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ARTICLE

Characterization of Adult Pacific Lamprey Swimming Behavior in Relation to Environmental Conditions within Large-Dam Fishways

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Abstract

Understanding the migration behaviors of adult Pacific Lamprey *Entosphenus tridentatus* inside fishways is critical to resolving why the species has low passage rates at hydropower dams. We used an acoustic camera to make in situ observations on the swimming behaviors of Pacific Lampreys at two large Columbia River dams (Bonneville and John Day) and to develop inferences regarding potential mechanisms influencing passage within lower fishway sections (entrances, collection channels, transition areas). Pacific Lampreys were primarily free-swimming in the middle and upper water column at both the high-velocity entrance (>1 m/s) and the low-velocity transition area (<1 m/s) of Bonneville Dam. In contrast, Pacific Lampreys in the high-velocity fishway channel at John Day Dam were more likely to orient to the fishway floor at the entrance and in the collection channel. Pacific Lampreys exhibited no interaction with diffuser grating along the fishway floor at Bonneville Dam and were observed free-swimming above these structures. Behavior in the Bonneville Dam transition area appeared to be affected by poor attraction flow and the presence of predatory White Sturgeon *Acipenser transmontanus*. Higher Pacific Lamprey tail-beat frequencies and lower ground speeds were observed at the fishway entrances of both dams and in the John Day Dam collection channel, indicating that Pacific Lampreys were exerting greater effort to achieve upstream progress under the high water velocities at these locations. High tail-beat frequencies and low ground speeds support the hypothesis that fishway entrances may act as short-distance, high-velocity barriers for Pacific Lampreys, while passage through the lower John Day Dam fishway may be limited by the endurance requirements for passing a long-distance (~80 m), high-velocity challenge (collection channel). Similar in situ applications offer the potential for understanding and improving the passage of migratory fish at anthropogenic barriers.

The Pacific Lamprey *Entosphenus tridentatus* is an anadromous species native to western North America, where management for Pacific salmon *Oncorhynchus* spp. has dominated for more than a century. When most fishways at hydropower dams in the Pacific Northwest were constructed in the 20th century, they were specifically designed and operated to accommodate the passage of Pacific salmonids (Clay 1995). Pacific Lampreys have experienced significant population declines in past decades and were petitioned for listing under the U.S. Endangered Species Act in the early 2000s (Moser and Close 2003). However, very little is known regarding what factors, whether natural or anthropogenic, explain the observed population declines (Murauskas et al. 2013). Migration barriers have been implicated as a leading cause for the species' decline in the Columbia and Snake River basins (Moser et al. 2002b; Keefer et al. 2013a) because Pacific Lamprey passage success at large hydropower dams (often ~50%) is far lower than what has been observed for Pacific salmonids (~95%).

A variety of factors acting at multiple scales may explain the difference in passage success between taxa, including differences in morphology, migration strategy, swimming

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