How might environmentally-driven changes in the distribution of arrowtooth flounder affect predation upon eastern Bering Sea walleye pollock?

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Outline

1) Processes affecting fish stock dynamics that are subject to environmental variation

2) Environmental variability in the eastern Bering Sea shelf, and its influence on the spatial distributions of arrowtooth flounder and juvenile walleye pollock spatial distributions.

3) Estimation of spatially-resolved estimates of predation mortality in the single-species walleye pollock model.

4) Projections of pollock stock dynamics under future climate scenarios.

5) The role of environmentally-driven trends in natural mortality in estimation of stock size and fishing rate reference points.

How might temperature variability affect fish population dynamics?

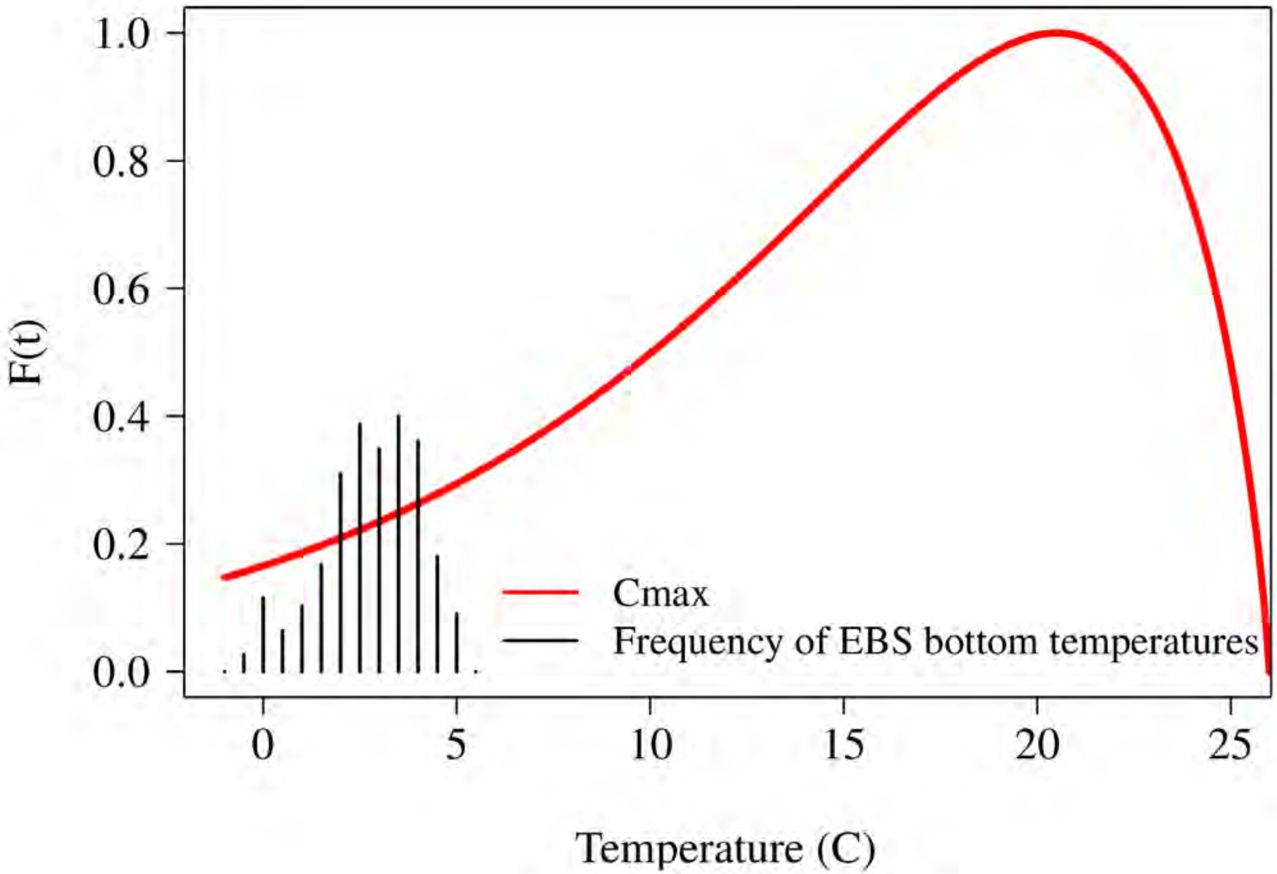
1) Bottom temperatures can affect metabolic rates (Holsman and Aydin 2015; Holsman et al. in press)

2) Bottom temperatures can affect predator-prey overlap

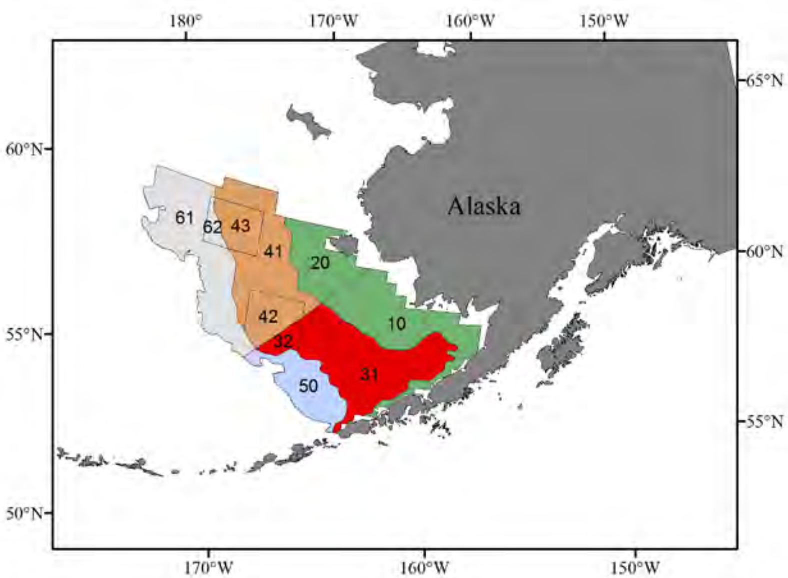
3) Temperature can affect recruitment strength (Mueter et al. 2011 showed a relationship with SST)

The maximum rate of consumption (C_{max}, g g^{-1} d^{-1}) is a function of temperature

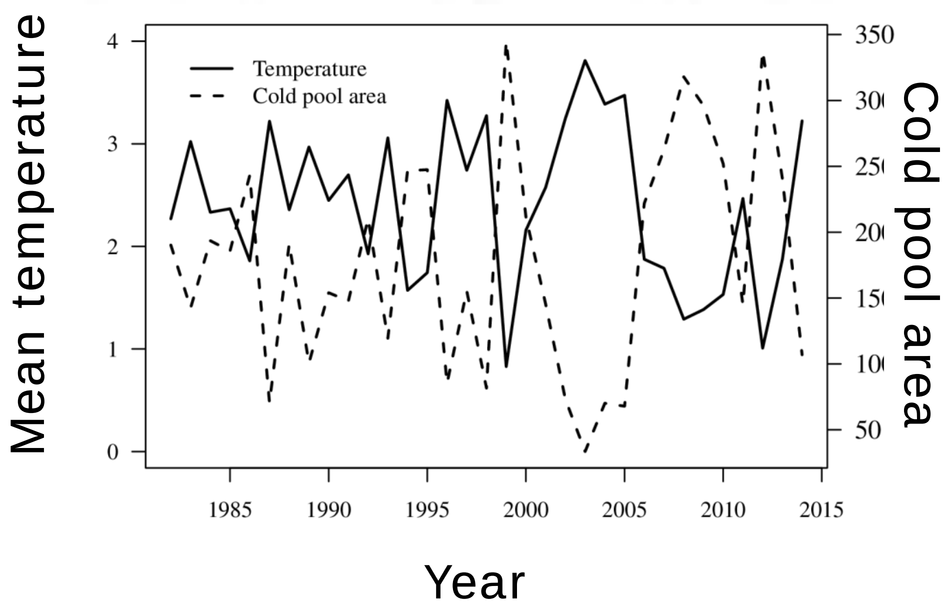
$$C = c_a w^{c_b} f(T)$$

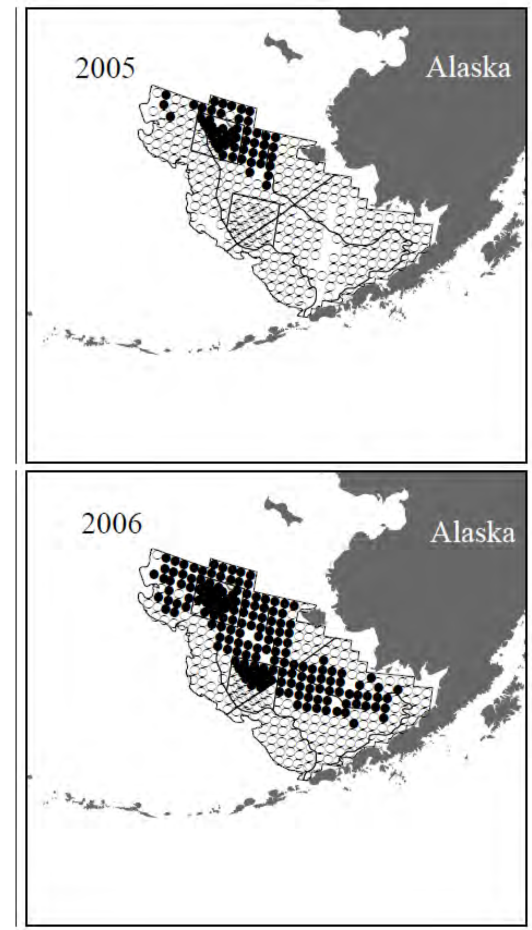


Temperature variability in the EBS shelf

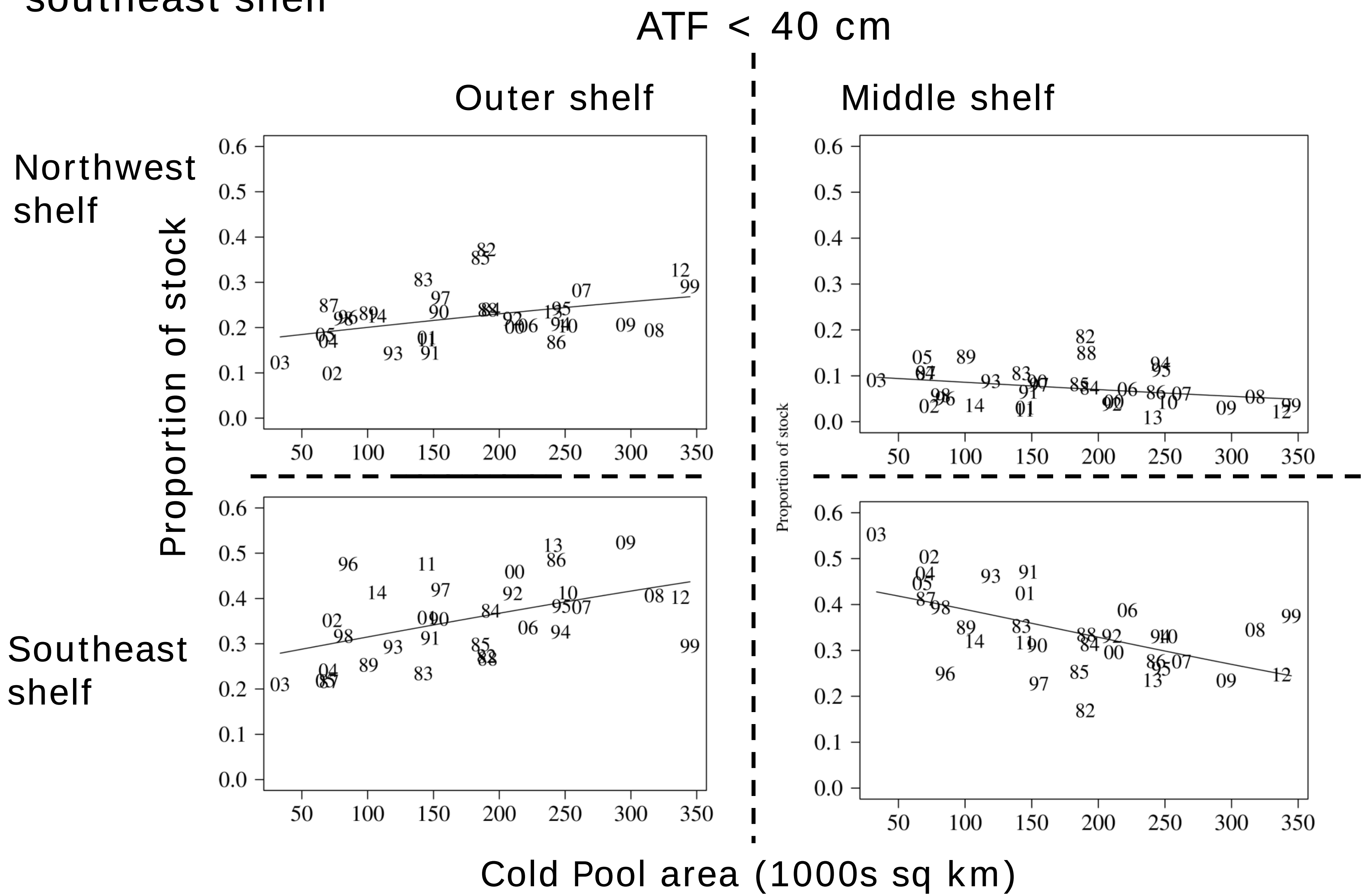


Annual bottom trawl survey with consistent methodology since 1982

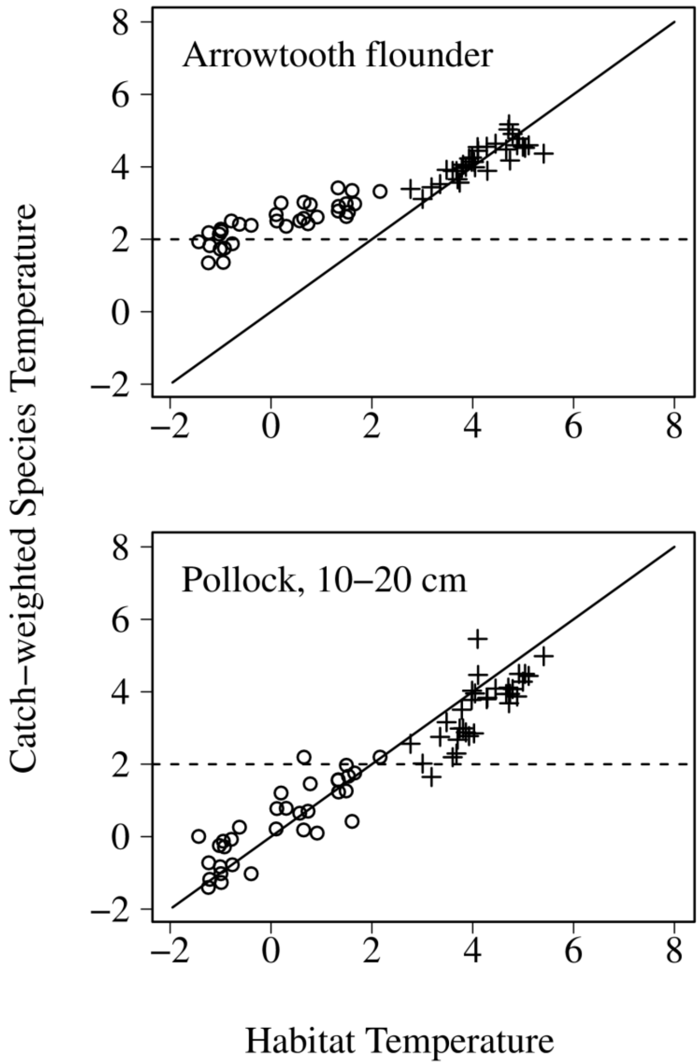




Changes in the spatial distribution occur primarily in the southeast shelf



The distribution-temperature relationships for juvenile pollock are less strong than those for ATF



How can predation mortality be estimated within an assessment model?

Predator

Consumption =

$$\underbrace{\left(\frac{w_{ATF}}{w_{wp}}\frac{C_{\max}a}{(b+\overline{N}_{dens})}\right)}_{\text{catchability}}\cdot \underbrace{ATF}_{\text{effort}}\cdot\overline{N}_{dens}\cdot area$$

Fishery

Catch =

$$qE\overline{N}$$

Catch per unit predator per area (CPUPPA)

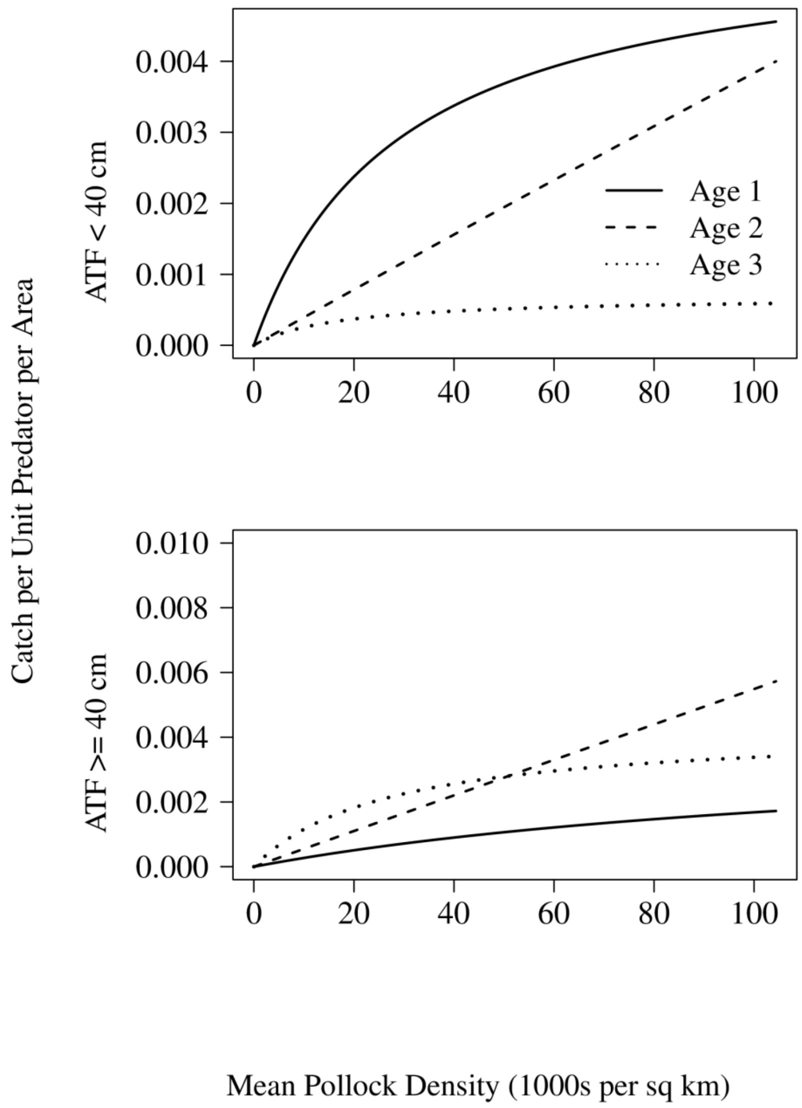
$$\frac{C}{ATF\cdot area}=\frac{w_{ATF}}{w_{wp}}\frac{C_{\max}a\overline{N}_{dens}}{(b+\overline{N}_{dens})}$$

Catch per unit effort (CPUE)

$$\frac{C}{E}=q\overline{N}$$

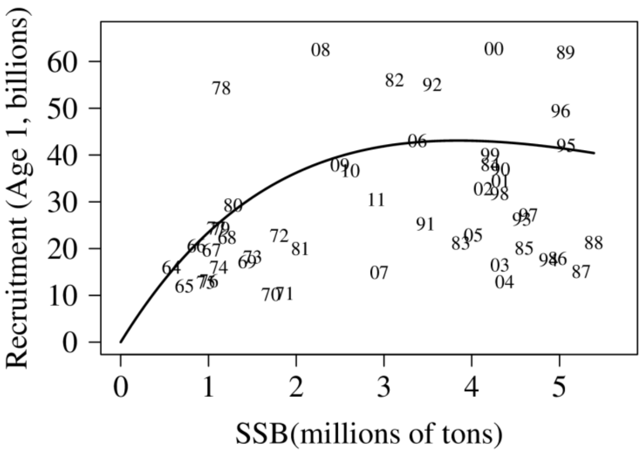
(Holling type II function response)

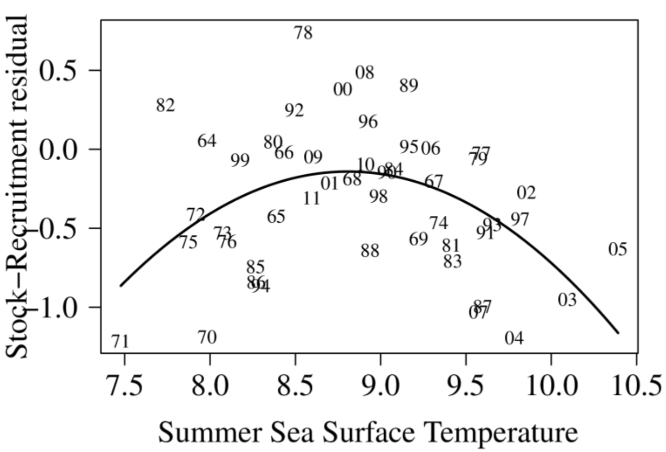
Estimates of functional response curves in the single-species assessment model



Projection of the effect of temperature upon pollock dynamics

Modeling of recruitment residuals

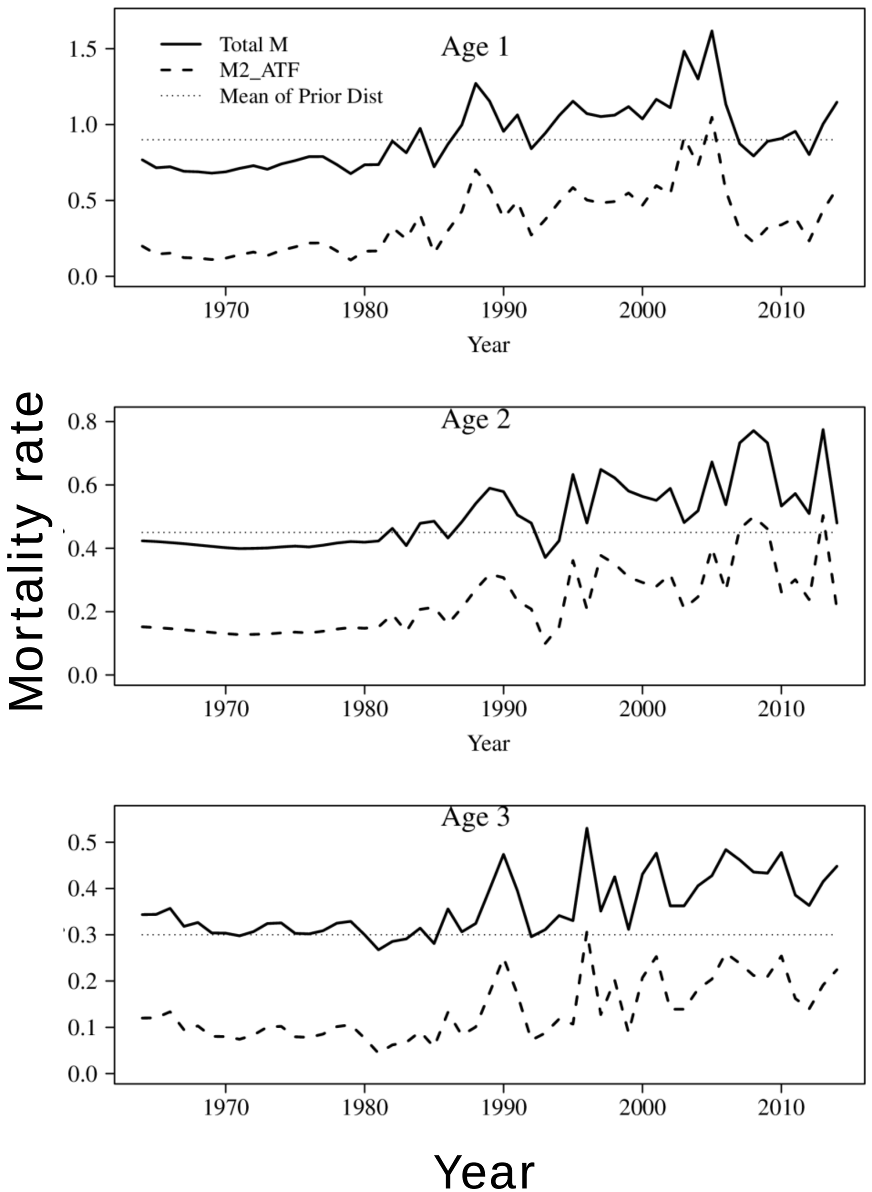




Longer-term projections would consider the effect of temperature on pollock recruitment

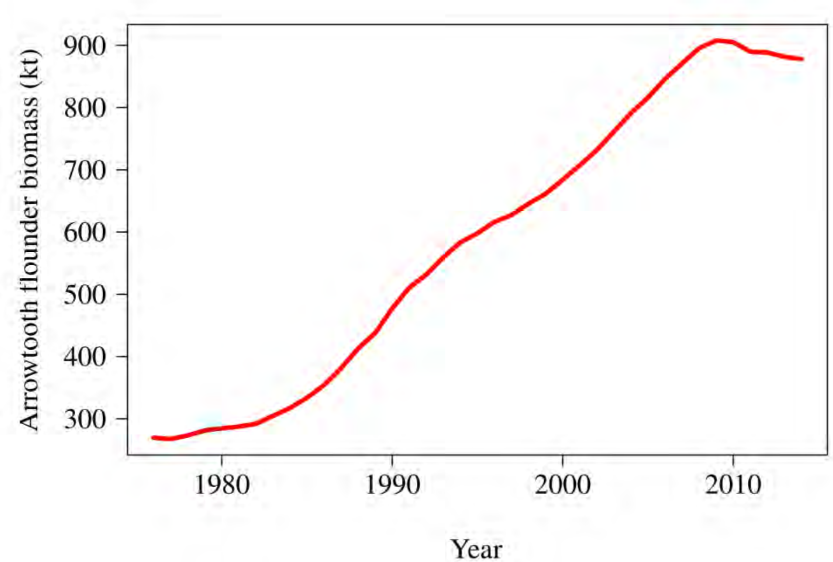
Temperature either too warm or too cold would be expected to have negative effects on pollock recruitment

Model estimates of ATF and ‘residual’ natural mortality

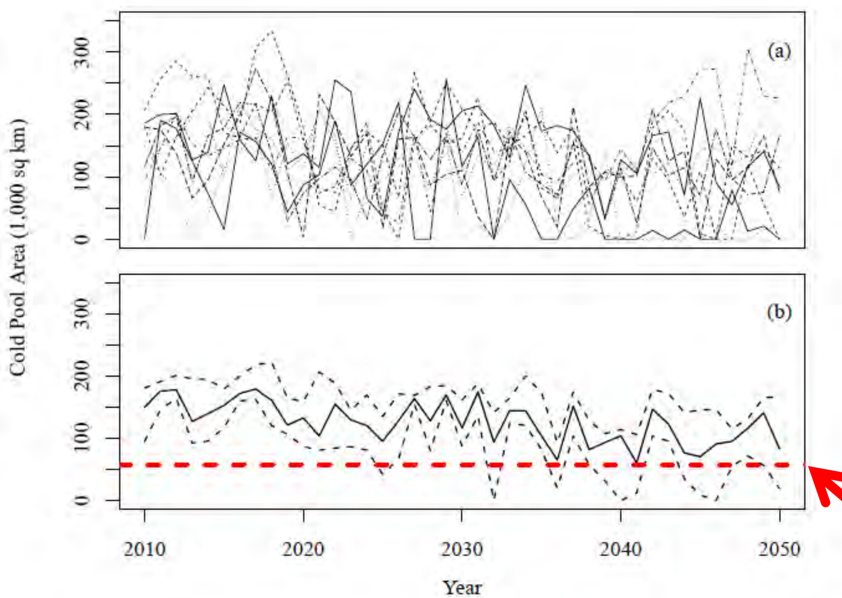


$$M = M_{ATF<40cm} + M_{ATF>=40cm} + M_{residual}$$

The total *M* for each age was constrained by a prior distribution, centered on the value used in the current assessment



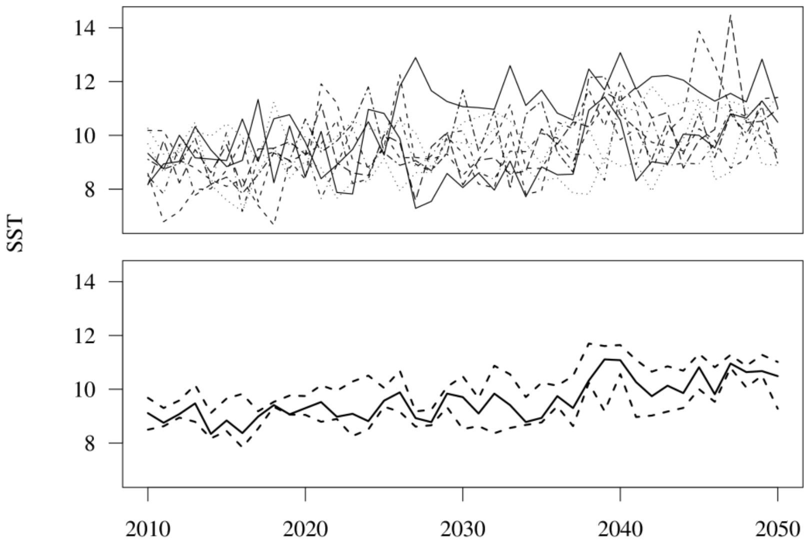
Projected environmental conditions from statistical downscaling



Decrease in cold pool area

Median cold pool area in 2045-2050 is 32% lower than median from 2011-2015

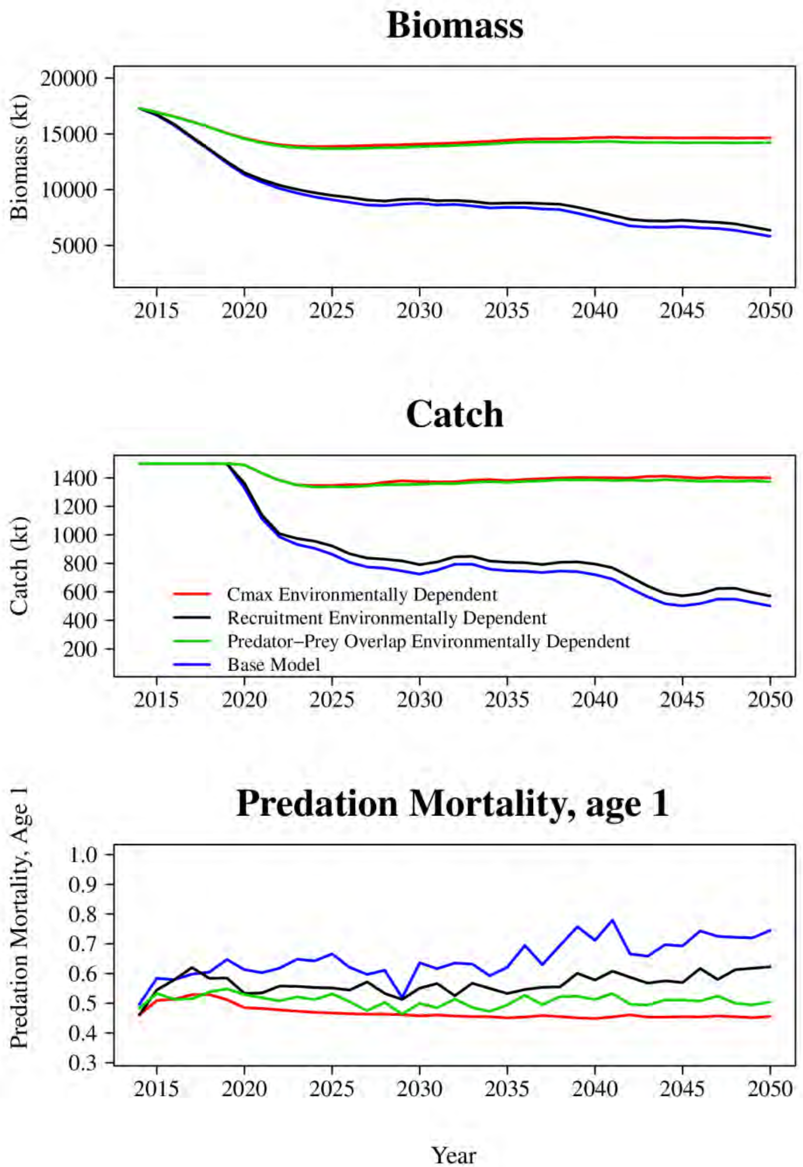
Cold pool area, 2003-2005



Increase in sea surface temperature

Median SST in 2045-2050 is 17% higher than median from 2011-2015

Relative influence of the three environmentally-dependent processes

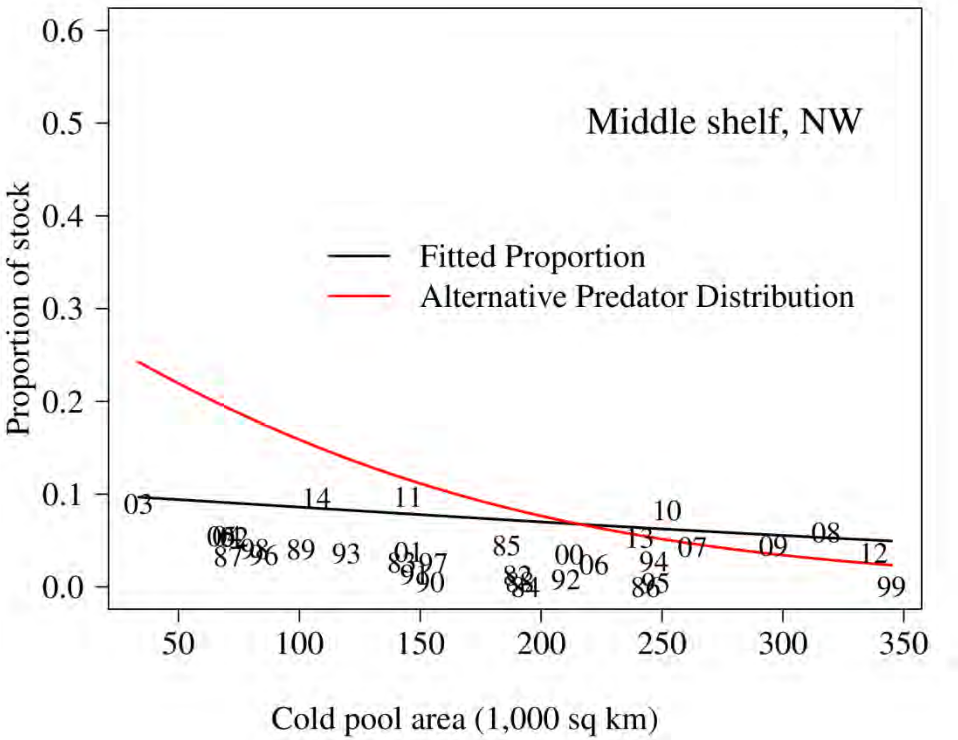


Of the 3 processes examined, the effect of temperature has on recruitment has the strongest effect on future dynamics

Large uncertainty in these projections

The increase in predation mortality reflects that ‘catchability’ increases as the abundance decreases (due to the type II functional response)

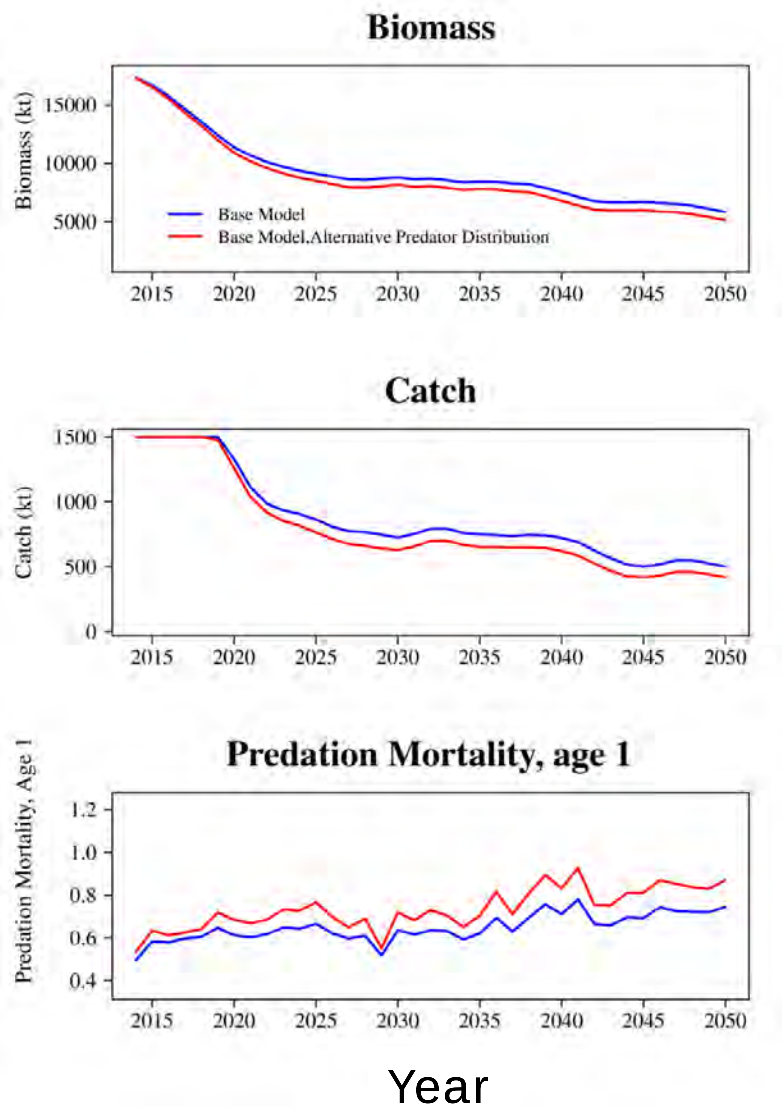
How sensitive are the pollock dynamics to changes in arrowtooth flounder distribution?



Hypothesize that in warm years arrowtooth flounder occupy the NW middle shelf to a greater extent than they currently do.

What would be the effect on the pollock dynamics?

Relative effect of expanded northward distribution of arrowtooth flounder during warm years



How should we incorporate environmentally-driven changes in natural mortality in the assessment/ management process?

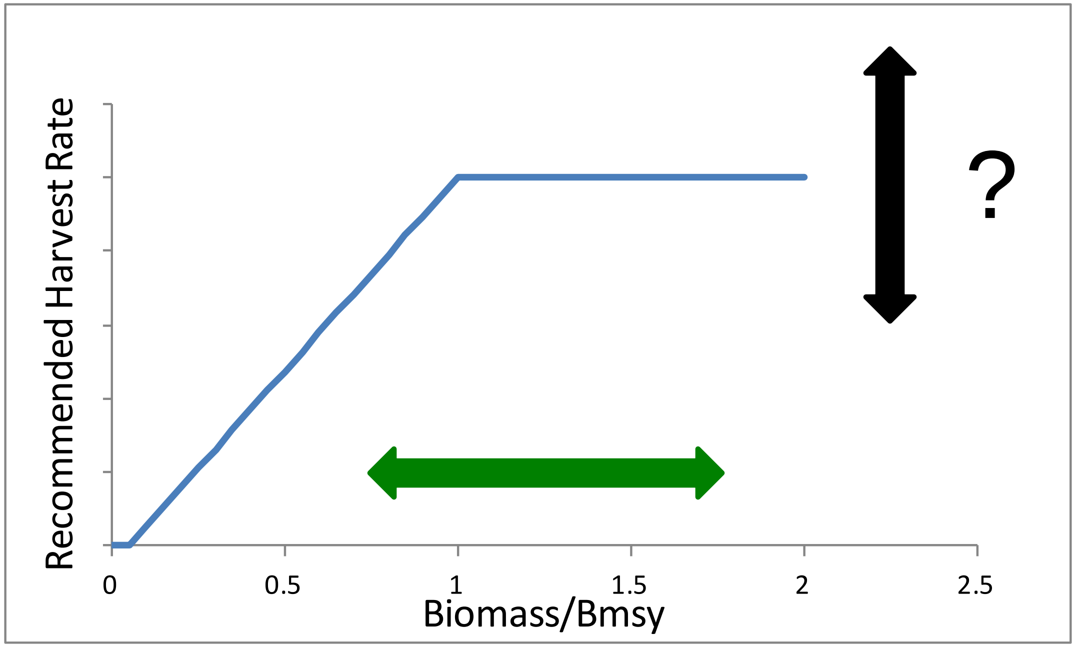
(thanks to Chris Legault for thinking about this)

Two approaches for thinking about this:

1) A fishing rate reference point based on the recent estimates of an increasing trend of natural mortality will also increase (based on spawning potential ratios).

2) If there is a level of total mortality that the stock can sustainably withstand, then high predation mortality leaves less room for fishery harvest. Fishing rates reference points should decrease (based on stock-recruitment and analysis and F_{msy}).

What is an environmentally-dependent control rule?



Advice (slightly modified from Legault and Palmer, in review):

It can make sense to include trends in natural mortality in stock assessments in order to get the best estimates of abundance.

Fishing rates reference points should be consistent with life-history metrics.

Conclusions

1) Information on spatial distributions of predator and prey populations allow spatially resolved estimates of predation mortality to be estimated within single-species stock assessments

2) The temperature-dependent variation in maximum consumption and predator-prey spatial overlap is expected to have a relatively minor effect on pollock dynamics compared to the influence of temperature on recruitment.

3) However, the importance of temperature-dependent predator-prey overlap may increase if the degree of overlap increases as temperature increases.

4) Incorporation of predation mortality within stock assessment can play an important role in improving estimation of stock abundance and our understanding of the factors that have caused stock fluctuations.

5) Estimates of fishing rate reference points that are consistent with the life-history parameters may be useful when variability and short-term trends in natural mortality occur.