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Thermal exposure of adult Chinook salmon in the Willamette River basin

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ABSTRACT

Radiotelemetry and archival temperature loggers were used to reconstruct the thermal experience of adult spring Chinook salmon (*Oncorhynchus tshawytscha*) in the highly regulated Willamette River system in Oregon. The study population is threatened and recovery efforts have been hampered by episodically high prespawn mortality that is likely temperature mediated. Over three years, 310 salmon were released with thermal loggers and 68 were recovered in spawning tributaries, primarily at hatchery trapping facilities downstream from high-head dams. More than 190,000 internal body temperature records were collected (*mean* ~2800 per fish) and associated with 14 main stem and tributary reaches. Most salmon experienced a wide temperature range (*minima* ~8–10 °C; *maxima* ~13–22 °C) and 65% encountered potentially stressful conditions (≥ 18 °C). The warmest salmon temperatures were in lower Willamette River reaches, where some fish exhibited short-duration behavioral thermoregulation. Cumulative temperature exposure, measured by degree days (DD) above 0 °C, varied more than seven-fold among individuals (*range*=208–1498 DDs) and more than two-fold among sub-basin populations, on average. Overall, ~72% of DDs accrued in tributaries and ~28% were in the Willamette River main stem. DD differences among individuals and populations were related to migration distance, migration duration, and salmon trapping protocols (i.e., extended pre-collection holding in tributaries versus hatchery collection shortly after tributary entry). The combined data provide spatially- and temporally-referenced information on both short-duration stressful temperature exposure and the biologically important total exposure. Thermal exposure in this population complex proximately influences adult salmon physiology, maturation, and disease processes and ultimately affects prespawn mortality and fitness. The results should help managers develop more effective salmon recovery plans in basins with marginal thermal conditions.

1. Introduction

Water temperature regimes strongly shape the physiology, behavior, and distribution of ectothermic fishes (Brett, 1995; Wood and McDonald, 1997; Perry et al., 2005). This is especially evident among the anadromous Pacific salmonids (*Oncorhynchus* spp.), a cold-water family that often traverses heterogeneous thermal habitats to fulfill life history requirements. Most *Oncorhynchus* populations use a combination of freshwater, estuarine and marine environments during juvenile emigration and again during subsequent adult reproductive migration (Groot and Margolis, 1991; Quinn, 2005). Selective pressures on life history traits (e.g., migration timing) and plastic migratory behaviors (e.g., behavioral thermoregulation) have resulted in migrations that largely avoid the stressful – and potentially lethal – effects of warm temperatures along migration routes. However, increasing river temperatures due to human activities (e.g., impoundment, water withdrawal, land use changes) and climate warming have increased warm-water exposure for some populations. Salmonids most at risk of adverse exposure include those with early season river entry followed by summer holding in freshwater such as stream-type Chinook salmon (*Oncorhynchus tshawytscha*), sockeye salmon (*Oncorhynchus nerka*), and summer steelhead (*Oncorhynchus mykiss*). Also at risk are those at the southern periphery of species' ranges (e.g., Keefer et al., 2008; Katz et al., 2013), populations in rivers susceptible to highly variable hydrologic conditions (e.g., Crozier and Zabel, 2006; Mantua et al., 2010), and some in highly-regulated systems (e.g., Naughton et al., 2005; Thompson et al., 2012).

Chinook salmon in Oregon's Willamette River system are

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