Modeling the Effects of Climate Change on the Catcher/Processor Sector of the BS Pollock Fishery

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Methods

Model Estimation

- Catcher/processor vessels (C/Ps) take trips of several weeks and move about the fishing grounds, stopping to fish as long as the expected profit from fishing in a location exceeds the expected profit of fishing in any other location.
- We are interested in the spatial distribution of effort, so we model the choice of fishing location with a spatial discrete choice model (Bockstael and Opaluch 1983, Smith and Wilen 2003)
- A vessel is assumed to make a choice of where to fish each haul from the available location options to maximize their profit.
- We use an alternative specific constant logit model to fit observed data. Fishing location choice is assumed to be a function of variables that vary by choice, such as expected CPUE and travel cost, and variables that do not vary by choice, such as total allowable catch (TAC) and climate regime.

Climate Effects

- Ongoing work by other BSIERP researchers (Hunt et al., Forthcoming in ICES J. Mar. Science) presents evidence that warm climate regimes and early sea ice retreat may negatively affect pollock survival and recruitment into the fishable biomass through food availability.
- Our climate analysis employs this hypothesis. If there is a negative relationship between warm climate years and abundance several years later, and total allowable catch (TAC) is proportional to biomass, then if warm years become more common TAC may decrease.

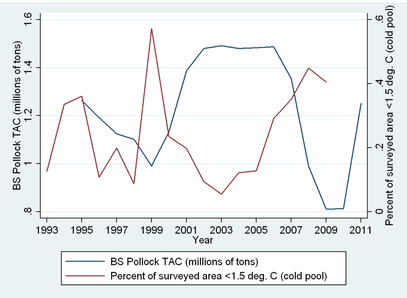

Figure 2. Bering Sea pollock TAC and size of the cold pool

- The alternative specific constants (ASCs) estimated by the model identify the unobserved quality of fishing grounds. Annual TAC is included in the estimation of the ASCs as a measure of abundance. If the spatial distribution of fish is affected by abundance, the effect on the distribution of effort will be captured in the marginal effect of TAC on the ASCs (Figure 3).
- The extent of the cold pool, as measured by average bottom temperature, can also have an unobservable effect on the spatial distribution of fish. Figure 4 shows the marginal effect on the probability of visiting an area, should the average bottom temperature rise by 1 degree Celsius.

Background

The potential effects of climate change on fisheries are generally explored using models based on ecological or biological data that ignore the economic drivers of fisheries (Cheung et al., 2009). These ecosystem-based models predict a poleward shift in the distribution of polar and sub-polar marine species (Perry et al., 2005).

There is evidence of a poleward shift of the pollock catcher/processer (C/P) fishing fleet over the period 1999-2009 (Figure 1). However, fisheries are driven by a variety of economic variables, including the spatial distribution of fish stocks, fish product prices, travel costs, and variation in vessels' harvesting capabilities, as well as climate variation.

How has the spatial distribution of the catcher/processor sector of Bering Sea pollock fishery changed with recent climate variation?

We use a spatial discrete choice framework to model the spatial fishing decisions of vessels as a function of economic and climate variables (as opposed to biological data exclusively). We estimate the effect of a warmer Bering Sea on the spatial distribution of fishing effort.

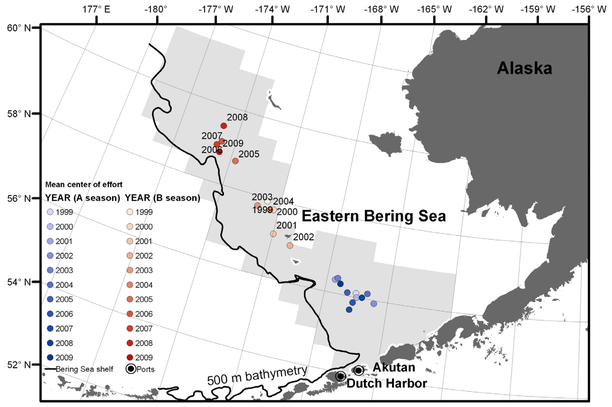

Figure 1. There is no evidence of a change in the mean center of the distribution of A season fishing. In the B season, however, the distribution of effort has shifted northwest.

Results

Model Estimation

Table 1 shows results of the alternative specific constant logit estimation of the choice of fishing location. that harvesters are driven by expected prices for their products, expected CPUE, and a variety of vessel and seasonal effects.

Table 1. Results of Alternative Specific Constant Logit Estimation (B season fishing)

Variable	Estimated Coefficient
Price	0.00056***
Expected CPUE	0.01345***
Cumulative duration of fishing	0.00287***
No E(CPUE)	-1.92184***
Distance	0.02292***
Distance*TAC	-0.00007***
Distance*Vessel HP	0.00018***
Distance*Vessel length	0.00002*
Distance*HP*Length	-0.00000**
Distance*July	0.00350***
Distance*August	0.00568***
Distance*September	0.00697***
Distance*October	0.00636***
Distance*CDQ	-0.00483***
Distance*%Full	-0.00046***
Distance*Estimated probability of changing areas	-0.04206***
June*Cold pool indicator	-0.45978***
Number of observations	44145
Pseudo R2	-0.74

Marginal Effects on the Distribution of Fishing of a Warming Bering Sea

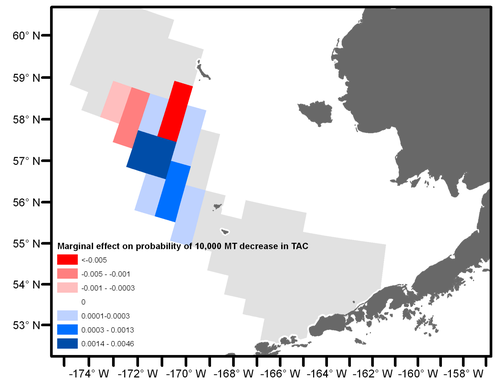

Figure 3. If TAC is related to past climate regimes (warm periods resulting in a decrease in abundance), then the effect of a warming Bering Sea on the distribution of fishing effort will be the effect of a marginal decrease in TAC on the probability of visiting each area, controlling for the economic variables included in Table 1, yearly average bottom temperature, and a time trend. The figure shows the marginal change in probability.

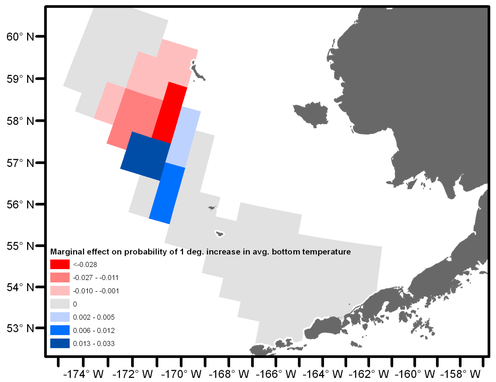

Figure 4. Bottom temperature affects where harvesters choose to fish because pollock avoid the cold pool (water of less than 2°C created by the extent of winter sea ice). While the cold pool generally dissipates by the middle of the B fishing season, it may concentrate fishing at the beginning of the season or have an effect on distribution that persists. Figure 4 shows the marginal effect on the probability of visiting an area of a 1°C increase in average bottom temperature.

Conclusions

- Economic variables such as expected CPUE, prices, and travel costs are important determinants of fishing location choice.
- Ice cover has an effect on A season pollock fishing, but there is no evidence of a change in the distribution of the fishery over the time period studied, 1999-2009.
- In B season fishing, however, there has been a shift in the distribution of fishing effort towards the northwest over the time period.
- Bering Sea ice cover is predicted to decrease by 40% by 2050, resulting in a smaller persistent cold pool and warmer bottom temperatures.
  - Under the assumed relationship that warmer temperatures lead to lower TAC, we find that a decrease in seasonal TAC of about 3% is predicted to lead to the change in effort distribution depicted in Figure 3.
  - Increases in bottom temperature may also have a direct effect through the concentration of fishing outside the cold pool. An increase of 1°C is predicted to lead to the change in effort distribution depicted in Figure 4.

References

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Acknowledgements

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