Apr 5th, 11:30 AM - 1:30 PM

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

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Pool, Suzan; Krembs, Christopher; Bos, Julia; and Albertson, Skip, "Using ferry monitoring data to explore the importance of isotherms on the winter survival of Northern anchovy in Puget Sound" (2018). *Salish Sea Ecosystem Conference*. 271.


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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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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.

Acknowledgments
We would like to thank Clipper Vacations for the successful partnership over the past several years, NANOOS for grant support, and Brandon Sackmann for his ingenious monitoring system design and continued support. We also thank Sandy Weaoland for the study area map.

References

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


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.