NOTE

Movement of Radio-Tagged Adult Pacific Lampreys during a Large-Scale Fishway Velocity Experiment

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Abstract
Optimization of fishways to pass multiple species is challenging because life history, swimming ability, and behavior often differ among species. For example, high fishway water velocities designed to attract adult Pacific salmon *Oncorhynchus* spp. at Columbia River dams inhibit fishway entrance and passage success of adult Pacific lampreys *Lampetra tridentata*, a species of conservation concern. We tested whether reduced water velocities (∼1.2 m/s, 0.15 m of head) at Bonneville Dam fishway openings improved entrance efficiency and other passage metrics for radio-tagged Pacific lampreys compared with control velocities (>1.98 m/s, 0.46 m of head) and near-zero (“standby”) velocities. Lamprey entrance efficiencies were significantly higher in the reduced-velocity treatment (26–29%) than in the control (13–20%) or standby (5–9%) treatment. In some years, significantly more Pacific lampreys passed through fishway collection channels and transition pools and reached the fish ladder during reduced-velocity treatment conditions, indicating that benefits extended beyond fishway entrances. However, overall passage efficiency at the dam was relatively unchanged, suggesting that additional passage bottlenecks for Pacific lampreys exist upstream from fishway entrances. The experiment demonstrated how operational changes can improve passage performance and how exploiting behavioral differences among species can improve multispecies management.

An ideal fish passage structure would preserve the population, community, and ecosystem processes upstream and downstream from the passage obstacle. However, developing optimal fish passage structures is challenging because behavior, metabolic scope, and swimming performance differ significantly among species (Haro et al. 2004). Fishway design is influenced by historical, operational, and economic factors (Monk et al. 1989; Clay 1995; Mallen-Cooper and Brand 2007; Keefer et al. 2010) and consequently favors individual fish with specific traits within species (e.g., size; Mallen-Cooper and Brand 2007; Keefer et al. 2009) or selects for a subset of species present (Oldani and Baigún 2002; Stuart and Berghuis 2002; Agostinho et al. 2007). It is well recognized that successful passage is strongly influenced by hydraulic attributes, such as velocity and turbulence, but is rarely understood in detail (Haro et al. 1999; Bunt 2001).

Reducing fishway selection can be achieved by modifying fishway structures or operations. Structural changes to fishway features such as entrance areas, transition pools, and fishway weirs typically aim to reduce passage bottlenecks (Monk et al. 1989; Bunt et al. 2001; Naughton et al. 2007). Operational changes can include manipulation of discharge or tailwater elevation to improve fishway entrance discovery and use (Clay 1995; Laine et al. 2002; Pon et al. 2009) or temporal adjustments that take advantage of seasonal or diel passage differences among species (Hard and Kynard 1997; Bunt et al. 2001; Ellis and Vokoun 2009).

Fishways at many dams in the Pacific Northwest were designed and are operated to facilitate passage by strong-swimming adult salmonids. Passage efficiency (defined as [number of adults passing fishways]/[number that approach the dam base]) at individual dams on the lower Columbia River is high (i.e., often >90%; Caudill et al. 2007) for adult salmonids, particularly when compared with the passage efficiency of adult

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