

## Prolonged Swimming Performance of Northern Squawfish

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**Abstract.**—We determined the prolonged swimming performance of two size-classes of northern squawfish *Ptychocheilus oregonensis* at 12 and 18°C. The percentage of fish fatigued was positively related to water velocity and best described by an exponential model. At 12°C, the velocity at which 50% of the fish fatigued (FV50) was estimated to be 2.91 fork lengths per second (FL/s; 100 cm/s) for medium-sized fish (30–39 cm) and 2.45 FL/s (104 cm/s) for large fish (40–49 cm). At 18°C, estimated FV50 was 3.12 FL/s (107 cm/s) for medium fish and 2.65 FL/s (112 cm/s) for large fish. Rate of change in percent fatigue was affected by fish size and water temperature. Large fish fatigued at a higher rate than medium-sized fish; all fish fatigued faster at 12 than at 18°C. The mean times to fatigue at velocities of 102–115 cm/s ranged from 14 to 28 min and were not affected by fish size or water temperature. Our results indicate that water velocities from 100 to 130 cm/s may exclude or reduce predation by northern squawfish around juvenile salmonid bypass outfalls at Columbia River dams, at least during certain times of the year. We recommend that construction or modification of juvenile salmonid bypass facilities place the outfall in an area of high water velocity and distant from eddies, submerged cover, and littoral areas.

The northern squawfish *Ptychocheilus oregonensis* is a major predator on juvenile salmonids in a variety of waters (Jeppson and Platts 1959; Thompson and Tufts 1967; Poe et al. 1991). In the Columbia River, northern squawfish predation on juvenile salmonids is most intense in the tailrace areas downstream from dams (Poe et al. 1991), a scenario accurately predicted for riverine systems by Brown and Moyle (1981). Predation near dams is severe partly because prey are concentrated near juvenile fish bypass outfalls and may be less able to avoid predators because of passage-related disorientation, stress, or injury (Matthews et al. 1986; Maule et al. 1988).

Concern over the decline of many stocks of Pacific salmon *Oncorhynchus* spp. has led to efforts aimed at increasing juvenile salmonid survival, including a reduction in predation-related mortality. Although predator removal efforts are currently underway in the Columbia River, other methods designed to protect juvenile salmon as they migrate downstream might be as efficient, ecologically more prudent, and less costly. One method of protecting juvenile salmonids is the construction or improvement of fish bypass facilities, which help intercept fish in forebay areas, divert them away from turbines, and allow them relatively safe passage through the dam before they exit into the tailrace. Because northern squawfish

appear to prefer low water velocities around bypass outfalls (Faler et al. 1988), a higher water velocity there might exclude them or reduce their numbers and thus decrease predation. Faler et al. (1988) found that radio-tagged northern squawfish did not use water velocities greater than 70 cm/s. However, their study did not fully address the swimming ability of northern squawfish in high water velocities.

Although the swimming performance of many fish species has been documented (see reviews by Beamish 1978 and Videler and Wardle 1991), Berry and Pimentel (1985) cautioned against using these data to predict the capabilities of unstudied species. Our objective, therefore, was to determine the endurance of northern squawfish at prolonged swimming speeds. Prolonged swimming speeds are those that a fish can maintain for up to 200 min before fatiguing (Beamish 1978). We also assessed the effects of fish size and water temperature on swimming performance. We anticipate that this information could aid in developing biological criteria for the location and operation of bypass systems for protecting juvenile salmonids from predation by northern squawfish.

### Methods

Northern squawfish were captured as needed from the Columbia River by electrofishing, with a Merwin trap, and by angling and were transported to our laboratory. They were held outdoors under natural photoperiod in circular tanks (1.2 m in diameter, 0.8 m deep) that received well

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