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HIGH-HEAD DAMS AFFECT DOWNSTREAM FISH PASSAGE TIMING AND SURVIVAL IN THE MIDDLE FORK WILLAMETTE RIVER

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ABSTRACT

Many high-head dams in Oregon's Willamette River basin were constructed without fish passage facilities for downstream migrants. Instead, fish pass dams via hydroelectric turbines, surface spillways or deep-water regulating outlets. The availability of these routes varies seasonally with dam operations and reservoir depth, which can fluctuate by tens of meters.

To assess how dam and reservoir operations affect fish movement timing and survival, we used rotary screw traps below three Willamette basin dams and at two riverine sites above reservoirs. Traps were operated 2950 days over 8 years, and >195 000 fish were collected. Samples above reservoirs were primarily native salmonids (*Oncorhynchus* spp.), daces (*Rhinichthys* spp.) and sculpins (*Cottus* spp.), while those below dams were often dominated by non-native Centrarchidae. Capture rates at riverine sites were highest from late winter to early summer, coincident with juvenile Chinook salmon emigration. Conversely, collection below dams was largely restricted to late fall and winter when reservoirs were drawn down to annual lows and discharge was high. We hypothesize that winter operations facilitated fish access to dam turbines and regulating outlets, whereas spring–summer operations entrapped fish in reservoirs and restricted volitional downstream passage.

Total fish mortality was ≤2% at riverine sites and was 36–69% below dams. Estimates were highest for non-native species and juvenile Chinook salmon. Fatal injuries were consistent with traumas related to pressure, shear and contact and there were size-related and morphology-related risk differences. Mitigation opportunities include fish bypass system development, retrofits for existing routes and seasonally appropriate reservoir draw down to allow fish passage. Copyright © 2012 John Wiley & Sons, Ltd.

KEY WORDS: entrainment; high-head dam; reservoir entrapment; turbine mortality; Willamette River

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INTRODUCTION

High-head, flood-control dams in Oregon's Willamette River basin present a variety of fish passage challenges. Most of the dams are located in major tributaries and were constructed without fish facilities for either upstream or downstream passage (Myers *et al*., 2006; NMFS, 2008). Consequently, native fish movements associated with seasonal habitat use or life history requirements can be severely restricted. Anadromous species, including ESA-listed spring Chinook salmon (*Oncorhynchus tshawytscha*) and winter steelhead (*Oncorhynchus mykiss*) are among the most impacted species because dams block adult access to historic spawning areas (Myers *et al*., 2006; Sheer and Steel, 2006) and restrict emigration of juveniles outplanted from hatcheries or produced by adults released above dams (NMFS, 2008; Keefer *et al*., 2010). The dams also affect the abundance, movement and distribution of non-native species by restricting some upstream range expansion and potentially also exporting exotics to downstream reaches and to habitats above reservoirs.

In this study, we used rotary screw traps to monitor downstream fish passage timing and survival in the Middle Fork Willamette River (hereafter, 'Middle Fork'). Fish were collected above reservoirs in lotic habitats where native fish assemblages are relatively intact and below three high-head dams whose reservoirs support a mix of native and non-native species. Dam passage routes were via hydroelectric turbines, low-elevation regulating outlets and (rarely) surface spillways. Turbine-related fish mortality and injury risks have been well documented at dams worldwide and stem from shear stress, blade strikes, cavitation, collisions and rapid pressure changes (Navarro *et al*., 1996; Coutant and Whitney, 2000; Mathur *et al*., 2000; Čada 2001; Čada *et al*., 2006; Ferguson *et al*., 2008). Surface spillway passage is generally more benign than turbine passage, although spillway height, plunge pool configuration and other features can cause mortality and a variety of injuries (Muir *et al*., 2001; Schilt, 2007; Williams, 2008). There have been few studies of fish passage through the high-pressure, high-velocity regulating outlets that are typical at Willamette basin

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