, and since a vertical drop of 1.25 ft may, by itself, be a barrier to spawning-run lamprey, it seems unlikely that a velocity barrier would be of any benefit.

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Table 1. Average lengths (mm) and weights (g) of sea lampreys used in 1980 burst swimming speed tests.

Date	Total number lampreys tested	Males			Females		
		Number	Average length (range in parenthesis)	Average weight (range in parenthesis)	Number	Average length (range in parenthesis)	Average weight (range in parenthesis)
May 8	24	11	426.3 (360-514)	143.8 (87-263)	13	437.8 (366-523)	164.2 (87-261)
13	25	5	429.4 (362-536)	150.6 (83-282)	20	428.7 (372-533)	149.2 (90-290)
14	24	5	429.4 (362-536)	150.6 (83-282)	19	431.7 (381-533)	152.0 (90-290)
15	34	7	405.0 (285-536)	128.7 (38-282)	27	422.6 (355-533)	142.8 (76-290)
20	59	18	438.8 (285-536)	162.6 (38-282)	41	436.4 (355-562)	165.6 (76-340)
21	59	18	438.8 (285-536)	162.6 (38-282)	41	436.4 (355-562)	165.6 (76-340)
22	51	15	435.7 (285-536)	164.9 (38-282)	36	429.7 (355-533)	156.9 (76-290)
27	34	14	477.9 (378-559)	223.7 (109-344)	20	481.0 (391-567)	225.3 (120-360)
29	37	15	479.7 (414-559)	225.1 (122-344)	22	477.0 (399-567)	220.1 (120-360)

(continued)

Table 2. (continued)

Date	Males				Females			
	Number tested	Number that swam flume	Average length (range in parenthesis)	Average weight (range in parenthesis)	Number tested	Number that swam flume	Average length (range in parenthesis)	Average weight (range in parenthesis)
June 18	23	0	--	--	30	6	415.2 (381-442)	137.8 (103-188)
19	21	1	450.0	180.0	24	0	--	--
23	26	2	509.0 (477-541)	231.5 (180-283)	26	3	482.0 (479-484)	208.7 (186-228)
24	22	16	454.2 (403-555)	179.6 (112-322)	21	10	442.9 (382-524)	174.9 (114-298)
25	23	6	458.3 (396-545)	193.0 (120-334)	26	8	453.5 (371-525)	185.8 (102-270)

ble 3. Water velocities and temperatures in the test flume during 19 swimming speed tests conducted with spawning-run a lampreys in Ocqueoc River water, and the results of these tests.

ater locity flume ft/s)	Water temp. (°F)	Test number	Date	Number lampreys in foot box	Number lampreys attempting to swim flume	Number of attempts	Average swimming time in sec (range in parenthesis)	Average distance swam (ft) (range in parenthesis)	Average rest period (min) (range in parenthesis)	Number successful in swimming flume	Number successful in one attempt
5	52	1	May 8	24	0	--	--	--	--	--	--
5	52-53	2	May 13	25	1	1	5	9.5	--	1	1
5	57-59	5	May 20	59	0	--	--	--	--	--	--
9	52-53	3	May 14	24	3	65	1.9 (1.0-3.0)	0.9 (-0.8-2.0)	3.2 (1.0-7.0)	0	--
9	59-60	10	June 2	36	0	--	--	--	--	--	--
9	60-63	6	May 21	59	8	19	2.6 (1.0-5.0)	4.2 (1.0-10.0)	2.9 (1.0-5.0)	8	2
9	64-65	8	May 27	34	5	22	1.5 (0.5-6.0)	2.1 (0.3-9.5)	3.0 (1.0-6.0)	5	1
9	64-66	14	June 17	45	11	49	2.4 (0.5-6.0)	2.1 (-5.3-9.0)	3.2 (0.5-7.3)	10	0
9	69-70	18	June 24	43	26	66	2.8 (0.3-6.0)	3.9 (0.3-10.0)	3.1 (0.3-5.5)	26	2
10	61	16	June 19	45	1	6	2.1 (1.0-3.0)	1.5 (1.0-3.5)	3.2 (1.5-4.5)	1	0
11	61-63	12	June 4	36	2	35	1.6 (1.0-3.0)	0.1 (-3.0-2.0)	3.9 (0.3-6.5)	0	--
11	63	15	June 18	53	8	64	2.3 (0.5-5.0)	1.0 (-2.0-4.3)	3.5 (0.5-6.5)	6	0

(continued)

able 3. (continued)

Water velocity in flume (ft/s)	Water temp. (°F)	Test number	Date	Number lampreys in foot box	Number lampreys attempting to swim flume	Number of attempts	Average swimming time in sec (range in parenthesis)	Average distance swam (ft) (range in parenthesis)	Average rest period (min) (range in parenthesis)	Number successful in swimming flume	Number successful in one attempt
12	65-68	17	June 23	52	10	87	2.1 (0.5-4.0)	0.7 (-4.5-3.8)	4.1 (0.5-13.5)	5	0
12	72-75	19	June 25	49	15	78	2.0 (0.3-4.0)	1.8 (0.0-6.0)	3.3 (0.8-8.5)	14	0
13	52-53	4	May 15	34	0	--	--	--	--	--	--
13	59-61	11	June 3	37	1	11	0.8 (0.5-1.0)	0.4 (-0.3-1.5)	6.0 (2.0-10.0)	0	--
13	61-63	13	June 16	49	4	40	1.7 (1.0-4.0)	0.2 (-3.0-4.5)	3.3 (0.5-9.0)	0	--
13	63-64	9	May 29	37	2	14	1.3 (0.5-2.0)	0.3 (-0.5-1.8)	4.7 (2.5-9.3)	0	--
13	64-67	7	May 22	51	5	46	1.4 (1.0-5.0)	0.6 (-1.0-3.5)	4.9 (2.0-14.5)	0	--

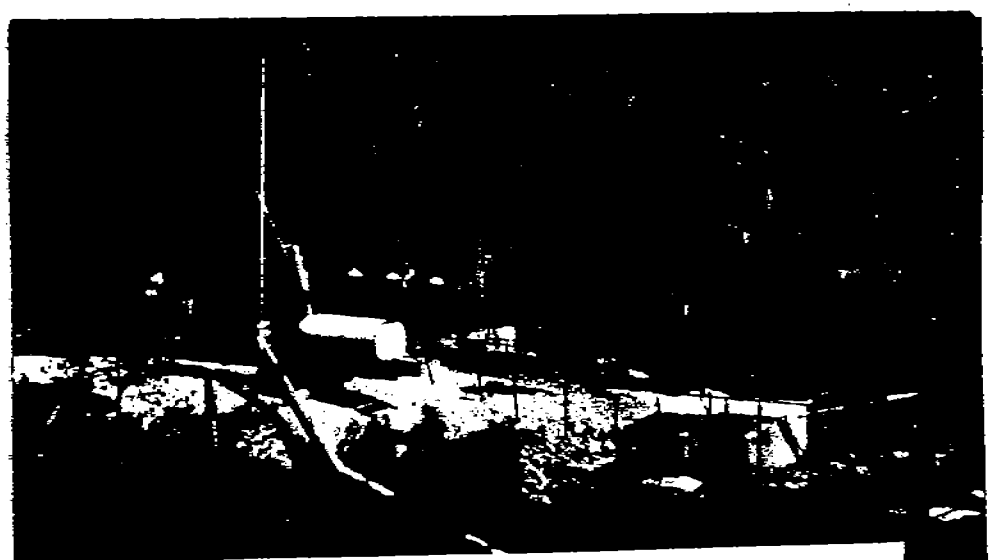

Fig. 1. Flow-through test apparatus used to determine burst swimming speed of spawning-run sea lampreys.

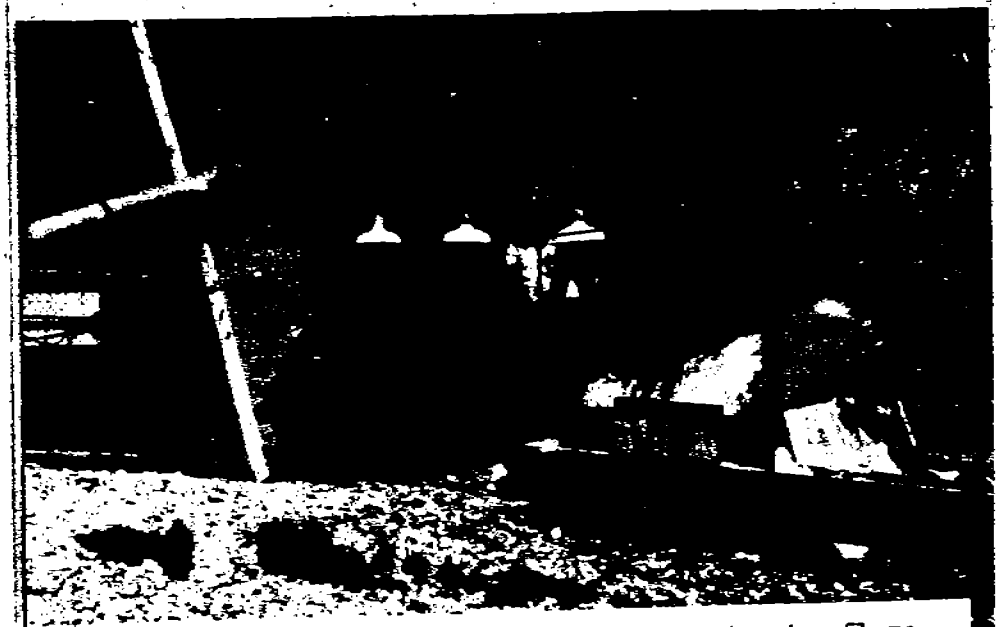

Fig. 3. Measuring the water velocity in the flume.

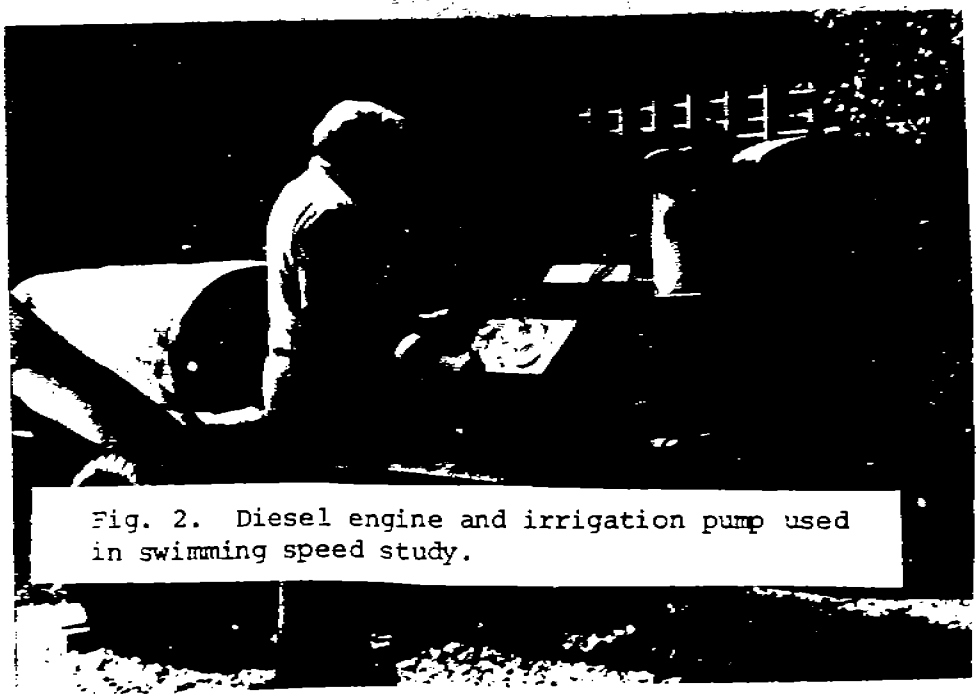

Fig. 2. Diesel engine and irrigation pump used in swimming speed study.