Modeling the relative importance of near-bottom temperature and dissolved oxygen to the distribution of adult Pacific halibut (*Hippoglossus stenolepis*)

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Background

Earlier studies suggest that depth, temperature, and dissolved oxygen (DO) content all play a role in adult Pacific halibut (*Hippoglossus stenolepis)* distribution (Sadorus et al. 2014; Loher and Seitz 2006). Furthermore, the relative importance of these factors may vary temporally, spatially, and by depth. The North American Pacific halibut fishery spans the area from northern California to the Bering Sea. This region supports a healthy but fully utilized stock with harvests for commercial, sport, subsistence, and ceremonial uses. Data critical for the halibut stock assessment are collected through a coastwide longline survey that operates each summer and includes water column profiles coincident with fishing at each station (Fig. 1). In this study, catch and profiler data from 2009-2012 are coupled and analyzed using tree regression models to identify the driving environmental factors to halibut distribution and how those factors may vary in importance by area.

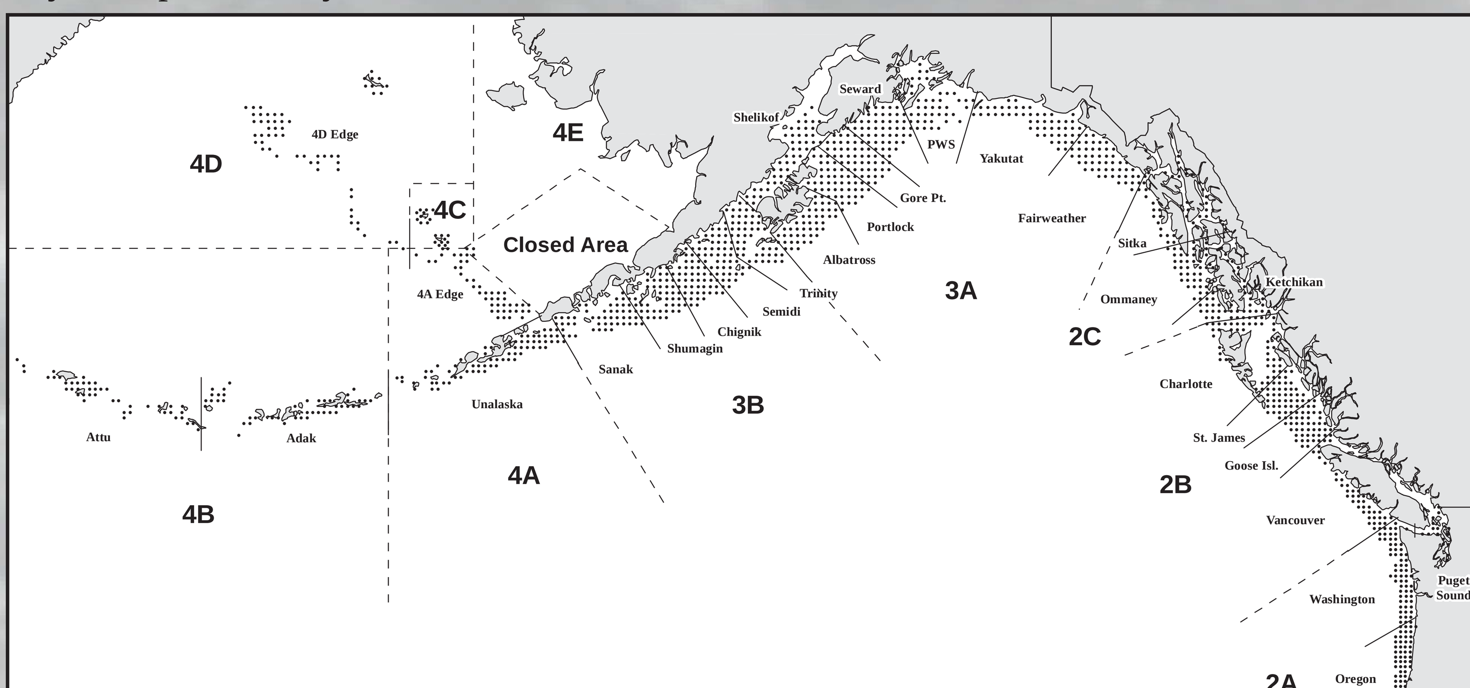

Figure 1. IPHC longline survey stations. Each station is visited annually during the summer months where both fishing and oceanographic information is collected.

Data collection methods

Environmental data are collected using profilers manufactured by Seabird Electronics™ (Bellevue, WA). The profilers collect surface to near-bottom oceanographic information and are deployed just prior to hauling the fishing gear at each station. The assumption is that halibut, a demersal flatfish, caught on the gear at that station are experiencing oceanographic conditions as recorded by the bottom-most reading of the profiler. For this analysis, pressure, temperature, and DO are used.

Fishing at each station consists of setting a longline with baited hooks and hauling the gear several hours later. The survey spans depths from 30-500 m and is conducted in the summer months.

Analysis

Catch information used here is numbers-per-unit-effort (NPUE) of halibut which is a standardized catch value that enables spatial and temporal comparisons. Figure 2 shows the average NPUE over all study years interpolated into an isosurface map. The North American range for Pacific halibut is quite extensive, but the center of distribution is clearly in the Gulf of Alaska.

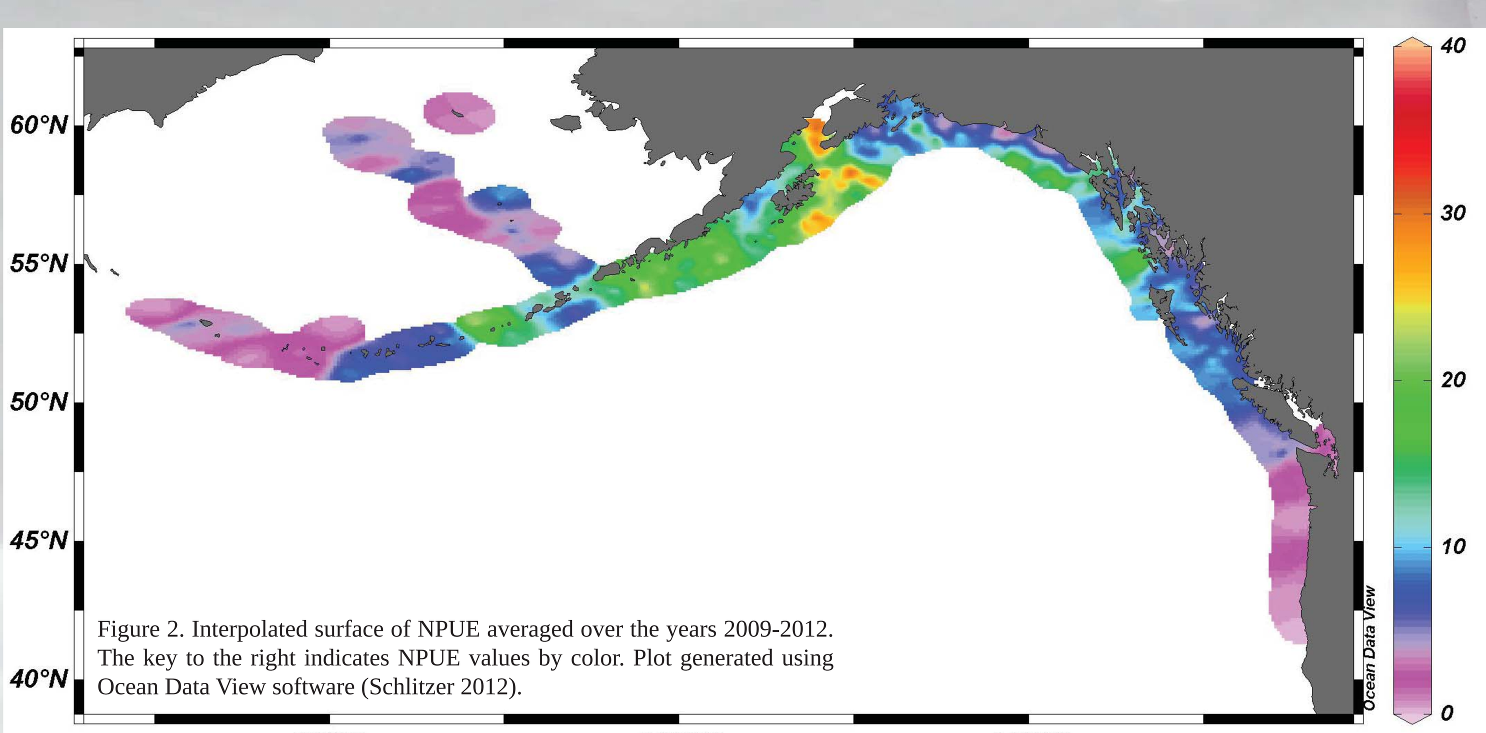

Figure 2. Interpolated surface of NPUE averaged over the years 2009-2012. The key to the right indicates NPUE values by color. Plot generated using Ocean Data View software (Schlitzer 2012).

Univariate regression indicates that both temperature and DO are highly significant factors in determining halibut NPUE (Fig. 3).

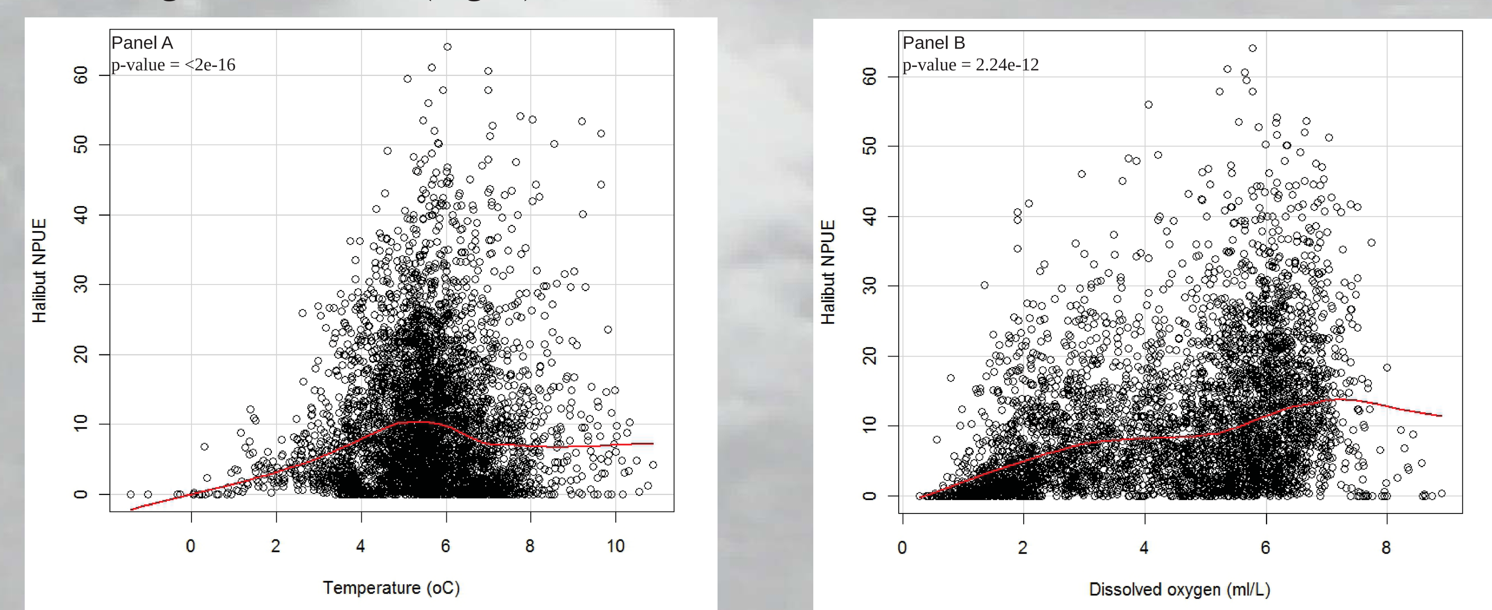

Figure 3. Scatterplots of NPUE in relation to temperature (Panel A) and DO (Panel B) indicate the ranges of values where Pacific halibut NPUE was highest and lowest among the stations sampled. A lowess smoothed line is included and in both cases is highly significant.

Many common modelling approaches (e.g. multiple linear regression) assume variable independence, but oceanographic variables are highly correlated with one another and require a method that can account for this. Tree regression (De'ath and Fabricius 2000), used in this analysis, is a form of clustering that provides interpretable results even when variables are collinear, non-linear, or interactive.

A water column profiler, the instrument used to collect oceanographic data for this study, is pulled aboard a survey vessel during the IPHC longline survey. Photo by Beth Dubofsky.

The trees are constructed by a series of splits that yield branches. At each split, the dissimilarity of sites (total sums of squares) within clusters is minimized and is maximized between clusters. The splits at the top of the tree represent variables that influence a wide spatial scale, and subsequent splits represent increasingly finer spatial detail. Terminal nodes indicate the mean NPUE for that grouping of stations. Deviance is used to assess model performance.

A tree was first built using all variables coastwide including latitude. Branches were clearly geographically distinct which resulted in dividing the data into four regions for analysis and dropping the geographic variable. The four regions are: West Coast (U.S. and British Columbia), Gulf of Alaska, Aleutian Islands, and Bering Sea (Fig. 4).

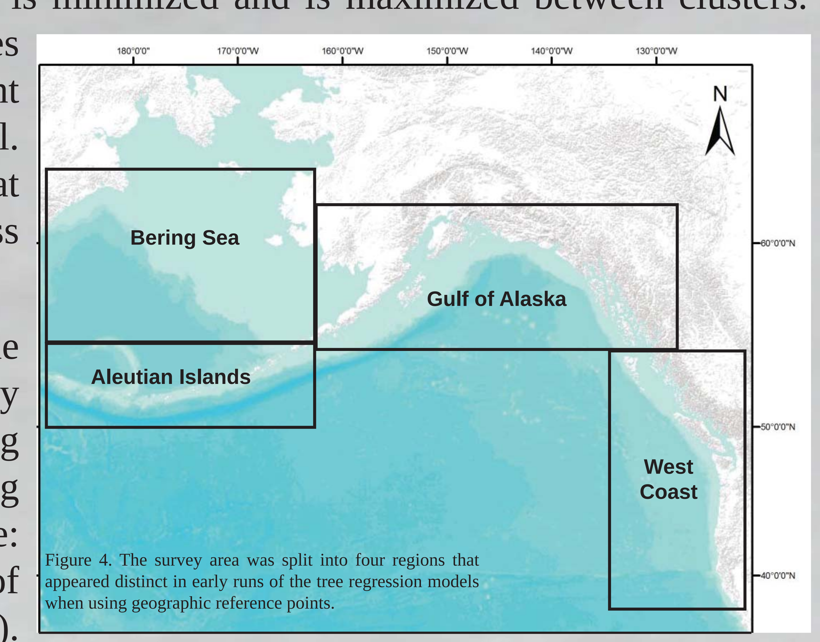

Figure 4. The survey area was split into four regions that appeared distinct in early runs of the tree regression models when using geographic reference points.

Tree regression summary of results

- The minimum DO tree split was lower in the West Coast region (1.4 ml/L) than in the Bering Sea (2.2 ml/L) and Aleutian Island (2.4 ml/L) regions, but the outcome was the same: lower DO was associated with lower NPUE and vice versa, even at moderate levels.
- Mid-range temperatures (4-7°C) were associated with higher NPUE than temperatures outside of this range.
- Where both temperature and DO were within acceptable ranges, depth was the primary explanatory variable with shallow depths associated with higher NPUE.
- In the Bering Sea where temperature was outside the optimal range, deeper stations (with relatively higher temperatures compared to shallow stations) where DO was adequate, were associated with higher NPUE.
- This modeling technique did not yield relevant results using Gulf of Alaska data so no corresponding tree is presented here.

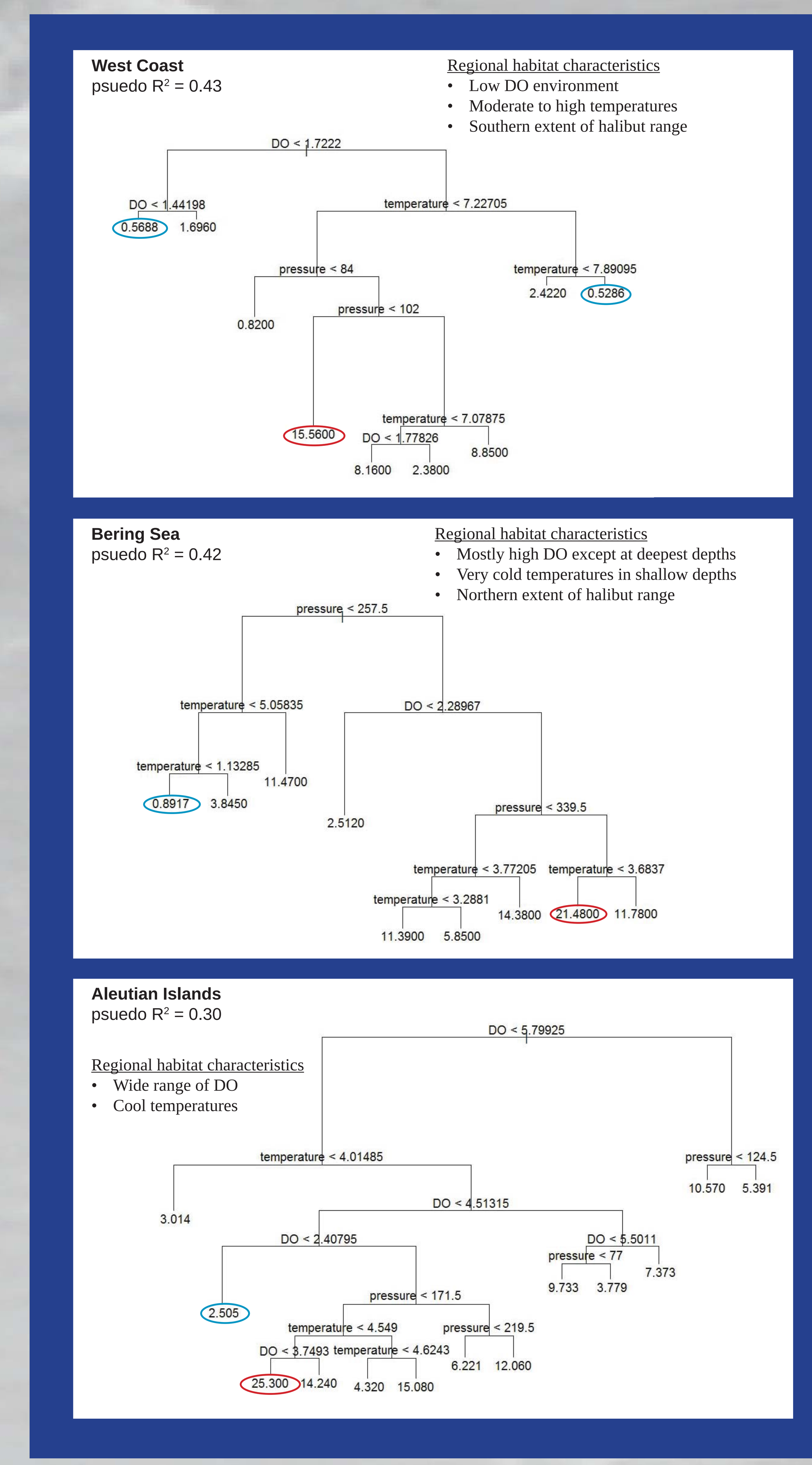

Figure 5. Tree regression models for the West Coast, Bering Sea, and Aleutian Islands regions. The terminal nodes indicate the mean NPUE for that cluster. The highest NPUE is circled in red and the lowest is circled in blue.

Conclusions

- In areas where temperature and DO are approaching threshold levels, the distribution of fish is affected, i.e. halibut are caught in lower numbers where environmental conditions are outside the optimal range.
- Nearing the organism threshold level for one variable may contract the organism "normal" range for the other variable. There is evidence for this in both the West Coast and Bering Sea.
- When temperature and DO are within optimal ranges (e.g. Gulf of Alaska), Pacific halibut distribution cannot be adequately explained by the environmental variables used in this analysis.

References

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