

Context-dependent diel behavior of upstream-migrating anadromous fishes

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Abstract Variability is a hallmark of animal behavior and the degree of variability may fluctuate in response to environmental or biological gradients. For example, diel activity patterns during reproductive migrations often differ from those in non-breeding habitats, reflecting trade-offs among efficient route selection, reproductive phenology, and risk avoidance. In this study, we tested the hypothesis that diel movements of anadromous fishes differ among freshwater migration habitats. We analyzed diel movement data from ~13 000 radio-, PIT-, and acoustic-tagged adult fishes from five Columbia River species: Chinook salmon, *Oncorhynchus tshawytscha*; sockeye salmon, *O. nerka*; steelhead, *O. mykiss*; Pacific lamprey, *Entosphenus tridentatus*; and American shad, *Alosa sapidissima*. All five species were active

during most of the diel cycle in low-gradient, less hydraulically complex reservoir and riverine habitats. Movement shifted to predominantly diurnal (salmonids and American shad) or nocturnal (Pacific lamprey) at hydroelectric dam fishways where hydraulic complexity and predator density were high. Results suggest that context-dependent behaviors are common during fish migrations, and that diel activity patterns vary with the degree of effort or predation risk required for movement.

Keywords Behavioral plasticity · Migration · Orientation · Predation risk · Sensory ecology

Introduction

Behavioral flexibility allows animals to rapidly and adaptively respond to changing conditions and to environmental stimuli that signal resources or risk. Diel behavior, for example, varies widely along a continuum from almost exclusively nocturnal, to crepuscular, to strongly diurnal. Within species, diel rhythms can be quite plastic across life stages and at a variety of temporal scales in response to proximate and ultimate factors (Helfman 1983; Boujard and Leatherland 1992; Rees 2002). Diel activity varies in response to environmental conditions (e.g., photoperiod, water temperature), physiological status (e.g., starvation, metamorphosis), predators, and life history requirements (e.g., migration, reproduction). Ecological context additionally affects

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