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Presentation Title: Measuring the additive effects of colonial waterbird predation on the survival of Upper Columbia River steelhead: Implications for predator management

Abstract for the 2021 Pacific Coast Steelhead Management Meeting

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The degree to which predation is an additive versus compensatory source of mortality is fundamental to understanding the effects of predation on prey populations and evaluating the efficacy of predator management actions. To address this critical uncertainty, we analyzed a long-term (2008-2018) mark-recapture-recovery dataset of Upper Columbia River steelhead trout that were PIT-tagged and subsequently exposed to predation by multiple bird species and colonies during out-migration through multiple river reaches (spatial-scales); jointly estimating probabilities of steelhead survival, mortality due to bird predation, and mortality due to other causes. This concurrent estimation approach allowed for an investigation of the additive effects of predation on steelhead survival. Results indicated that cumulative effects of bird predation were substantial, with predation probabilities (proportion of available fish consumed) ranging from 0.31 (95% CRI = 0.27-0.38) to 0.53 (0.42-0.64). Comparisons of total smolt mortality ($1 - \text{survival}$) with mortality due to avian predation indicated that avian predation accounted for 42% (30–56%) to 70% (53–87%) of total mortality, indicating more steelhead were consumed by avian predators than died from all other mortality sources combined during out-migration through the river-reaches evaluated. Of the predator species evaluated, predation by Caspian terns was often the highest and the most variable. Increases in Caspian tern predation probabilities were associated with statistically significant decreases in steelhead survival probabilities in all evaluated years and salmonid life-stages (smolt out-migration and smolt-to-adult returns). Results provide evidence that predation by Caspian terns was an additive source of mortality during the smolt life-stage and a partially additive source of mortality to the adult life-stage, indicating more juvenile steelhead would survive outmigration to the Pacific Ocean and would return as adults to the Columbia River in the absence of predation by Caspian terns. Results have important implications for predator management actions aimed at increasing the survival of steelhead in the Columbia River.