RIVER RESEARCH AND APPLICATIONS

River. Res. Applic. **23**: 963–978 (2007)

Published online in Wiley InterScience
(www.interscience.wiley.com) DOI: 10.1002/rra.1019

ESTIMATING ADULT CHINOOK SALMON EXPOSURE TO DISSOLVED GAS SUPERSATURATION DOWNSTREAM OF HYDROELECTRIC DAMS USING TELEMETRY AND HYDRODYNAMIC MODELS‡

ERIC L. JOHNSON,[a]* TAMI S. CLABOUGH,[a] CHRISTOPHER A. PEERY,[a] DAVID H. BENNETT,[b] THEODORE C. BJORNN,[a]† CHRISTOPHER C. CAUDILL[a] and MARSHALL C. RICHMOND[c]

[a] *Idaho Cooperative Fish and Wildlife Research Unit, Department of Fish and Wildlife Resources, University of Idaho, Moscow, Idaho 83844-1141, USA*

[b] *Department of Fish and Wildlife Resources, University of Idaho, Moscow, Idaho 83844, USA*

[c] *Pacific Northwest National Laboratory, P.O. Box 999, MS K9-36, Richland, Washington 99352, USA*

ABSTRACT

Gas bubble disease (GBD) has been recognized as a potential problem for fishes in the Columbia River basin. GBD results from exposure to gas supersaturated water created by discharge over dam spillways. Spill creates a downstream plume of water with high total dissolved gas supersaturation (TDGS) that may be positioned along either shore or mid-channel, depending on dam operations. We obtained spatial data on fish migration paths and migration depths for adult spring and summer Chinook salmon, *Oncorhynchus tshawytscha*, during 2000. Migration paths were compared to output from a two-dimensional (2-dimensional) hydrodynamic and dissolved gas model to estimate the potential for GBD expression and to test for behavioural avoidance of the high TDGS plume. We observed salmon swam sufficiently deep in the water column to receive complete hydrostatic compensation 95.9% of the time spent in the Bonneville Dam tailrace and 88.1% of the time in the Ice Harbor Dam tailrace. The majority of depth uncompensated exposure occurred at TDGS levels >115%. Adult Chinook salmon tended to migrate near the shoreline and they tended to remain in relatively deep water. Adults moved into the high dissolved-gas plume as often as they moved out of it downstream of Bonneville Dam, providing no evidence that adults moved laterally to avoid areas with elevated dissolved gas levels. When water depths decreased due to reduced river discharge, adults tended to migrate in the deeper navigation channel downstream from Ice Harbor Dam. The strong influence of dam operations on the position of the high-TDGS plume and shoreline-orientation behaviours of adults suggest that exposure of adult salmonids to high-TDGS conditions may be minimized using operational conditions that direct the spilled water mid-channel. Our approach illustrates the potential for combined field and modelling efforts to estimate the fine-scale environmental conditions encountered by fishes in natural and regulated rivers. Published in 2007 by John Wiley & Sons, Ltd.

KEY WORDS: fish behaviour; gas bubble disease; hydrologic modelling; Chinook salmon; fish depth; gas supersaturation

Received 25 January 2007; Accepted 22 February 2007

INTRODUCTION

The impacts of main stem dams in the Columbia River basin on anadromous salmonids, especially those from threatened and endangered stocks have received much attention over the past 25 years (National Research Council, 1996; Ruckelshaus *et al*., 2002). One dramatic effect of dams on river conditions is the elevated levels of dissolved gas caused by the entrainment of atmospheric gases as water passes over spillways. Since the early 1990s, voluntarily spilling water over dam spillways has been one management effort used to improve survival of juvenile salmonids *Oncorhynchus* spp. passing Columbia and Snake River dams by reducing the number of smolts passing through turbines and bypass systems (Schoeneman *et al*., 1961; Muir *et al*., 2001). Spilling at lower Columbia and Snake River projects typically begins the first week of April and continues through the end of August during which time spill volume is increased during the evening and night to take advantage of the tendency of juvenile salmonids to pass dams at night (Brege *et al*., 1996). However, spillway discharge at dams during the spring and early summer

*Correspondence to: Eric L. Johnson, Idaho Cooperative Fish and Wildlife Research Unit, Department of Fish and Wildlife Resources, University of Idaho, Moscow, Idaho 83844-1141, USA. E-mail: ejohnson@uidaho.edu
†Deceased.