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

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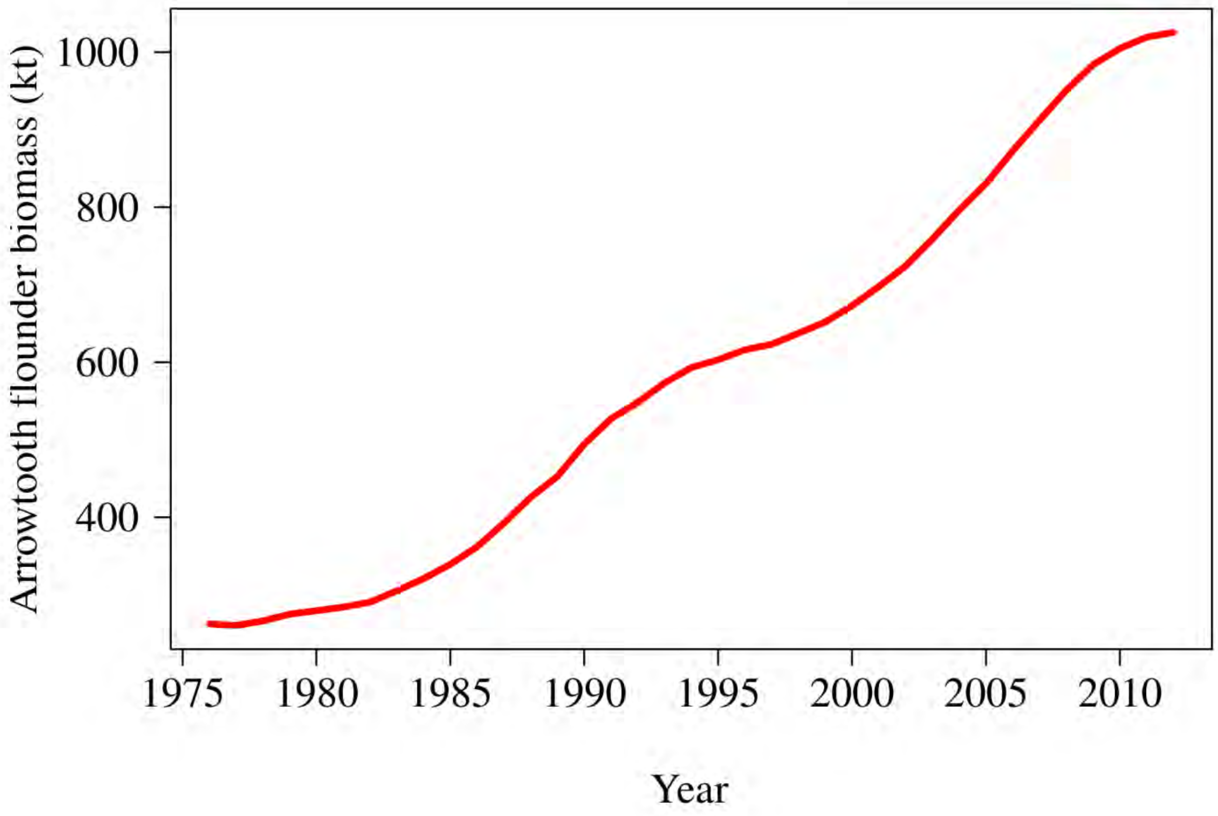
Arrowtooth (ATF) flounder biomass



Outline

1) Description of study area and environmental variability.

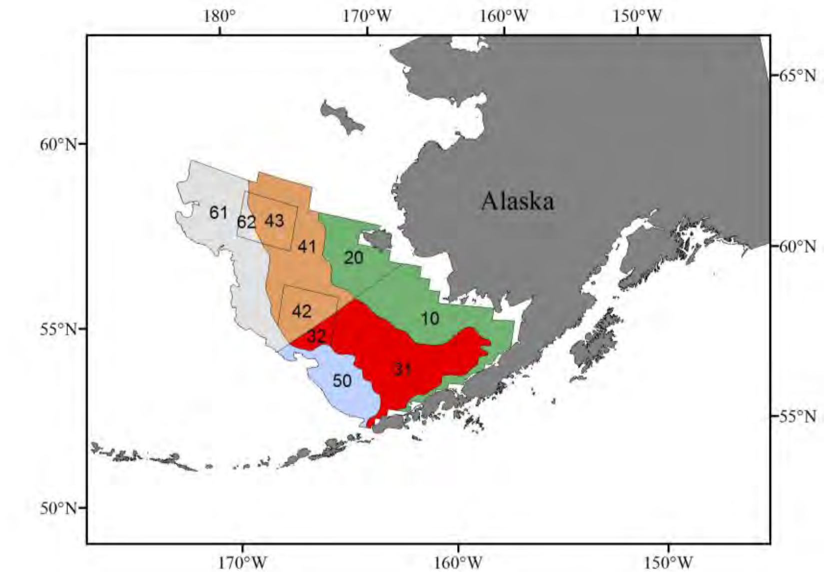
2) The influence of environmental variability on arrowtooth flounder and juvenile walleye pollock spatial distributions.

3) Estimation of consumption of walleye pollock by arrowtooth flounder.

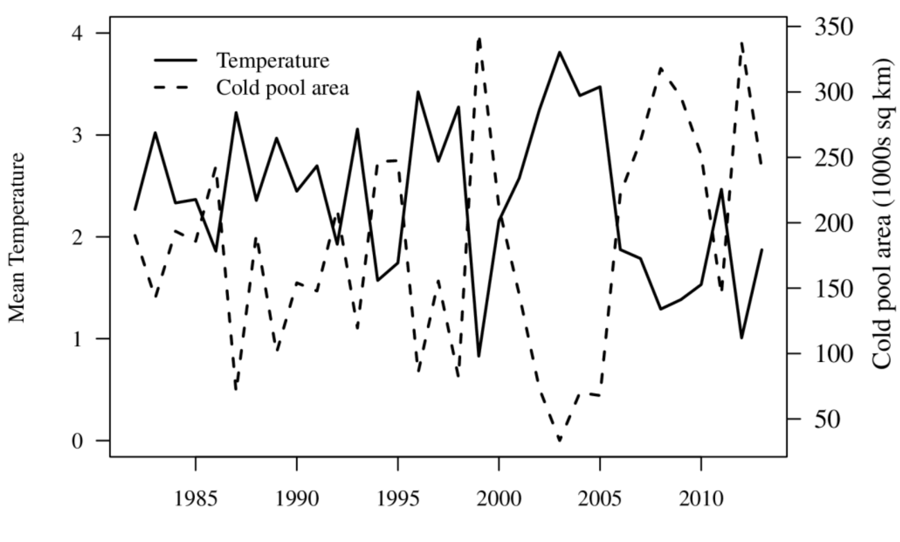
4) Incorporation of spatially-resolved estimates of predation mortality in the single-species walleye pollock model.

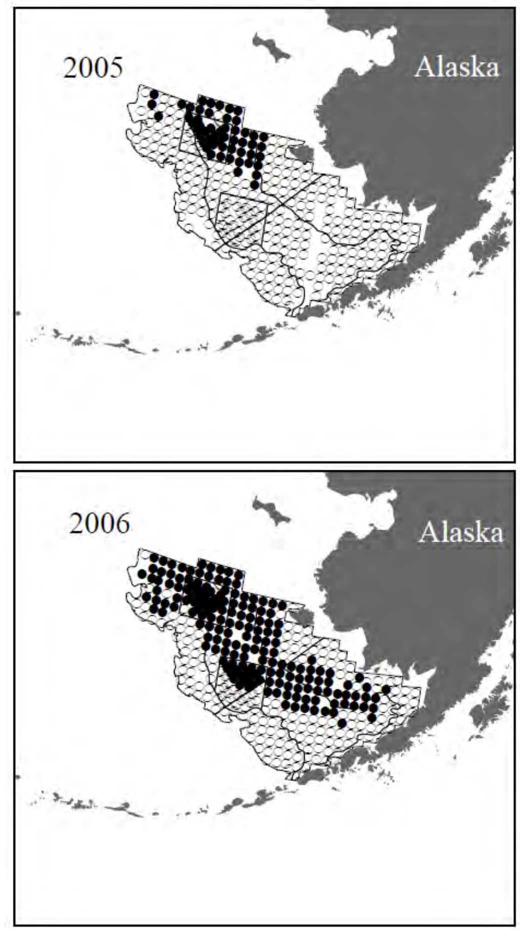
5) Potential impacts of future climate conditions on predator distributions and predation.

Temperature variability in the EBS shelf

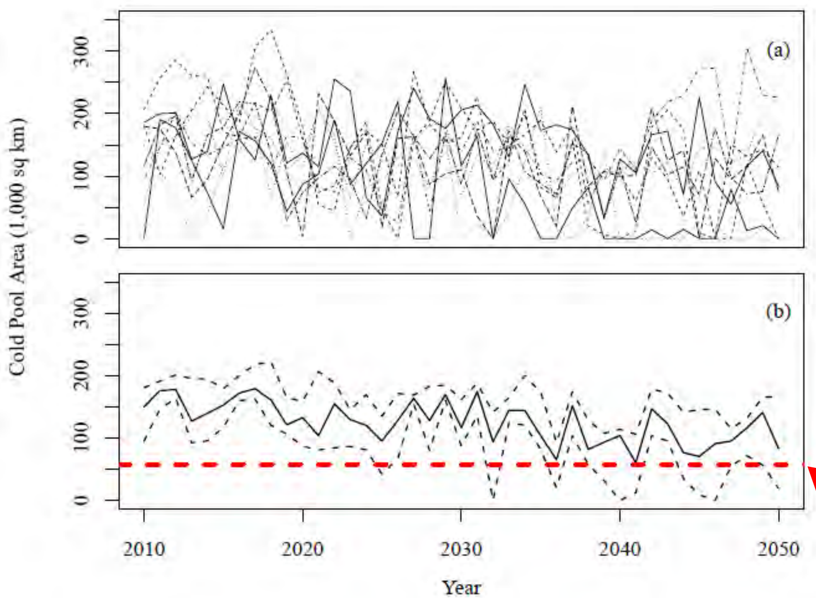


Annual bottom trawl survey with consistent methodology since 1982





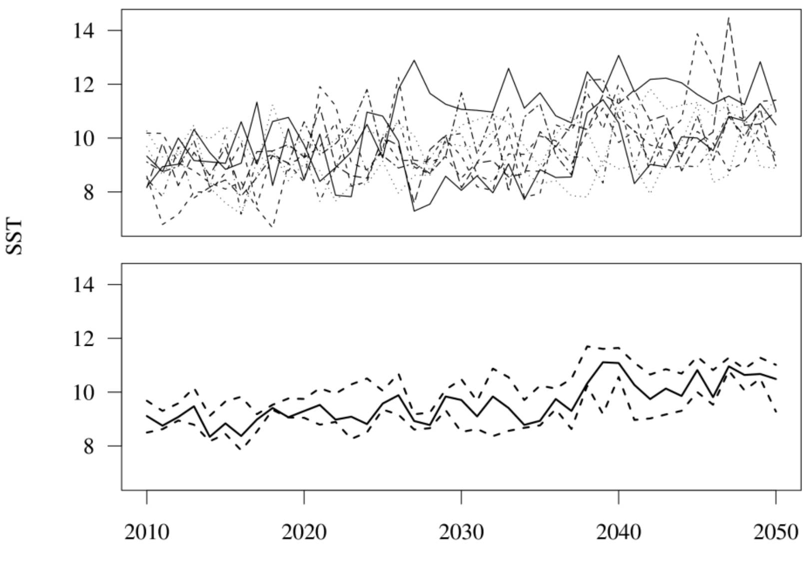
Projected environmental conditions from statistical downscaling



Decrease in cold pool area

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

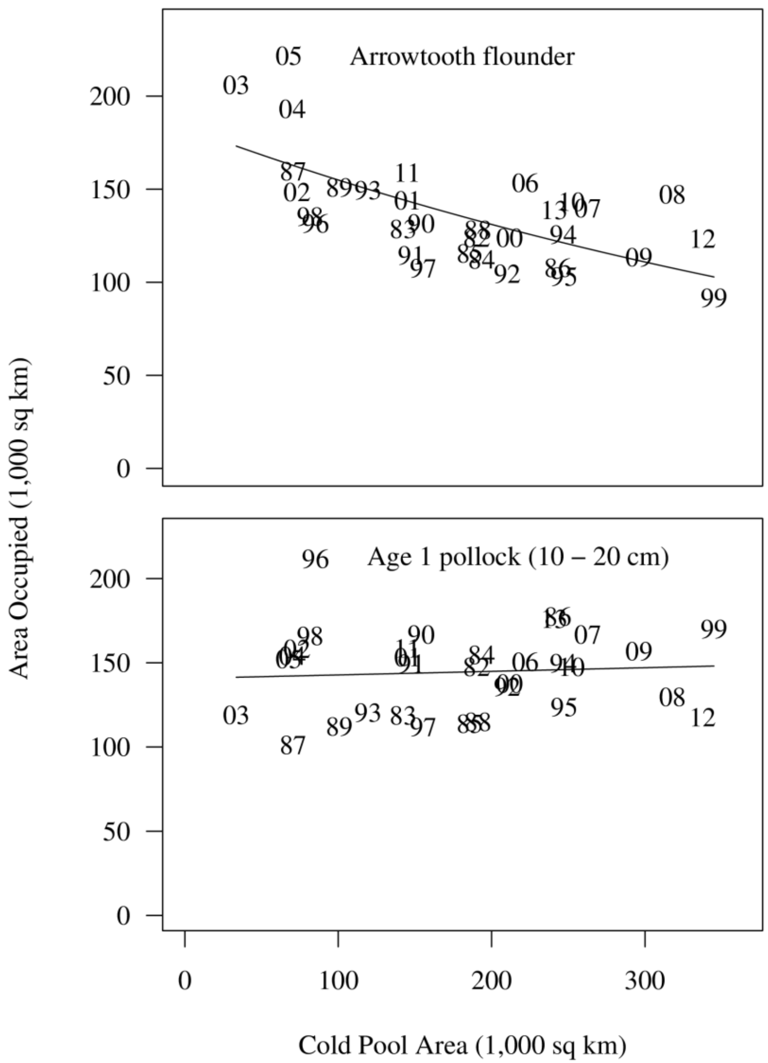
Cold pool area, 2003-2005



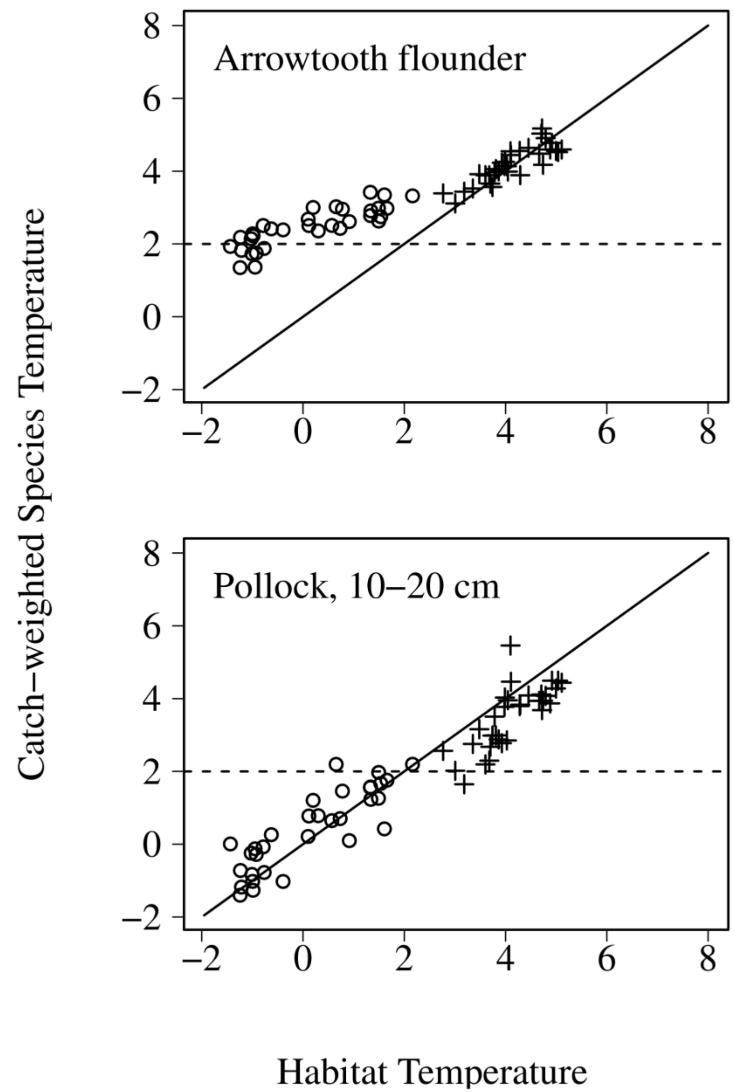
Increase in sea surface temperature

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

The spatial distribution of arrowtooth flounder is inversely related to the area of cold pool.

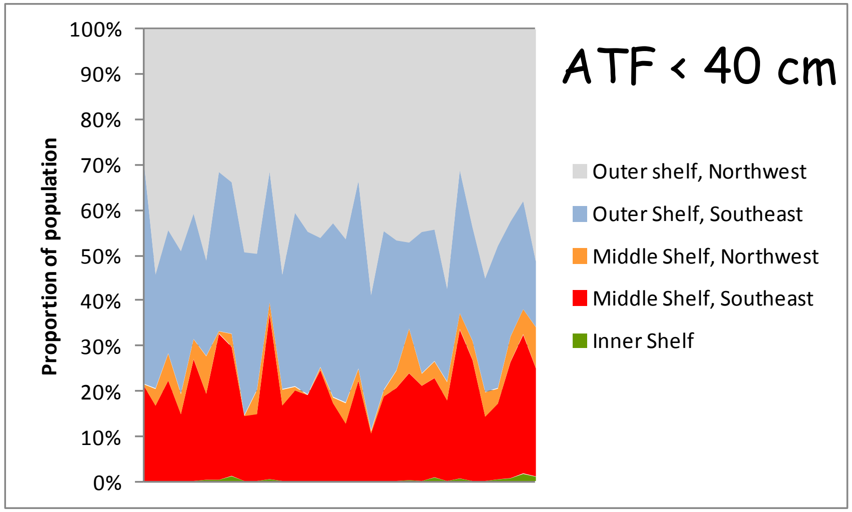


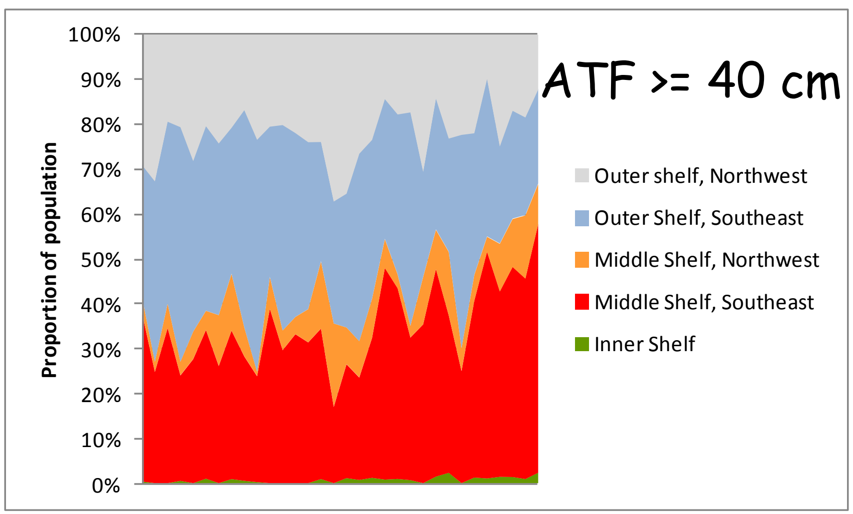
The distribution-temperature relationships for juvenile pollock are less strong than those for ATF



Relative distribution across strata

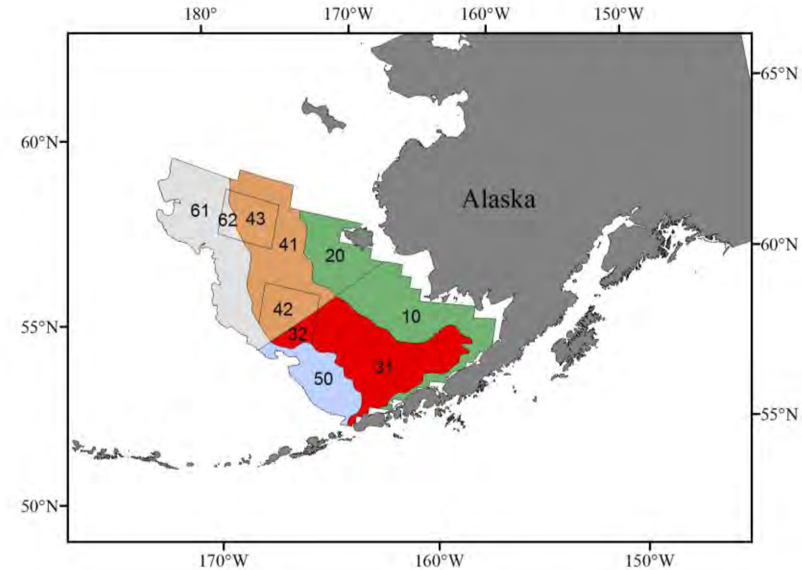
Arrowtooth flounder



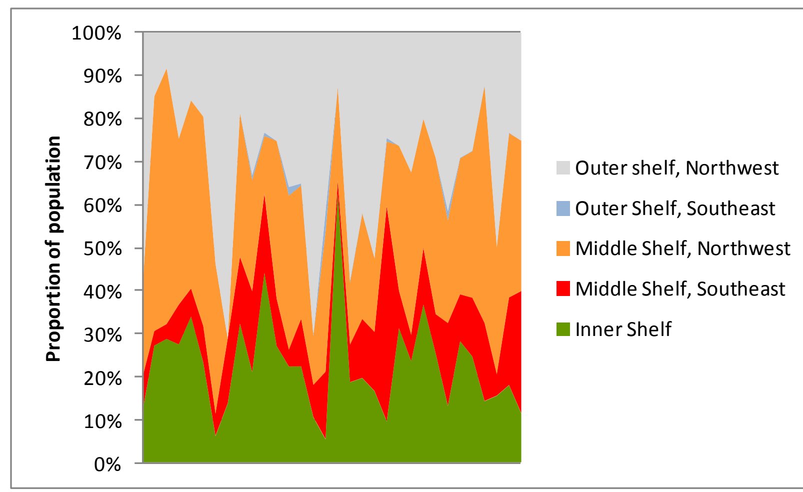


Large Small

Cold pool



Age 1 walleye pollock



Large Small

Cold pool

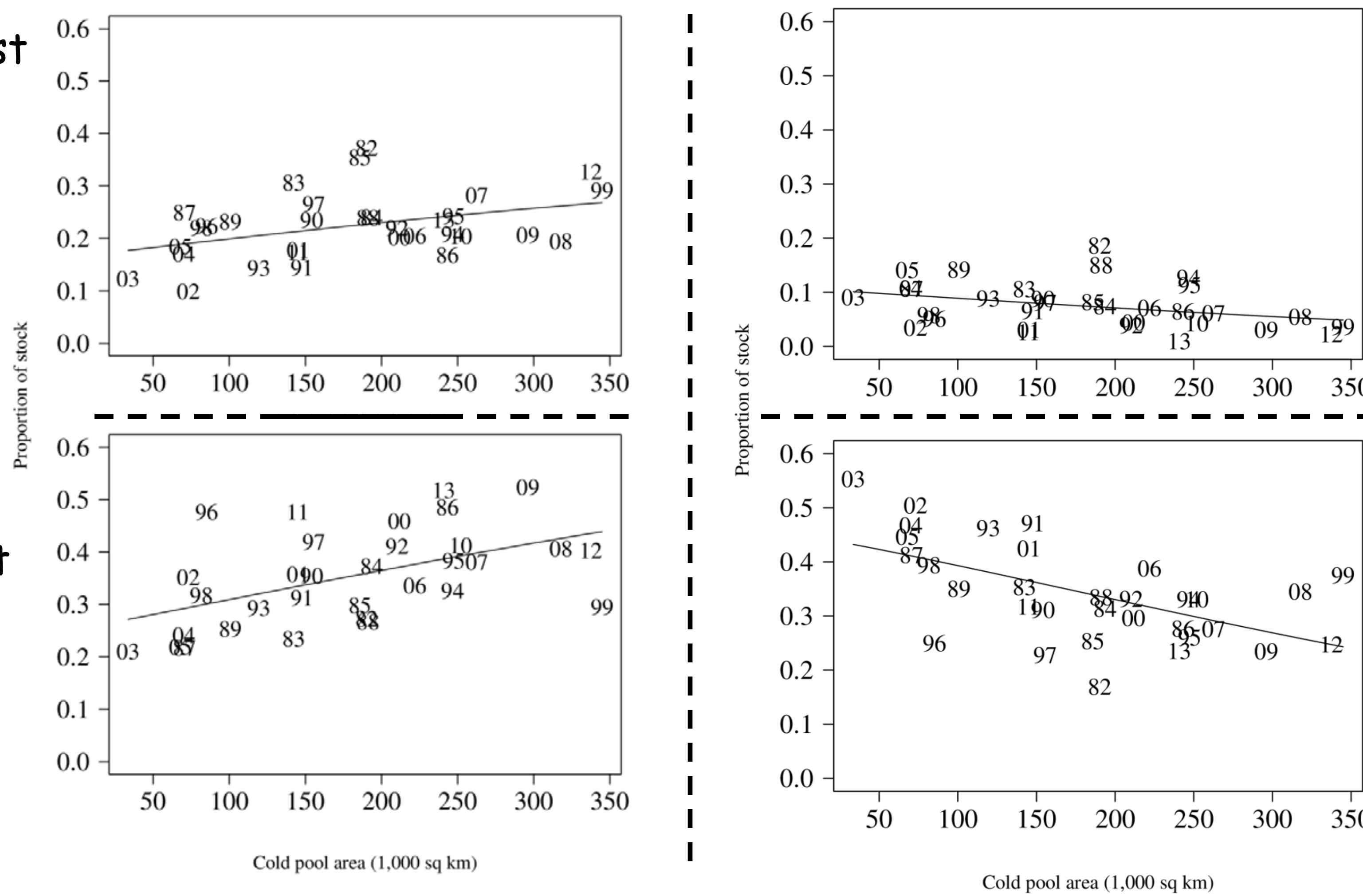
Changes in the spatial distribution occur primarily in the southeast shelf

ATF >= 40 cm

Outer shelf | Middle shelf

Northwest shelf

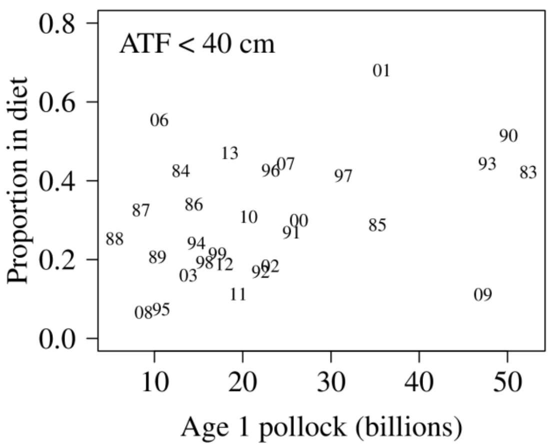
Southeast shelf

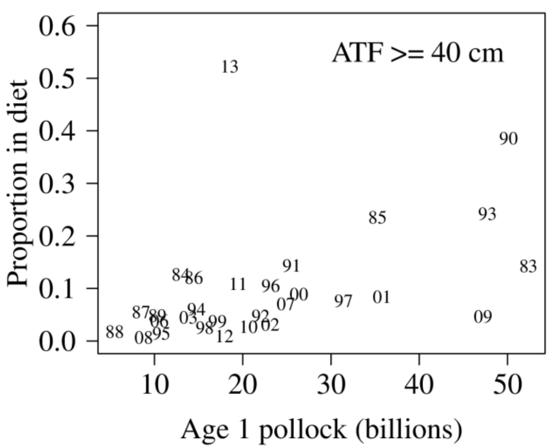


Estimates of consumption – based on diet data

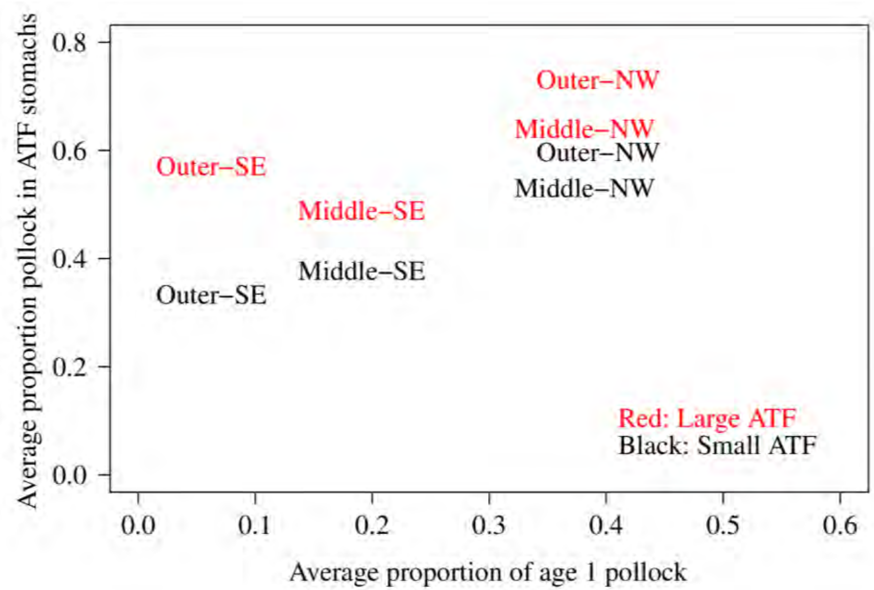
$$\text{Consumption} = \sum_{i=1}^{strata} \left(\frac{Q}{B} \right) B_i \, p_i$$

p = proportion of age 1 pollock in arrowtooth stomachs





The proportion in the diet is a function of prey abundance and spatial area



How can we incorporate species interactions in assessment models?

(i.e., how can we estimate natural mortality?)

Option 1: Fix or estimate M without consideration of diet data

Advantages:	simple, historical precedent
Disadvantages:	model is not confronted with relevant data

Option 2: Include predation mortality in a single-species model

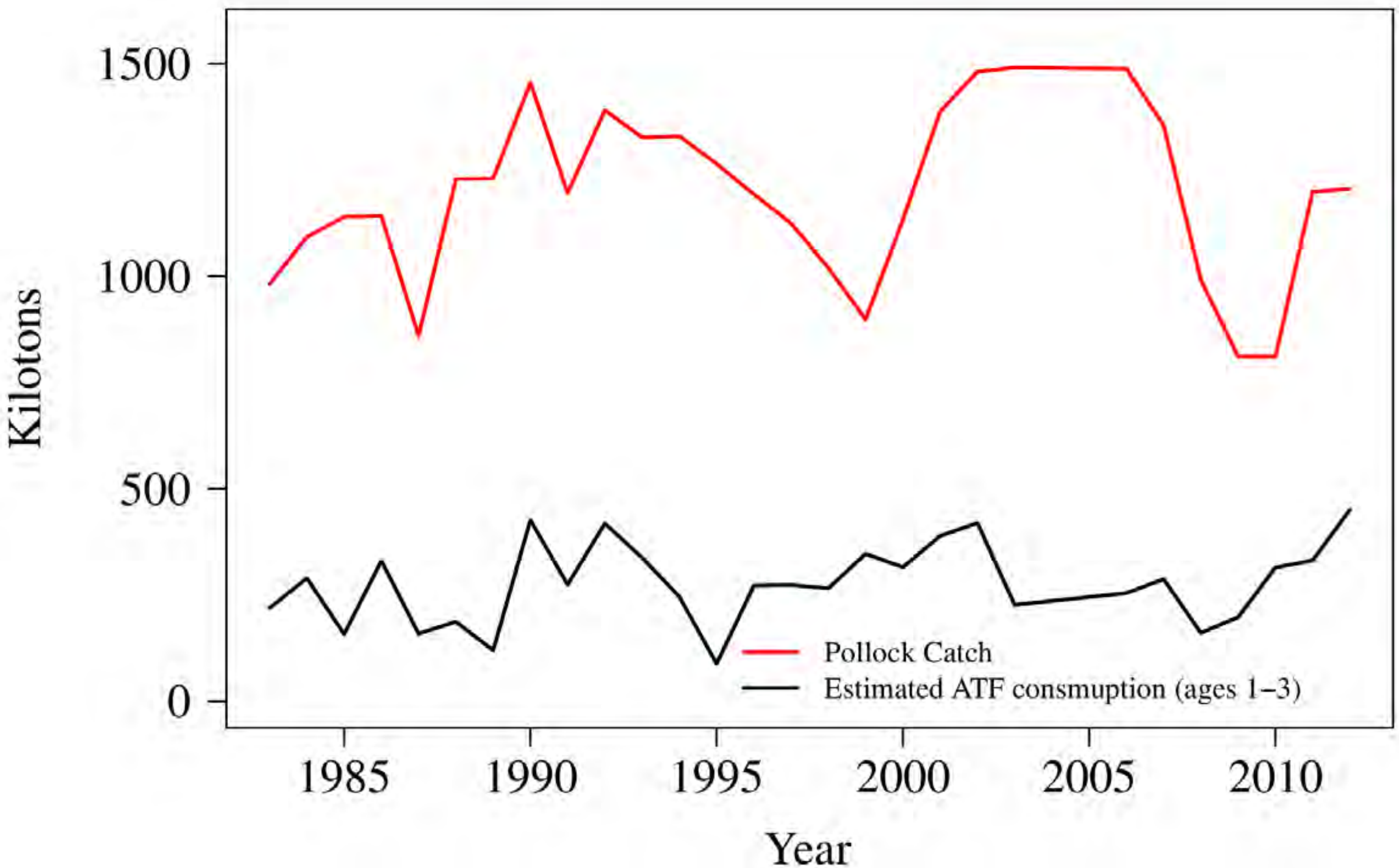
Advantages:	straightforward extension of current methods
Disadvantages:	does not consider predator-prey feedback

Option 3: Construct multispecies assessments

Advantages:	more detailed analysis can enhance understanding
Disadvantages:	complicates identification of management policies

Estimates of pollock consumption by ATF

Ranges between 7% and 39% of fishery catch



How is predator consumption like a fishery?

Predator

Consumption =

$$\left(\frac{a}{b+\overline{N}_{dens}}\right)\cdot ATF\cdot\overline{N}_{dens}\cdot area$$

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

catchability effort

Catch per unit predator
per area (CPUPPA)

$$\frac{C}{ATF\cdot area}=\frac{a\overline{N}_{dens}}{b+\overline{N}_{dens}}$$

(Holling type II function response)

Fishery

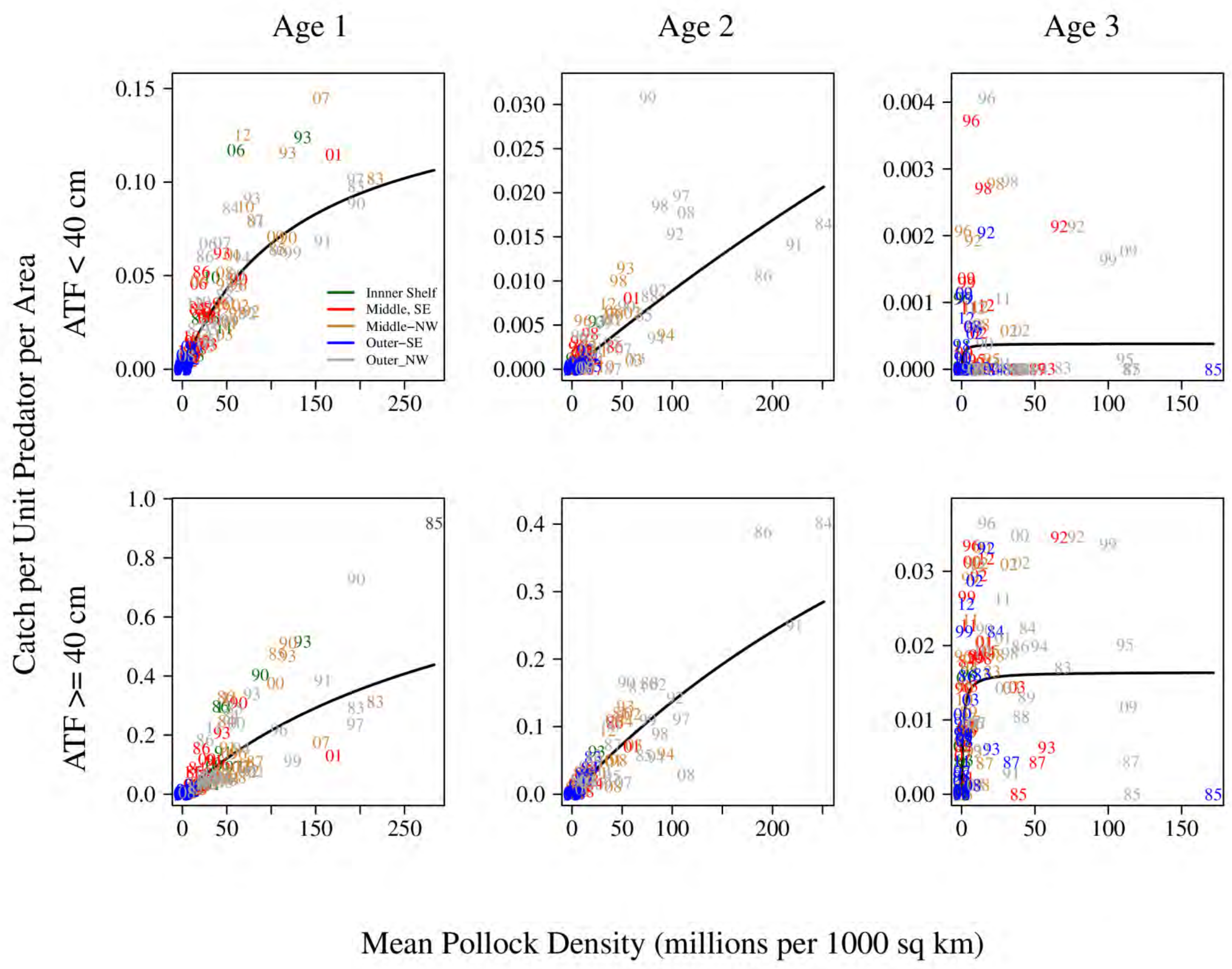
Catch =

$$qE\overline{N}$$

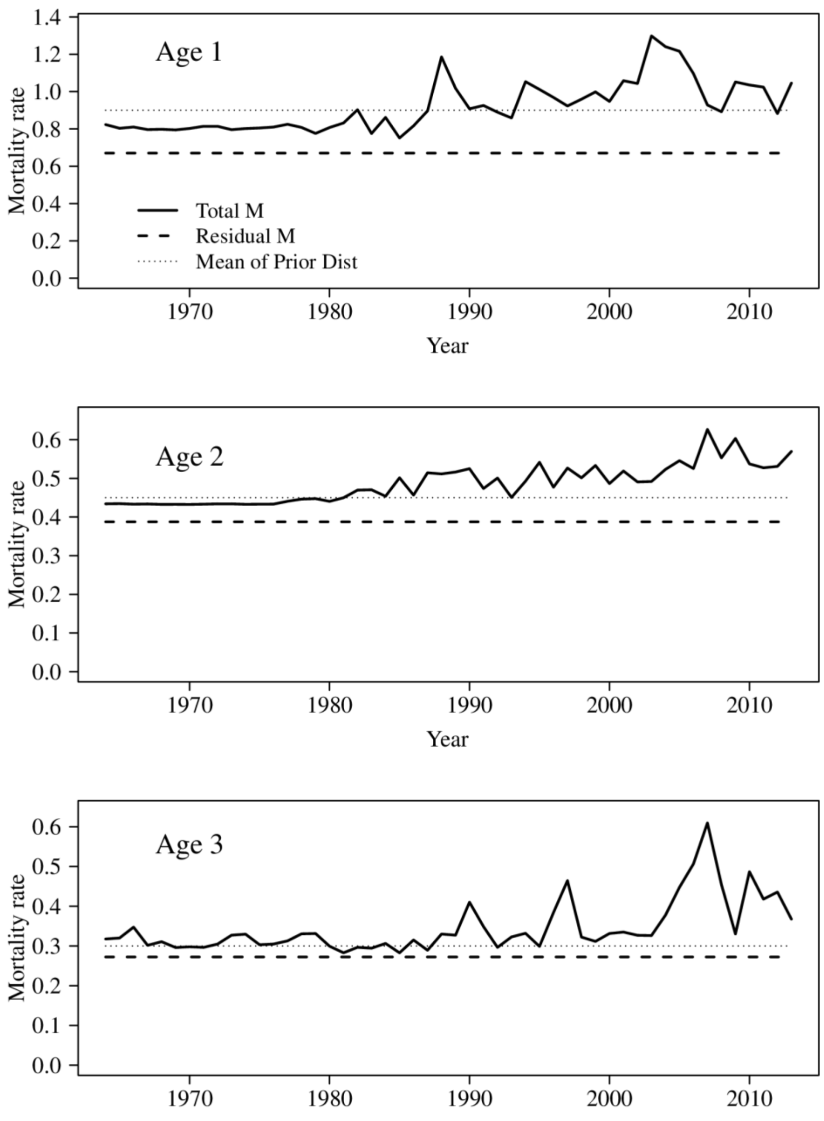
Catch per unit effort (CPUE)

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

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



Model estimates of ATF and 'residual' natural mortality

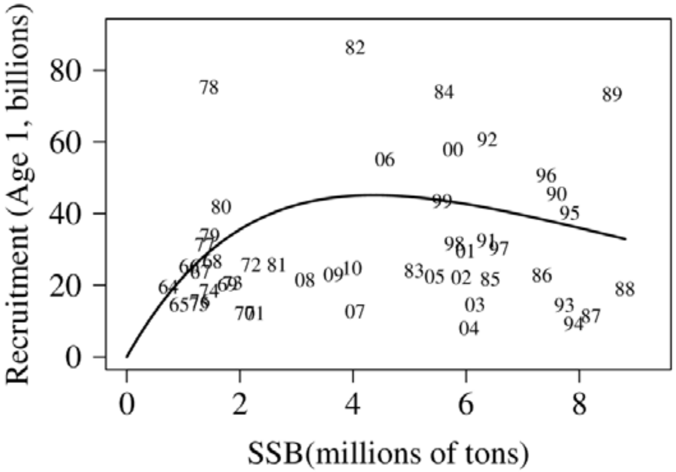


$$M = M_{ATF<40cm} + M_{ATF>=40cm} + M_{residual}$$

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

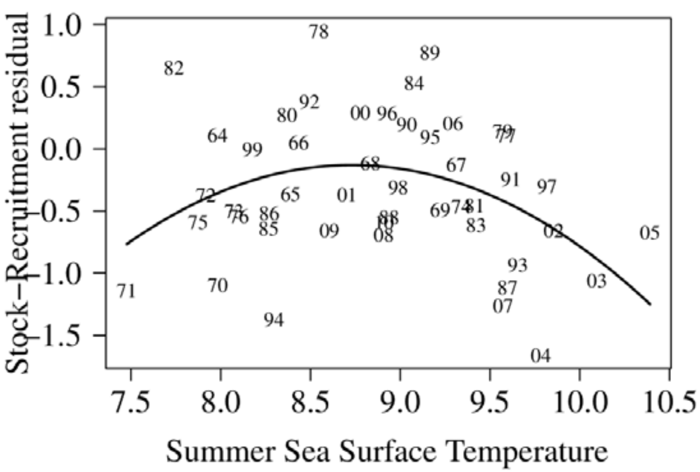
Projection of the effect of temperature upon pollock dynamics

Modeling of recruitment residuals

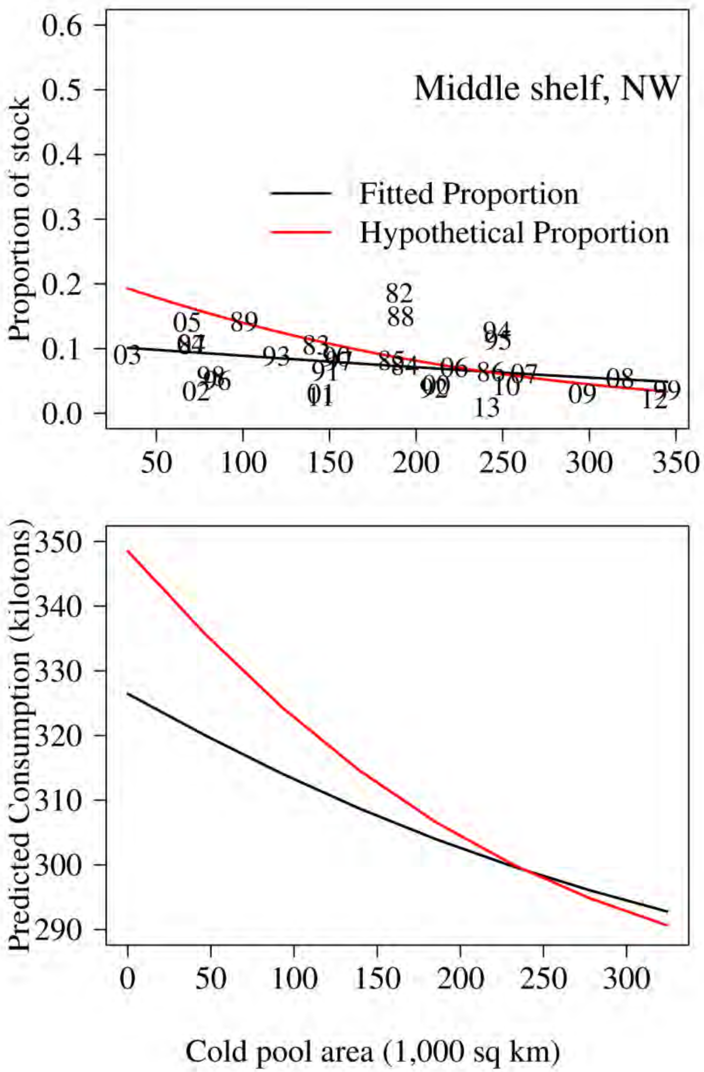


Longer-term projections would consider the effect of temperature on pollock recruitment

We can attempt to separate the effect due to impacts to recruitment vs the effects due *solely* to changes in predator distribution



How sensitive are consumption estimates to changes in species distribution?



Arrowtooth flounder and pollock density held constant at their estimated 2012 levels.

The consumption for 2012 is estimated both with the fitted and hypothetical relationships between the proportion in the Middle shelf –NW and cold pool area

Based on current spatial patterns:
11% change in consumption over the range of cold pool sizes

Based on hypothetical spatial patterns:
20% change in consumption

Conclusions

1) Information on spatial distributions of predator and prey populations allow spatially-resolved estimates of predation mortality

2) Natural mortality of walleye pollock appears to have increased over time.

3) Temporal changes in natural mortality affect not only population abundance, but likely also fishery rate reference points.

4) The impact of future climate conditions on ATF predation due solely to changes in spatial distributions would be expected to be minor. However, this could change if the ATF distribution moves more into the NW Middle shelf.

5) More precise information on temporal variability in spatial patterns of predation will require more data.