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LABORATORY DETERMINATION OF MAXIMUM SWIMMING SPEED OF MIGRATING SEA LAMPREYS: A FEASIBILITY STUDY

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Summary of LABORATORY DETERMINATION OF MAXIMUM SWIMMING SPEED OF MIGRATING SEA LAMPREYS: A FEASIBILITY STUDY

We completed a preliminary study to test the feasibility of using the stamina-tunnel respirometer for determining maximum or burst swimming speeds of in-migrant, prespawning sea lampreys. Accurate determinations of maximum speeds and times (distances) are needed for the prototype velocity barriers, weirs, or flumes that could block adult lampreys from access to upstream areas in rivers and streams tributary to the Great Lakes. Such barriers could provide a less costly, nonchemical method of sea lamprey control.

We tested 10 lampreys (42 to 54.5 cm long) twice at 6 C and once at 10 C after they had been acclimated to those respective temperatures for at least 1 week. Water velocity ranged from 50 to 150 cm/s. Analysis of the data obtained in this feasibility study suggested three problems: (1) that the range of maximum burst speeds among migrating adults probably exceeds that measured among the 10 adults studied; (2) that the physical dimensions and configuration of our stamina tunnel may have interfered with normal swimming behavior of the test lampreys and thereby led to underestimates of maximum (burst) speeds; and (3) that the potential maximum swimming speed of the 10 test lampreys, 150 cm/s, exceeded the maximum current velocity for which the stamina tunnel was designed. Field observations suggest that maximum (burst) speeds in nature could exceed twice this value, thus making questionable the use of the stamina tunnel for maximum swimming-speed determinations.

Lampricides (TFM and Bayer 83) have successfully reduced populations of sea lamprey (Petromyzon marinus) in the Great Lakes to 5-10% of their peak abundance. Effective control has permitted the rehabilitation of populations of lake trout (Salvelinus namaycush), especially in the Upper Great Lakes. Because of the ever-increasing costs of chemical treatment, however, alternative or supplemental strategies must be developed to maintain or improve the sea lamprey control program without jeopardizing its cost effectiveness.

Velocity barriers in spawning streams may block lampreys from access to upstream spawning areas and thus show promise as a new method of control. With proper engineering and application of principles of stream hydraulics, perhaps a weir could be built which would permit salmonid and most other fish species to move upstream, yet would bar the spawning migrations of lampreys. Such weirs would not only reduce the costs of manpower and materials for lamprey control, but would also eliminate the need for chemical treatment of the upper reaches of many rivers where effective control cannot now be achieved.

Before experimental weirs can be designed and built, more information is needed on the maximum or burst swimming speed of migrating sea lampreys. At the request of the Sea Lamprey Control Program and in collaboration with the Laboratory's Section of Ecology and Limnology, we agreed to assess our capabilities for providing this information. The purpose of this study was to examine the feasibility of using the tunnel respirometer at the Great Lakes Fishery Laboratory to measure the maximum or burst swimming speed of migrating sea lampreys.

Methods and Materials

Ten mature sea lampreys were obtained from the Laboratory's Hammond Bay Biological Station on May 5, 1977. The lampreys were acclimated in water over 90% saturated with dissolved oxygen in flow-through holding tanks. They were acclimated at 6 C for 1 week and 10 C for 3 weeks before testing at those temperatures. No food was required since sea lampreys cease feeding when the spawning migration begins. Photoperiod was 14L:10D.

We performed all tests using a tunnel respirometer (stamina tunnel) like that described by Bell and Terhune (1970), with methods similar to those of Beamish (1974). A lamprey was placed in a slow current (velocity <5 cm/s) in the stamina tunnel and allowed 15 minutes to adjust to the apparatus, after which the water velocity was rapidly increased within 5 seconds to the test velocity. The total time the animal swam at the test velocity was recorded. Lampreys were randomly assigned to the test velocities. All 10 lampreys were swum twice at 6 C (May 12-13 and May 16-17) and once at 10 C (June 13-14). After the second series of tests (May 16-17), they were measured and marked.

To prevent lampreys from attaching to the walls during tests, a wire cage liner was inserted in the tunnel. The wire grid at the downstream end of the tunnel was electrified to prevent the lamprey from partially supporting itself with its tail against the grid and to induce it to keep swimming until exhausted.

Results

A preliminary estimate of burst swimming speed of sea lampreys was derived empirically from the data collected. Burst speed appears to lie within the range of 150-170 cm/s (Table 1, Figs. 1 and 2). Three of the four fish tested at 150 cm/s failed to swim against a current of that speed. According to Webb (1975), burst speed is temperature independent while stamina at lower velocities is temperature dependent. Our data, though limited, support this idea. The data suggest that lampreys acclimated and tested at 10 C generally had greater endurance at intermediate speeds than fish acclimated and tested at 6 C, but performance at the highest speed tested was similar for the two groups (Figs. 1 and 2). For the last two runs, the velocity can be expressed as body lengths per second (L/s) and burst speed appears to be between 3.0 and 3.5 L/s (Table 2, Fig. 3). These values are somewhat higher than expected and lie near the designed capability of the tunnel respirometer.

We observed two noteworthy aspects of swimming behavior in adult sea lampreys during these laboratory tests: (1) the diameter of the tunnel (16 cm) restricted the anguilliform swimming movements of the lampreys--at times the tunnel walls seemed to limit the amplitude of the lateral body undulations; and (2) we also observed that the lampreys reduced the amplitude of their lateral body undulations at peak speeds. Whether this phenomenon is a normal behavior pattern or an adaptive response to the restrictive internal dimensions of the tunnel is not clear.

Discussion

The Great Lakes Fishery Laboratory's tunnel respirometer is not altogether satisfactory as a device for collecting the data necessary to design an effective velocity barrier. On the basis of these preliminary studies, we estimate that burst speeds lie within the range 150-170 cm/s. Assuming that actual burst speeds do not exceed that range (the design limit of the respirometer), a statistically more reliable estimate could be obtained from more extensive studies. However, other considerations make the value of such an estimate questionable. The interior dimensions of the tunnel appeared to restrict the swimming movements of the lamprey, suggesting that burst speed measurements obtained in the respirometer would underestimate a given lamprey's actual burst speed under natural conditions. Also, the physical and chemical cues triggering the upstream migration of sea lampreys in nature would probably result in different burst speeds than those obtained under laboratory conditions.

We recommend that appropriate field tests be done using a prototype velocity barrier. A test of this type would eliminate the problems of interpretation inherent in using a tunnel respirometer. It would not only assess whether lampreys are excluded by the barrier at a given velocity, but whether other fish can pass. If the results of these preliminary studies were to be used as a first estimate of burst speed, then the prototype barrier must be designed to produce a minimum current velocity of 170 cm/s.

Literature Cited

Beamish, F. W. H. 1974. Swimming performance of adult sea lamprey, *Petromyzon marinus*, in relation to weight and temperature. Transactions of the American Fisheries Society 103(2):355-358.

Bell, W. H., and L. D. B. Terhune. 1970. Water tunnel design for fisheries research. Fisheries Research Board of Canada Technical Report 195:1-69.

Webb, P. W. 1975. Hydrodynamics and energetics of fish propulsion. Bulletin of the Fisheries Research Board of Canada 190:1-159.

Table 1. Burst speed of adult sea lampreys arranged in ascending order of test velocities (cm/s).

Velocity (cm/s)	L/s	Endurance (s)	Number of fish	Length (cm)	Acclimation temp. (°C)	Date
50	-	30	-	-	6	5/12
60	-	101	-	-	6	5/12
70	-	160	-	-	6	5/12
80	-	31	-	-	6	5/13
90[a]	-	407	-	-	6	5/12
100	-	22	-	-	6	5/12
100[a]	-	981	-	-	6	5/13
100	2.2	37	5	46.0	6	5/16
110	-	10	-	-	6	5/13
110	2.3	0	8	47.0	6	5/17
110	2.1	48	7	53.5	10	6/13
110	2.2	17	6	50.0	10	6/14
120	-	21	-	-	6	5/13
120	2.3	12	2	53.0	6	5/16
120	2.4	7	1	51.0	6	5/16
120	2.3	45	2	53.0	10	6/14
120	2.6	61	8	47.0	10	6/14
130	-	6	-	-	6	5/13
130[a]	2.4	127	3	54.5	6	5/16
130	2.6	8	6	50.0	6	5/17
130	2.4	55	4	54.0	10	6/13
130	2.9	6	10	45.0	10	6/14
140	2.6	4	7	53.5	6	5/17
140	3.1	9	10	45.0	6	5/17
140	2.8	32	1	51.0	10	6/13
140	3.3	0	9	42.0	10	6/13
150	3.6	0	9	42.0	6	5/16
150	2.8	15	4	54.0	6	5/16
150	2.8	0	3	54.5	10	6/14
150	3.3	0	5	46.0	10	6/13

[a] The lamprey was not impinged until the indicated time, but it maintained position in the current by resting its tail on the downstream grid.

Table 2. Endurance of adult sea lamprey arranged in ascending order of test velocities (L/s).

L/s	Velocity (cm/s)	Endurance (s)	Number of fish	Length (cm)	Acclimation temp. (°C)	Date
2.1	110	48	7	53.5	10	6/13
2.2	100	37	5	46.0	6	5/16
2.2	110	17	6	50.0	10	6/14
2.3	110	0	8	47.0	6	5/17
2.3	120	12	2	53.0	6	5/16
2.3	120	45	2	53.0	10	6/14
2.4	120	7	1	51.0	6	5/16
2.4[a]	130	127	3	54.5	6	5/16
2.4	130	55	4	54.0	10	6/13
2.6	120	61	8	47.0	10	6/14
2.6	130	8	6	50.0	6	5/17
2.6	140	4	7	53.5	6	5/17
2.8	140	32	1	51.0	10	6/13
2.8	150	15	4	54.0	6	5/16
2.8	150	0	3	54.5	10	6/14
2.9	130	6	10	45.0	10	6/14
3.1	140	9	10	45.0	6	5/17
3.3	140	0	9	42.0	10	6/13
3.3	150	0	5	46.0	10	6/13
3.6	150	0	9	42.0	6	5/16

[a] The lamprey was not impinged until the indicated time, but it maintained position in the current by resting its tail on the downstream grid.

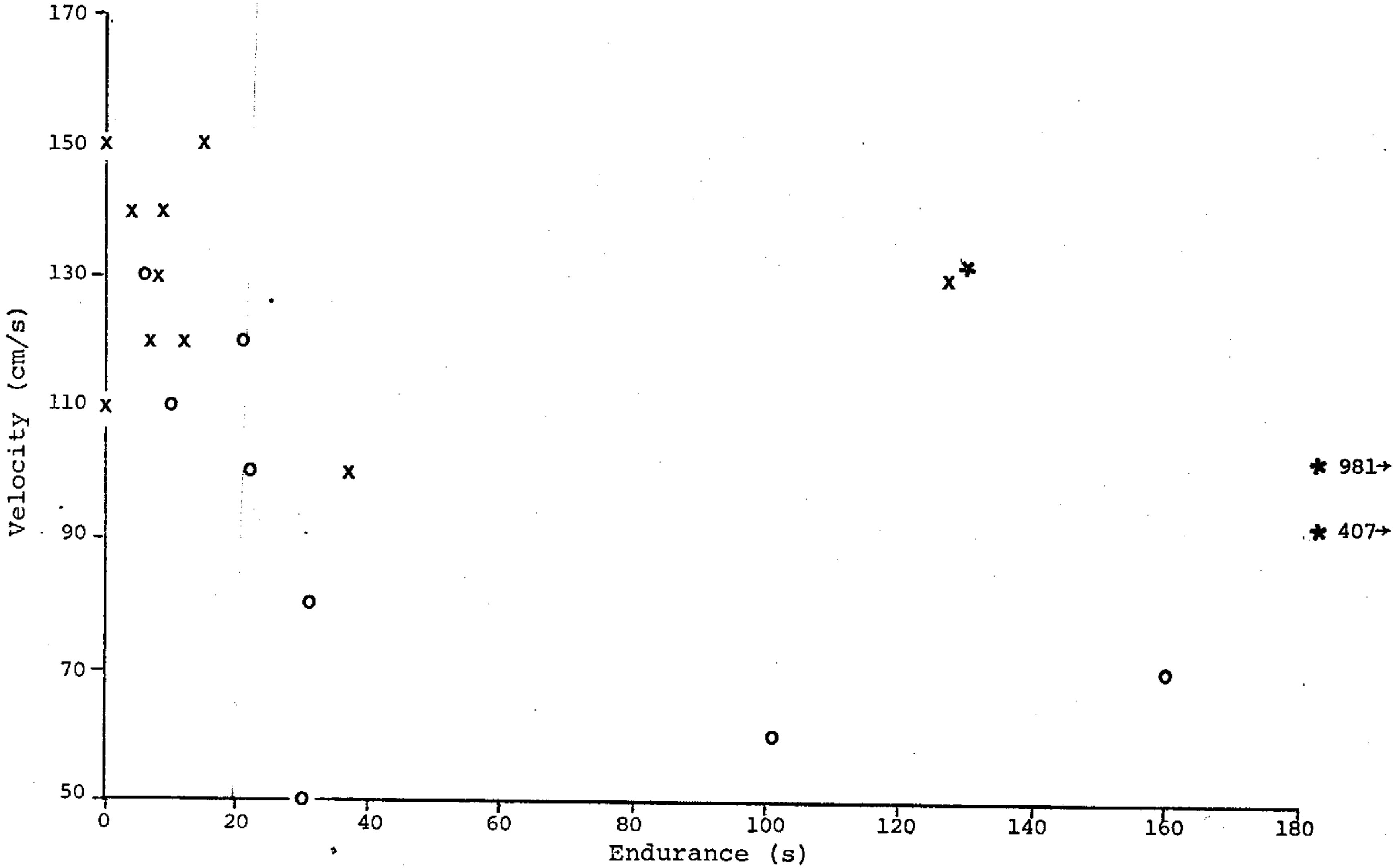

Figure 1. Acclimation and test temperature. O = Run 1: 6 C, 5/12-5/13/77. X = Run 2: 6 C, 5/16-5/17/77. ✱ = The lamprey was not impinged until the indicated time, but it maintained position in the current by resting its tail on the downstream grid.

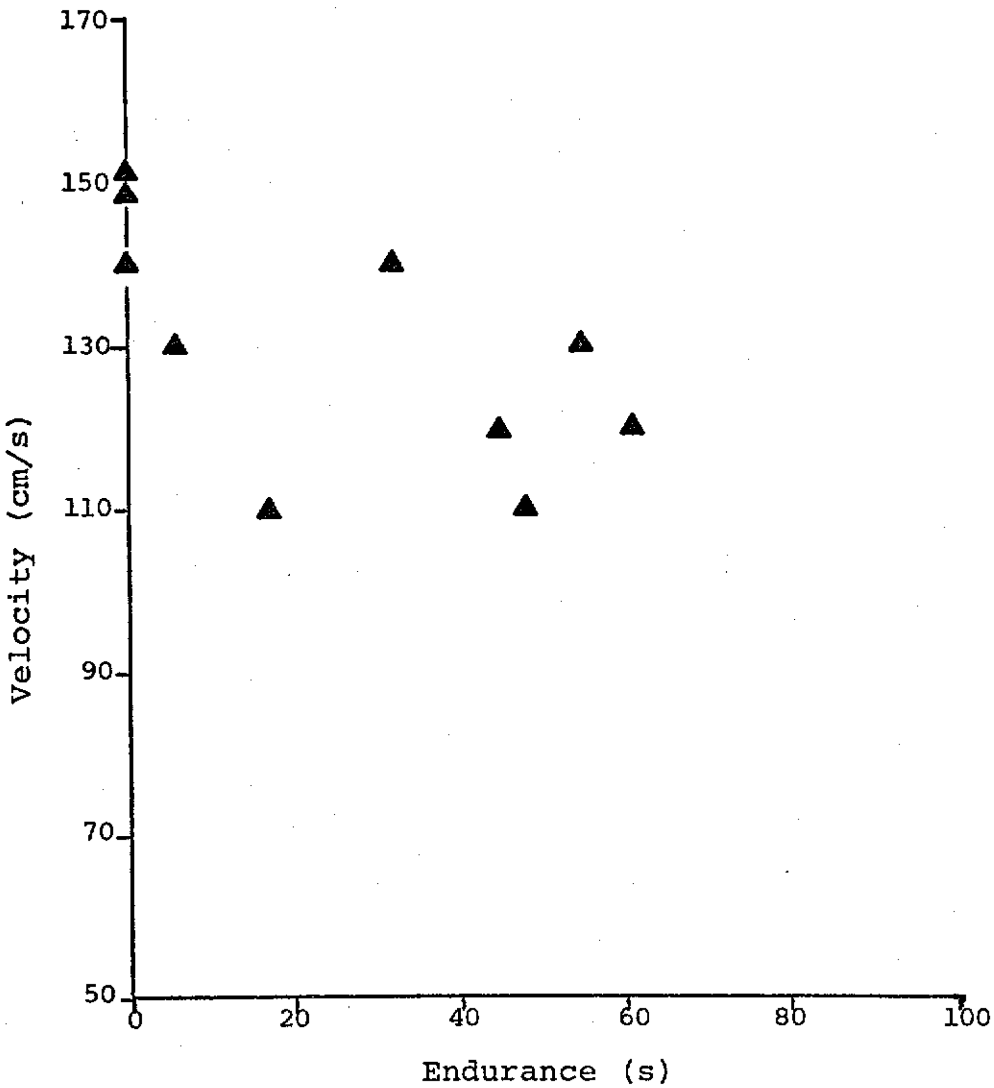

Figure 2. Acclimation and test temperature. ▲ = Run 3: 10 C, 6/16-6/14/77.

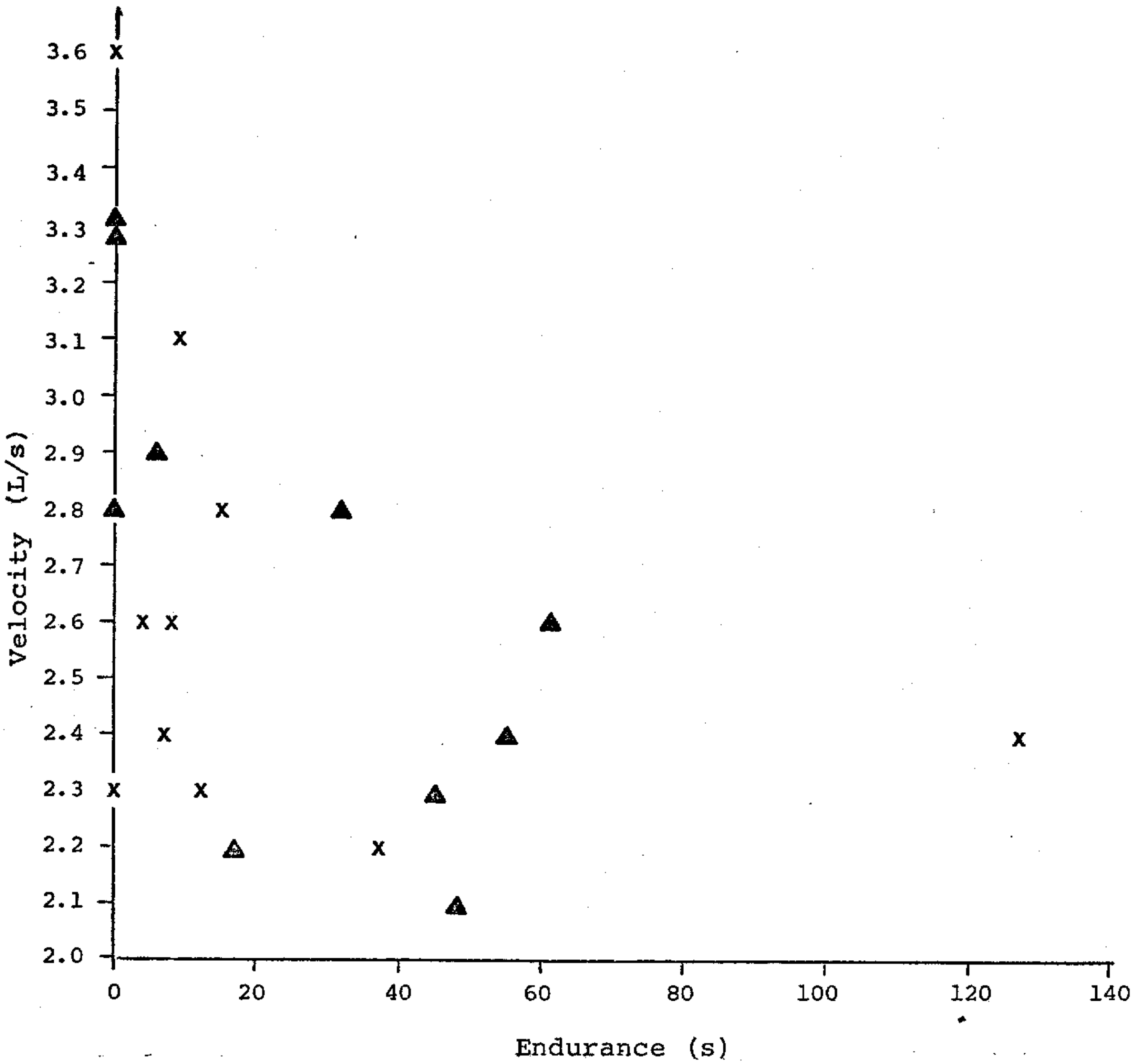

Figure 3. Acclimation and test temperature. X = Run 2: 6 C, 5/16-5/17/77. ▲ = Run 3: 10 C, 6/13-6/14/77.