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Reservoir provides cool-water refuge for adult Chinook salmon in a trap-and-haul reintroduction program

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Abstract. Trap-and-haul is a mitigation strategy at many hydropower dams lacking upstream fish-passage facilities, and protocols are needed to maximise its effectiveness. We used biotelemetry to assess the potential benefits of releasing transported adult Chinook salmon (*Oncorhynchus tshawytscha*) into a cold-water reservoir *v.* a relatively warm-water tributary before spawning. Over 5 years, we released 160 salmon into Foster Reservoir (Oregon, USA) and another 102 into the South Santiam River near historical salmon spawning areas further upstream. In total, 70% of reservoir-released salmon entered an upriver tributary after spending a median of 3–95 days annually in the reservoir. Data recovered from 61 archival temperature loggers indicated that salmon were ~3–6°C cooler per day in the reservoir than in the river. We estimated that cumulative exposure of reservoir-released fish was reduced by 64 degree days, on average (range = −129 to 392), relative to river-released fish. Release into the reservoir was not risk free; 14% of all reservoir-released fish fell back downstream *v.* 1% of river-released fish. We conclude that reduced transport distance, reduced thermal exposure and potential survival benefits of releasing salmon into reservoirs should be weighed against risks of factors such as fallback and homing errors.

Additional keywords: behavioral thermoregulation, biologger, homing, mitigation, native species, philopatry.

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Introduction

Dams have blocked fish from accessing their historical habitats worldwide (Gehrke *et al.* 2002; Agostinho *et al.* 2008; Liermann *et al.* 2012) and are particularly deleterious to migratory species (Gustafson *et al.* 2007; DeHaan and Bernall 2013; Ziv *et al.* 2012). Fish reintroduction above barriers without passage facilities is an increasingly common strategy for restoring or augmenting imperiled populations (George *et al.* 2009; Anderson *et al.* 2014; Lusardi and Moyle 2017). Fish reintroduction requires suitable upstream habitat and, for many diadromous or otherwise migratory species, collection and transport of reproductive-aged adults and, in some cases, emigrating juveniles (Shute *et al.* 2005; Anderson *et al.* 2014). Unfortunately, trap-and-haul strategies also present a variety of risks because collection, transport and release are each potentially stressful events where fish mortality risks are elevated (Lusardi and Moyle 2017). Collection facilities and transport operations often temporarily place fish in artificial, high-density environments where disease transmission increases (Ögut *et al.* 2005; Harmon 2009), and release into post-transport habitats can be physiologically taxing or put fish at increased risk of predation or harvest (Schreck *et al.* 1989; DeWeber *et al.* 2017). Furthermore, natal origin of transported fish may be important to post-release behaviour and metapopulation dynamics if prespawn adults originating below dams are transported above dams, particularly in philopatric species.

In the Willamette River basin (Oregon, USA), high-head hydroelectric dams without fish-passage facilities block access to spawning and rearing habitat of spring-run Chinook salmon (*Oncorhynchus tshawytscha*) in several large tributaries. Willamette River spring Chinook salmon were listed as threatened under the *USA Endangered Species Act* (National Marine Fisheries Service 1999) following large populations declines. Several other endemic fishes, including threatened winter-run steelhead (anadromous rainbow trout, *O. mykiss*), bull trout (*Salvelinus confluentus*) and Pacific lamprey (*Entosphenus tridentatus*), also experienced large declines as a result of habitats being fragmented or blocked by dams (Sheer and Steel 2006; Mesa *et al.* 2010; US Fish & Wildlife Service 2011; National Marine Fisheries Service 2016). Hatchery programs have been a primary mitigation method for maintaining spring Chinook salmon in the upper Willamette River, along with