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Do elevated stream temperatures affect larval Pacific Lamprey growth, behavior or physiology?

Annual Report: 2023

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On the cover: Astarte Brown and Michael Flesher electrofishing in the Umatilla River to collect larval Pacific Lamprey.

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Executive Summary:

Lampreys are obligate ectotherms and directly influenced by the ambient water temperature. In lamprey species other than Pacific Lamprey, evidence exists that lethal water temperatures for larvae occur near 27.0-31.0°C (e.g., Potter and Beamish 1975; Arakawa and Yanai 2021). Although few studies have addressed the thermal tolerance of Pacific Lamprey, recent investigations indicated the ultimate upper incipient lethal temperature (UUILT) for larvae exceeds 27.5°C (Whitesel and Uh, 2022) and provided preliminary evidence that larvae have the ability to occupy natural areas warmer than 27.5°C (Whitesel and Sankovich 2022; Sankovich and Whitesel 2022a, 2022b). How climate change will ultimately influence the status of Pacific Lamprey is uncertain (see Wang et al. 2020). Currently, many of the locations where Pacific Lamprey rear naturally experience maximum water temperatures near 26.0°C. With predictions that during the next 25-35 years air temperatures in the Pacific Northwest may rise 2-5°C (Wu et al. 2012), maximum water temperatures where some Pacific Lamprey exist now may exceed the lethal limit for larvae. Whether there are effects on larvae at warm but sublethal temperatures is not well understood. We propose to investigate the effects of sublethally warm stream temperatures on larval Pacific Lamprey, specifically with respect to their growth, behavior, and physiology.

The study area for this project was the Umatilla River, Oregon. Based on historical data, we partitioned the river into four thermal zones (TZ1 - TZ4) (see Whitesel and Sankovich 2022). Thermal Zone 2 (TZ2) was characterized by summer maximum temperatures that were expected to approach 31.0°C and be relatively constant throughout the zone. Thermal Zone 4 (TZ4) was characterized by summer maximum temperatures that were expected to range from < 27.5°C at the downstream end to 19.9°C at the upstream end. We considered TZ4 a control area (temperatures < UUILT) and TZ2 as a treatment area (temperatures nearing or exceeding the UUILT).

To determine if growth differed between larval lamprey in TZ2 and TZ4 during the period of peak stream temperatures, we captured larval lamprey via electrofishing on 19 (TZ2) and 20 (TZ4) July 2023, placed each captured lamprey in an individual container, and partially buried the containers in the stream bed. Each larval lamprey was measured (nearest 1 mm in total length [TL]) and weighed (nearest 0.1 g) before being placed in the container. The containers were approximately 17 cm wide and long and 11 cm high and had screening material on the sides and top to allow stream flow to pass through them (Appendix Figure 1). We filled the containers with Type 1 habitat to a depth of approximately 3.5 cm to allow the larval lamprey to burrow.

We buried the containers (n = 24 and 20 in TZ2 and TZ4, respectively) at three sites in TZ2 and two sites in TZ4 and deployed temperature recorders on the substrate surface and 4-7 mm below it at each of the sites. The containers and temperature recorders (recording hourly) were left in place until 29 August 2023 (i.e., for 39 - 40 days), when the larval lamprey were removed from their containers, placed in smaller, individual tubes (137 mm long and 28 mm in diameter; Appendix Figure 2) submersed under water in a cooler, and transported to the

Oregon Department of Fish and Wildlife's Fish Pathology Laboratory in La Grande. The larvae were held overnight in the tubes in the cooler, with oxygen being supplied by aquarium aerators. The larvae were measured (nearest 1 mm in TL) and weighed (nearest 0.0001 g) the next day, after being euthanized with a lethal dose of tricaine methane sulfonate (MS-222). In addition, each euthanized larva was dissected to extract its liver, which was weighed (to determine a hematosomatic index [HIS]) and frozen at -80°C for subsequent determination of total lipid. The HSI for each larva was calculated as (liver mass/TM) x 100.

In TZ2, three of the containers held dead larval lamprey, and two of the containers held no larval lamprey. Additionally, one larval lamprey escaped while we were attempting to transfer it from its container to a tube. Thus, in the laboratory, we measured and weighed 18 larval lamprey from TZ2. In TZ4, two of the containers were found out of the water on the bank of the Umatilla River on 29 August. They contained no larva, so we measured and weighed 18 individuals from TZ4 in the laboratory.

In the Umatilla River, maximum temperatures recorded on the substrate surface were 30.3 °C and 25.4°C in TZ2 and TZ4, respectively, while maximum temperatures recorded below the substrate surface were 30.4 °C and 24.9°C in those respective thermal zones (Appendix Table 1). Four larval lamprey in each temperature zone increased in length while in the containers, while the remainder either did not grow or decreased in length. The median proportional change in length [(final TL – initial TL)/initial TL] for larval lamprey from TZ2 was -0.02, and that for larval lamprey from TZ4 was -0.01 (Appendix Table 2). There was no significant difference in proportional growth for larval lamprey from the two temperature zones (Mann Whitney test; p = 0.114). The median HSI of larvae that reared in TZ2 (0.582) was significantly less than that of larvae that reared in TZ4 (0.666) (Mann Whitney test; P = 0.040) (Appendix Table 2). Since HSI was negatively related to TM (r = 0.495, P = 0.002), HSI was standardized for TM ($HSI_{standardized}$) using the equation $HSI_{standardized}$ = (HSI / ((-0.564 x TM) + 0.7359))-0.3749. The median $HSI_{standardized}$ of larvae reared in TZ2 (0.655) was similar to that of larvae reared in TZ4 (0.635) (Mann Whitney test; P = 0.707)(Appendix Table 2). Analysis of total lipid in liver tissue is pending.

In previous years of this study, larvae demonstrated the ability to occupy areas where the maximum water temperature above and below the substrate reached values of 33.6°C and 29.0°C, respectively, suggesting that their UUILT is at least 29.0°C (Whitesel and Sankovich 2022; Sankovich and Whitesel 2022a, 2022b). In general, our results have indicated elevated stream temperatures may affect growth in certain circumstances but have minimal or no effects on burrowing behavior and hepatic physiology (Sankovich and Whitesel 2022c, 2023). It is important to note, however, that study containers forced larvae to be exposed to specific natural conditions, whereas unconstrained larvae may behaviorally thermoregulate by selecting cooler microhabitat in which to burrow and rear. Furthermore, in natural and laboratory conditions, it is possible warmer temperatures were thermally stressful to larvae and resulted in impaired growth. Alternatively, it is possible that larvae reared in warmer temperatures were food limited or had a higher metabolic rate than those reared in cooler temperatures. Larval Pacific Lamprey may occupy other rivers that reach temperatures exceeding 29.0°C (Reid

and Goodman, personal communication). However, it is unclear whether sublethal effects outside of those we evaluated exist. How cooler temperatures in the substrate might serve as a thermal refuge and mitigate for elevated stream temperatures above the substrate is also unknown.

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Appendix Table 1. Minimum, maximum, and mean stream temperatures recorded on the surface of the stream bed and in the substrate at sites in relatively warm and cool temperature zones (2 and 4, respectively) where larval Pacific Lamprey were held in individual containers in the Umatilla River from 19 July to 29 August 2023.

Temperature zone	Reach	Location	Stream temperature (°C) Minimum	Maximum	Mean
2	12	surface	16.3	30.3	23.4
		buried	16.4	30.3	23.3
2	1	surface	16.2	30.2	23.1
		buried	16.5	30.4	23.2
2	14	surface	-	-	-
		buried	16.5	27.5	22.3
4	10	surface	17.9	24.0	20.2
		buried	18.1	23.6	20.2
4	6	surface	15.5	25.4	19.7
		buried	16.1	24.9	19.8

Appendix Table 2. Proportional change in length, final Hepatosomatic index and final Hepatosomatic index standardized (median, minimum and maximum) of larval Pacific Lamprey held individually in containers buried in relatively warm and cool temperature zones (2 and 4, respectively) in the Umatilla River from 19 July to 29 August 2023. Significance indicated by *.

Characteristic	Temperature Zone	Median	Minimum	Maximum
Proportional change in total length	2 (n = 18)	-0.02	-9	6
	4 (n = 18)	-0.01	-7	5
Hepatosomatic index	2 (n = 18)	0.582	0.414	0.740
	4 (n = 18)	0.666 *	0.454	1.010
Hepatosomatic index (standardized)	2 (n = 18)	0.655	0.424	0.803
	4 (n = 18)	0.635	0.307	1.054

Appendix Figure 1. Design of the containers in which larval lamprey were held during the growth experiment in the Umatilla River from 19 July to 29 August 2023.

Appendix Figure 2. Design of the tubes in which larval lamprey were held while being transported from the Umatilla River to the Oregon Department of Fish and Wildlife's Fish Pathology Laboratory in La Grande.

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