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TRANSPORTING JUVENILE SALMONIDS AROUND DAMS IMPAIRS ADULT MIGRATION

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Abstract. Mitigation and ecosystem-restoration efforts may have unintended consequences on both target and nontarget populations. Important effects can be displaced in space and time, making them difficult to detect without monitoring at appropriate scales. Here, we examined the effects of a mitigation program for juvenile salmonids on subsequent adult migration behaviors and survival. Juvenile chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*O. mykiss*) were collected and uniquely tagged with passive integrated transponder (PIT) tags at Lower Granite Dam (Washington State, USA) on the Snake River and were then either transported downstream in barges in an effort to reduce out-migration mortality or returned to the river as a control group. Returning adults were collected and radio-tagged at Bonneville Dam (Washington–Oregon, USA) on the Columbia River 1–3 years later and then monitored during ~460 km of their homing migrations. The proportion of adults successfully homing was significantly lower, and unaccounted loss and permanent straying into non-natal rivers was higher, for barged fish of both species. On average, barged fish homed to Lower Granite Dam at rates about 10% lower than for in-river migrants. Barged fish were also 1.7–3.4 times more likely than in-river fish to fall back downstream past dams as adults, a behavior strongly associated with lower survival. These results suggest that juvenile transport impaired adult orientation or homing abilities, perhaps by disrupting sequential imprinting processes during juvenile out-migration. While juvenile transportation has clear short-term juvenile-survival benefits, the delayed effects that manifest in adult stages illustrate the need to assess mitigation success throughout the life cycle of target organisms, i.e., the use of fitness-based measures. In the case of Snake River salmonids listed under the Endangered Species Act, the increased straying and potential associated genetic and demographic effects may represent significant risks to successful recovery for both target and nontarget populations.

Key words: chinook salmon; delayed effects; differential mortality; juvenile transportation; long-distance migration; mitigation; Oncorhynchus; *sequential imprinting; steelhead; unintended consequences.*

INTRODUCTION

Habitat restoration and remediation, captive-breeding programs, fish hatcheries, and direct interventions with wild populations have all been used to mitigate for human-caused impacts on habitats and animal populations (NRC 1996, Primack 2004). However, evaluations of the "success" of such projects are often limited to local-scale studies of direct effects on organisms or ecosystems. Indirect, delayed, and unintended effects are rarely considered because of logistical and economic constraints and because such effects are often manifested in spatially or temporally distant locations from the initial mitigation effort.

One of the most extensive interventions ever undertaken for wild-animal populations is the broad-based recovery effort for anadromous salmonids in the Pacific Northwest (Ruckelshaus et al. 2002). Among the most prominent of these efforts is that for Snake River chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*O. mykiss*). These populations have experienced steep declines and were listed as threatened under the U.S. Endangered Species Act during the early 1990s (Good et al. 2005). Population-growth rates lower than replacement have been attributed to a variety of human impacts (NRC 1996, McClure et al. 2003), including mortality associated with migration past eight dams and reservoirs of the Federal Columbia River Power System (FCRPS), though ocean conditions and climate regime also appear to play a strong role in regulating population dynamics (McFarlane et al. 2000). A central mitigation strategy to increase juvenile survival and adult returns of Snake River salmonids has been mass juvenile transportation through the FCRPS, with millions of chinook salmon and steelhead barged downstream in most years (e.g., Ward et al. 1997, Williams et al. 2005). The program involves fish collection at Snake River dam bypass facilities, selective loading on barges, and transport past dams and through hundreds of kilometers of reservoir at travel speeds up to 14 times faster than those experienced by in-river

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