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Using ferry monitoring data to explore the importance of isotherms on the winter survival of Northern anchovy in Puget Sound

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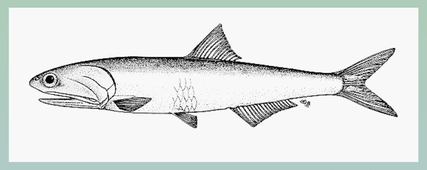
Introduction

The Salish Sea displays strong seasonality in water temperature which can impose physiological limits on temperature sensitive species. Using a ferry vessel is one mode of measuring near-surface water temperature. With monitoring equipment on the *Victoria Clipper* IV passenger ferry, we collected several years of geo-referenced and high-frequency water temperature measurements between Seattle, WA and Victoria, B.C. The ferry-based monitoring data can be used to identify when conditions are potentially favorable for temperature sensitive species such as Northern anchovy (*Engraulis mordax*). This forage fish species can survive in water between 8 and 25 °C and has a temperature threshold of 8-9 °C. In British Columbia, Northern anchovies prefer to spawn in 13 to 18 °C water and in July and August (Fisheries and Oceans Canada 2016). In Puget Sound, Northern anchovies spawn throughout the basin (Penttila 2007). With winter survival and successful spawning, Northern anchovies can potentially exploit the spring plankton blooms that occur between April and May. We examine near-surface isothermal patterns to describe when Northern anchovies may survive winter conditions in the Salish Sea.



Credit: Whitehead, Nelson, and Wongratana (1988).

Methods

Ferry-based Monitoring

- The *Victoria Clipper IV* passenger ferry transits ~80 mi between Seattle, WA and Victoria, B.C. (Fig. 1).
- An optical fluorometer is installed in the vessel's port engine room and measures temperature, chlorophyll fluorescence, turbidity, and CDOM at 5-sec intervals (Fig. 2).
- Data are geo-referenced with a GPS located above the stern deck (Fig. 2).

Data Processing and Analysis

- We collected >22 million records over 8 years.
- The large, high-frequency data set was reduced to 7.1 million records by excluding ports and vessel maintenance.
- The reduced data set was gridded into mean temperature for each 0.01 °N latitude and day.
- Resulting heat maps contain data in 120,164 grids.
- Data analysis and plotting were done in the R statistical software using packages dplyr and ggplot2 (R Core Team 2017, Wickham 2009, and Wickham et al. 2017).

Results and Discussion

- Mean gridded water temperature ranged from 5.3 °C to 21.0 °C for the entire time period (Fig. 3).
- Near-surface water temperatures show seasonal patterns with coldest waters in winter and warmest waters in summer.
- The coldest water that occur in winter, generally from December to April, could affect winter survival of Northern anchovy.
- Winters of 2014-2015 and 2015-2016 had temperatures above the minimum threshold for Northern anchovy.
- For spawning of Northern anchovy, the favorable water temperature occur from July to September and in the southern area of Puget Sound.
- Between the Admiralty Sill and Seattle, plankton blooms occur in late spring, mid-summer, and late summer (Pool et al. 2015). Anchovies prey on plankton, including euphausiids, copepods, and decapod larvae (Whitehead et al. 1988). Thus, anchovies have the potential to exploit plankton blooms, particularly upon winter survival in cold water conditions.
- Heat maps are an effective and realistic representation of data without obscuring days of no data such as in a contour plot.
- Isotherms can also be applied to other temperature sensitive species such as Pacific herring, oysters, and phytoplankton species which produce harmful algal blooms.

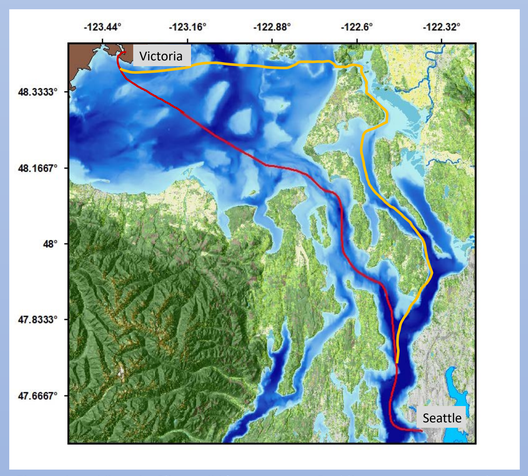


Figure 1. *Victoria Clipper IV* ferry routes. Red line represents regular ferry route. Yellow line represents alternate route used in poor weather conditions.

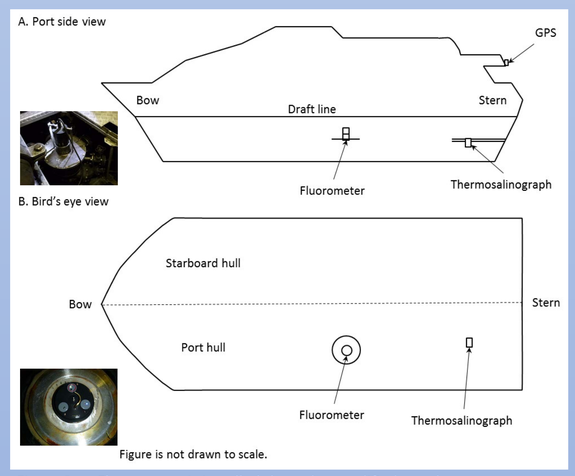


Figure 2. Fluorometer is installed through a modified sea chest cover. Optical lenses measure: 1) chlorophyll, 2) turbidity, and 3) CDOM.

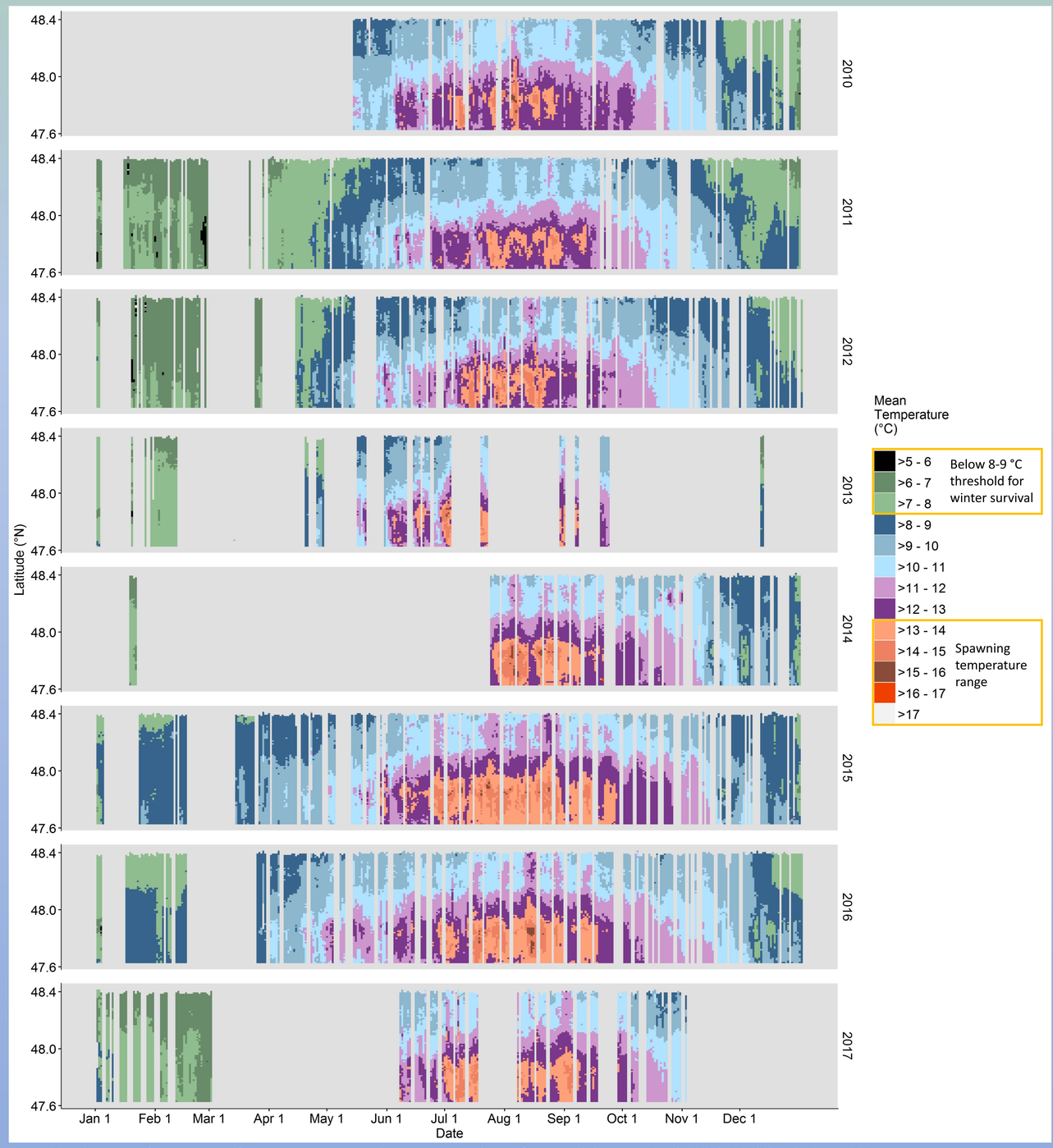


Figure 3. Heat map of mean near-surface water temperature that was measured every five seconds between Seattle, WA (~47.6 °N) and Victoria, B.C. (~48.3 °N). Each panel represents one year. Within each panel, one grid represents mean temperature at the 0.01 °N latitude interval and day. Shaded areas represent no data.

Acknowledgments

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The poster was presented at the Salish Sea Ecosystem Conference on April 5, 2018 in Seattle, Washington.