A decade of coastwide environmental monitoring on the annual IPHC fishery-independent setline survey and practical applications of the data in a spatio-temporal assessment model

Lauri L. Sadorus and Raymond Webster
International Pacific Halibut Commission, Seattle, WA, USA, E-mail: lauri.sadorus@iphc.int

Abstract
In 2009, the International Pacific Halibut Commission (IPHC) commenced an annual coastwide environmental monitoring program. At each station surveyed during the IPHC's fishery-independent setline survey (FISS), water column profilers are deployed to collect conductivity (C), temperature (T), pressure (depth; D), dissolved oxygen (DO), pH, and fluorescence (Chl). These data are used to monitor the conditions of Pacific halibut habitat in North American waters of the Pacific Ocean and Bering Sea. The data have led to a better understanding of the environmental conditions throughout Pacific halibut habitat, including spatial variability in environmental variables. The monitoring has also enabled the ability to detect annual anomalies such as seasonal hypoxic zones that can greatly affect local Pacific halibut density. Incorporation of environmental covariates into the IPHC spatio-temporal modelling of density indices allows for the exploration of relationships between Pacific halibut density and environmental variables. As an example, we present results from modelling of data from surveys of the west coast of the United States of America.

**IPHC environmental monitoring program**

**Oceanographic conditions on the Pacific halibut grounds**

**Dissolved oxygen**
- Mean near-bottom DO has varied from hypoxic (< 1.4 mg/L) to relatively high (8 mg/L).
- Hypoxia is sometimes detected at the deepest FISS stations where deep basin water has flowed up onto the slope and outer shelf.
- Shallow water hypoxia is occasionally detected at FISS stations off the U.S.A. west coast.

**Chlorophyll**
- Highly variable spatially and temporally.
- In example year 2010, mean chlorophyll was 32 mg/m² and ranged from 0.1-334 mg/m².
- In example year 2017, the mean was greater at 86 mg/m², but the range was more narrow at 0-428 mg/m².

**Temperature**
- Near-bottom mean temperature increased in all regions profiled over the 2009-2018 time period.
- All areas indicate fluctuations between warmer and colder years at the higher end of the range.
- Increase in minimum temperature in the most recent years in all regions except Region 2.

**Spatio-temporal modeling to examine environmental effects on Pacific halibut distribution**

**Example**
- In 2017, the FISS encountered a large number of tightly clustered stations off the northwest USA coast that caught zero Pacific halibut, where fish are normally encountered.
- A previous study (Sadorus et al. 2014) found that Pacific halibut have a minimum DO concentration threshold of about 0.9 mg/L, i.e. they avoid DO below this level.
- Model results confirmed that there was strong evidence that Pacific halibut density indices were dependent on the DO covariate.
- In 2018, low levels of DO were also observed over a wide area. However the affected zone typically has relatively low Pacific halibut catch rates, and the hypoxic stations were interspersed with stations above the minimum DO threshold. The result was that hypoxia did not have nearly the distributional impact in 2018 as it did in 2017.

**References**

**Acknowledgements**
We would like to thank all of the people who have been instrumental in making the environmental data collection program a big success, especially:
- The FISS team along with all of the vessels, crews, and sea samplers who have worked tirelessly to deploy the profilers and collect high-quality data.
- Jay Walker of IPHC who has been the program’s technical partner and ensured that the data are collected properly and make it from the profilers to the database.
- Peggy Sullivan from NOAA/JISAO who has processed thousands of our profiles, making the data available to scientists worldwide to utilize for their research.