

## Environmental fluctuation and shifting predation pressure contribute to variation in early marine survival of steelhead

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### Abstract

Steelhead smolts must migrate through distinct freshwater, estuarine, and coastal habitats, each with unique biological and physical characteristics, on their route from natal streams to the ocean to complete their life cycle. Fewer than 15% of steelhead trout (*Oncorhynchus mykiss*) smolts survived their migration from the Nisqually river through Puget Sound to the Pacific Ocean from 2006 to 2009 and in 2014. Rapid smolt migration coupled with evidence of smolt mortality at harbor seal (*Phoca vitulina*) haulouts during 2014 indicated pinniped predation was an important source of mortality. When Puget Sound temperatures increased with the Northeast Pacific heat wave from late 2014 to 2016, steelhead smolt survival probabilities increased to 38% in 2016 and 2017, then decreased again as Puget Sound water temperatures cooled. One of the many ecological changes that accompanied the increased marine temperatures included the increased abundance of northern anchovy (*Engraulis mordax*; anchovy) in Puget Sound. The years of lowest smolt mortality coincided with abundant larval and post-larval anchovy during the previous year; and we hypothesize that the resulting high abundance of age-1+ anchovy provided an alternative prey source for predators of migrating steelhead smolts. Identification of ecological mechanisms that drive patterns in the survival of ESA-threatened steelhead provide critical understanding of the systems within which management strategies must operate.