

Effects of Body Size and River Environment on the Upstream Migration of Adult Pacific Lampreys

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Abstract.—Dams in the Columbia River basin present significant obstacles to declining populations of anadromous Pacific lampreys *Lampetra tridentata*. Mitigation efforts have focused on fine-scale improvements in passage at individual dams, but there is an increasing need for basinwide estimates of survival and escapement. We developed a half-duplex passive integrated transponder (PIT) tag monitoring array at five Columbia and Snake River dams to evaluate adult lamprey migrations. We tagged 3,598 lampreys over 3 years and calculated the rates of main-stem escapement through 15 river reaches. From these data, we assessed the relative effects of lamprey size, river discharge, water temperature, and migration timing on upstream passage. The results indicated high attrition as lampreys progressed upstream. In each year, about one-half of the fish passed one dam, 28–33% passed two dams, 17–19% passed three dams, 4–5% passed four dams, and about 1% passed the first dam on the Snake River (five dams and >300 km upstream from their release sites). In most reaches, upstream passage was strongly size dependent, the largest lampreys being two to four times more likely to pass than the smallest fish. Lamprey size was more predictive of passage than were the river discharge, temperature, or migration timing variables. These findings suggest that adult Pacific lamprey migration is affected by physiological constraints and that effective mitigation for the difficult passage conditions at dams should include size-related considerations.

Anadromous Pacific lampreys *Lampetra tridentata* are widely distributed around the Pacific Rim, from Mexico and Baja California (Ruiz-Campos and González-Guzmán 1996; Renaud 2008) north to the Bering Sea (Beamish 1980; Goodman et al. 2008) and west to Japan (Yamazaki et al. 2005). The species has experienced rangewide population declines and regional extirpations in response to loss and degradation of freshwater habitat, dam-related mortality, and a suite of ecosystem changes (Beamish and Northcote 1989; Close et al. 2002; Kostow 2002). Few Pacific lamprey populations have been routinely monitored, however, and little is known about the mechanisms behind the declines at either broad geographic scales or in

individual river basins. Some of the uncertainty reflects our limited understanding of basic Pacific lamprey life history, particularly with regard to population structure, ocean distributions, ecological constraints, and environmental effects on survival across life stages.

Pacific lampreys in the Columbia River basin are perhaps the most-studied adult population in North America. Run size estimates based on visual counts and migration timing data have been collected intermittently at Columbia and Snake River dams for several decades (e.g., Starke and Dalen 1995; USACE 2007), providing one of the few population-level time series for the species. The counts, collected opportunistically as part of intensive programs monitoring salmonids (*Oncorhynchus* spp.), indicate order-of-magnitude reductions in the number of Pacific lampreys over the past few decades, particularly at interior sites like the Snake River basin (Close et al. 2002). Declines stem from habitat loss from the construction of dams (e.g., McClure et al. 2008), increases in nonnative predators, dam-related out-migration mortality (Moser and Close 2003), potential

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