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

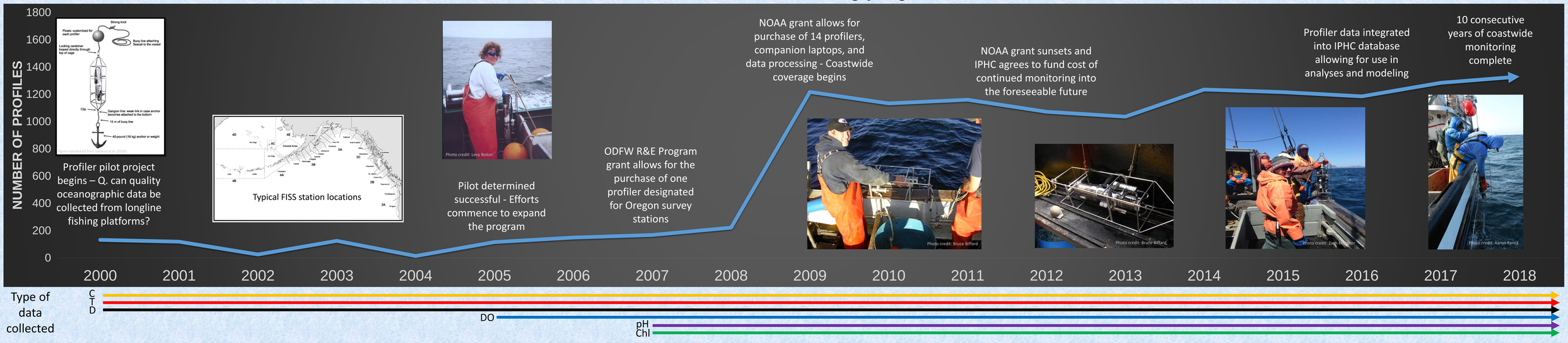
Lauri L. Sadorus and Raymond Webster
International Pacific Halibut Commission, Seattle, WA, USA, E-mail: lauri.sadorus@iphc.int

INTERNATIONAL PACIFIC HALIBUT COMMISSION

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

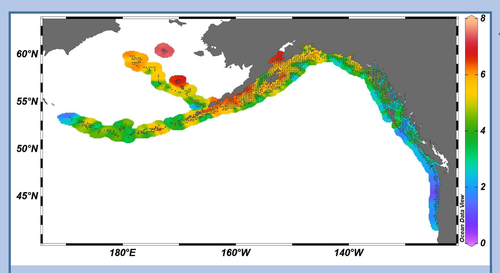


Figure 1. Mean near-bottom DO concentration (ml/L) spanning 2009-2018. Key to DO concentration is to the right and the black dots represent FISS stations where the data were collected.

Dissolved oxygen

- Mean near-bottom DO has varied from hypoxic (< 1.4 ml/L) to relatively high (8 ml/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.

pH

- During IPHC monitoring, ocean acidity has generally correlated with DO concentration, i.e. near-bottom pH levels are higher where DO is higher and lower where DO is lower.
- pH tends to be lower in the east than elsewhere.
- pH tends to be lower at deeper stations compared to shallow stations.

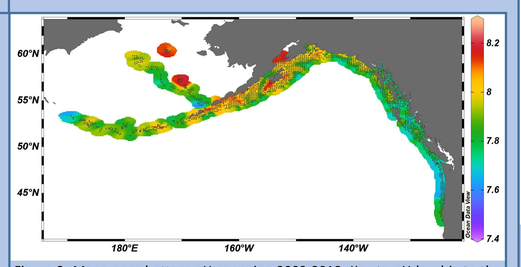


Figure 2. Mean near-bottom pH spanning 2009-2018. Key to pH level is to the right and the black dots represent FISS stations where the data were collected. Note that values used from 2014-2018 are preliminary.

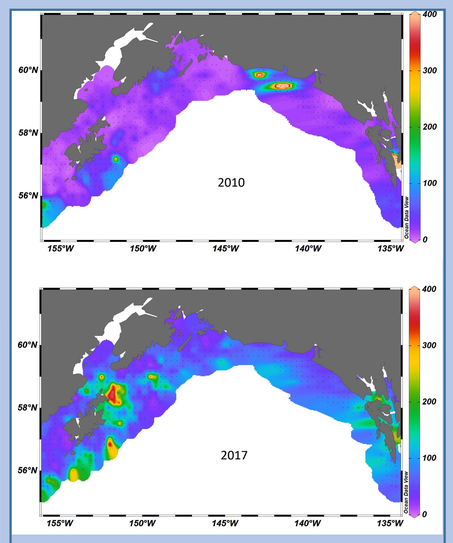


Figure 3. Depth integrated chlorophyll *a* concentration (mg/m^3) for two example survey years, 2010 and 2017, in the Gulf of Alaska. Key is to the right and the black dots represent FISS stations where the data were collected.

Chlorophyll

- Highly variable spatially and temporally.
- In example year 2010, mean chlorophyll was 32 mg/m^3 and ranged from 0-1,334 mg/m^3.
- In example year 2017, the mean was greater at 86 mg/m^3, but the range was more narrow at 0-428 mg/m^3.

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.

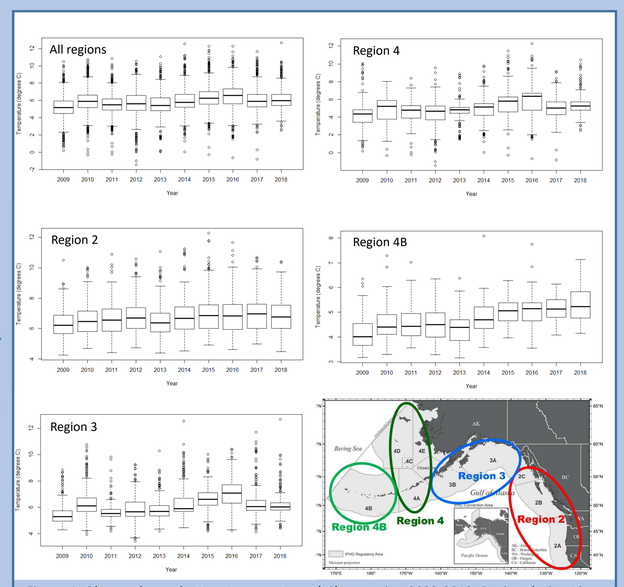


Figure 4. Observed near-bottom temperatures (°C) spanning 2009-2018. Region designations displayed in the lower right panel (reproduced from Stewart and Hicks 2019).

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

Purpose

- The IPHC uses a spatio-temporal model (Webster et al. In review) to examine distribution and density changes of Pacific halibut throughout the monitored area.
- Modelling output is used in the IPHC stock assessment, and ensures standardized treatment of data inputs across areas and time, while accounting for process and sampling uncertainty.
- Recently, environmental covariates have been added to the analysis to examine distribution changes driven by oceanographic conditions.
- To date, spatio-temporal modeling has provided strong evidence of relationships between Pacific halibut catch rates and environmental covariates, such as dissolved oxygen and temperature.

Example

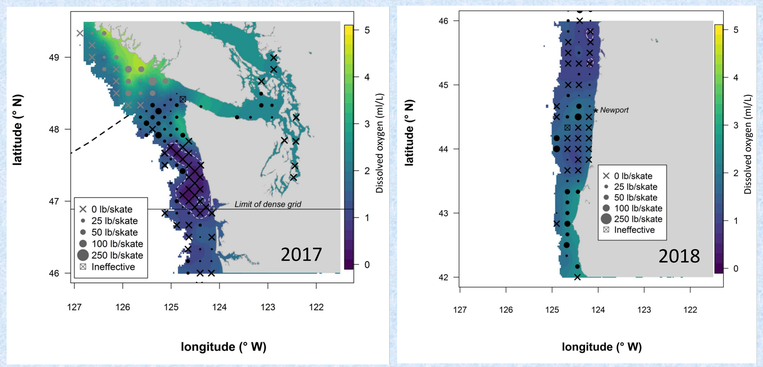


Figure 5. Estimated DO in northern Regulatory Area 2A in 2017 (left panel) and central Area 2A in 2018 (right panel) with O32 Pacific halibut WPUE values from the FISS overlaid with black symbols.

- 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 ml/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

Sadorus, L. L., Mantua, N. J., Essington, T., Hickey, B., and Hare, S. 2014. Distribution patterns of Pacific halibut (Hippoglossus stenolepis) in relation to environmental variables along the continental shelf waters of the US West Coast and southern British Columbia. Fish. Oceangr. 23(3): 225-241.

Sadorus, L., Walker, J., and Sullivan, M. 2016. IPHC Oceanographic data collection program 2000-2014. Int. Pac. Halibut Comm. Tech. Rep. 60. 32 p.

Stewart, I., and Hicks, A. 2019. 2019 Pacific halibut (*Hippoglossus stenolepis*) stock assessment: Development. Int. Pac. Halibut Comm. Scientific Review Board Meeting, June 26-28, 2019, Seattle, WA, U.S.A. Report IPHC-2019-SRB014-07.

Webster R. A., Soderlund, E., Dykstra, C. L., and Stewart, I. J. In review. Monitoring change in a dynamic environment: spatio-temporal modelling of calibrated data from different types of fisheries surveys of Pacific halibut.

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 sees 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.