Relationships between environmental variability and eastern Bering Sea flatfish population distributions

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Objectives

1) Describe the Eastern Bering Sea System and recent trends in environmental variability

2) Describe effects of environmental variability on flatfish distributions and speculate on possible mechanisms

3) Discuss the management implications of shifts in flatfish distributions in response to environmental variability

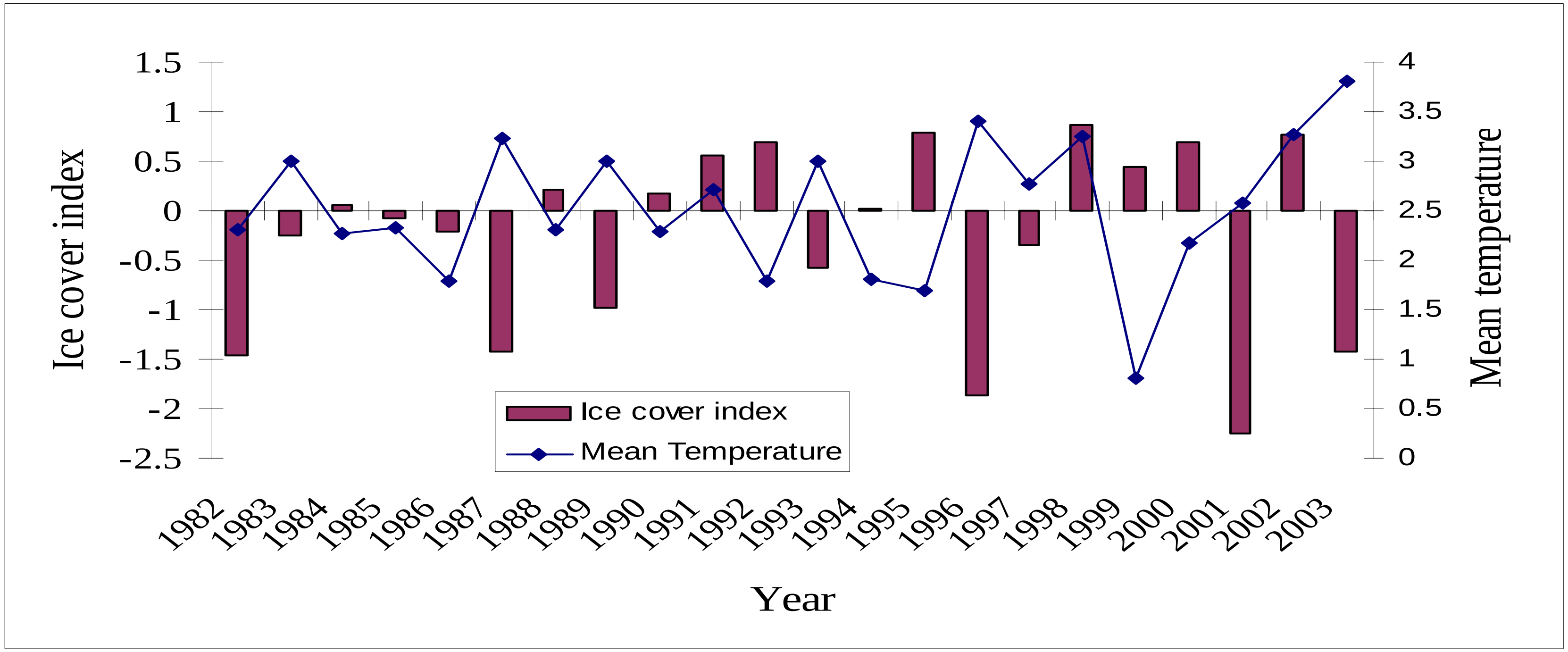
Study area

Highly productive system – Primary productivity ranges from 200 to 800 g C m^{-2}

Sea ice plays a major role in primary and secondary productivity, particularly in the formation of the "cold pool"

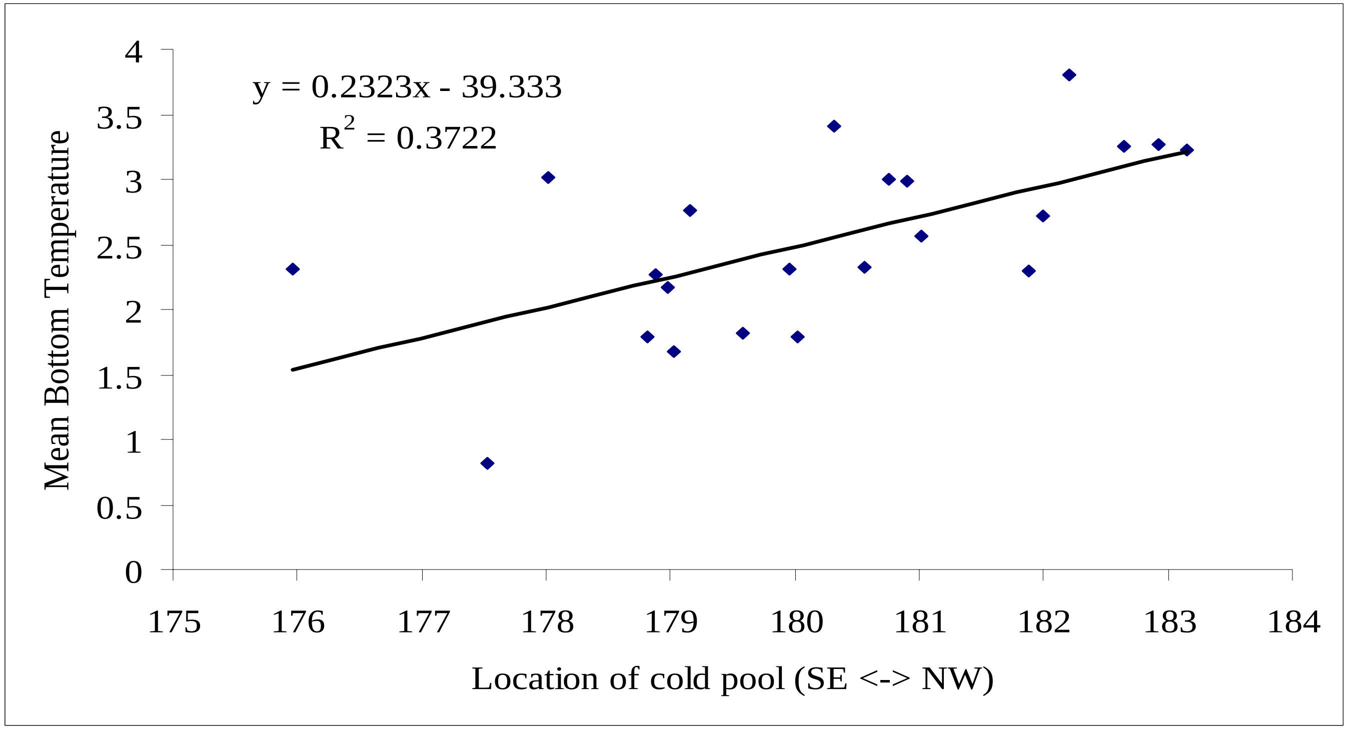
Time Series of Environmental Data

Ice cover index – a measure of the quantity of sea ice
Mean bottom temperature – from bottom trawl survey



Time Series of Environmental Data

Cold pool location – relative location along a southeast to northwest axis



How have flatfish distributions responded to environmental variability?

Methods

Eastern Bering Sea trawl data used for analysis, 1982-2003

1) Consistent gear and sampling design since 1982
2) Summer survey, stations location on a 20 nm x 20 nm grid

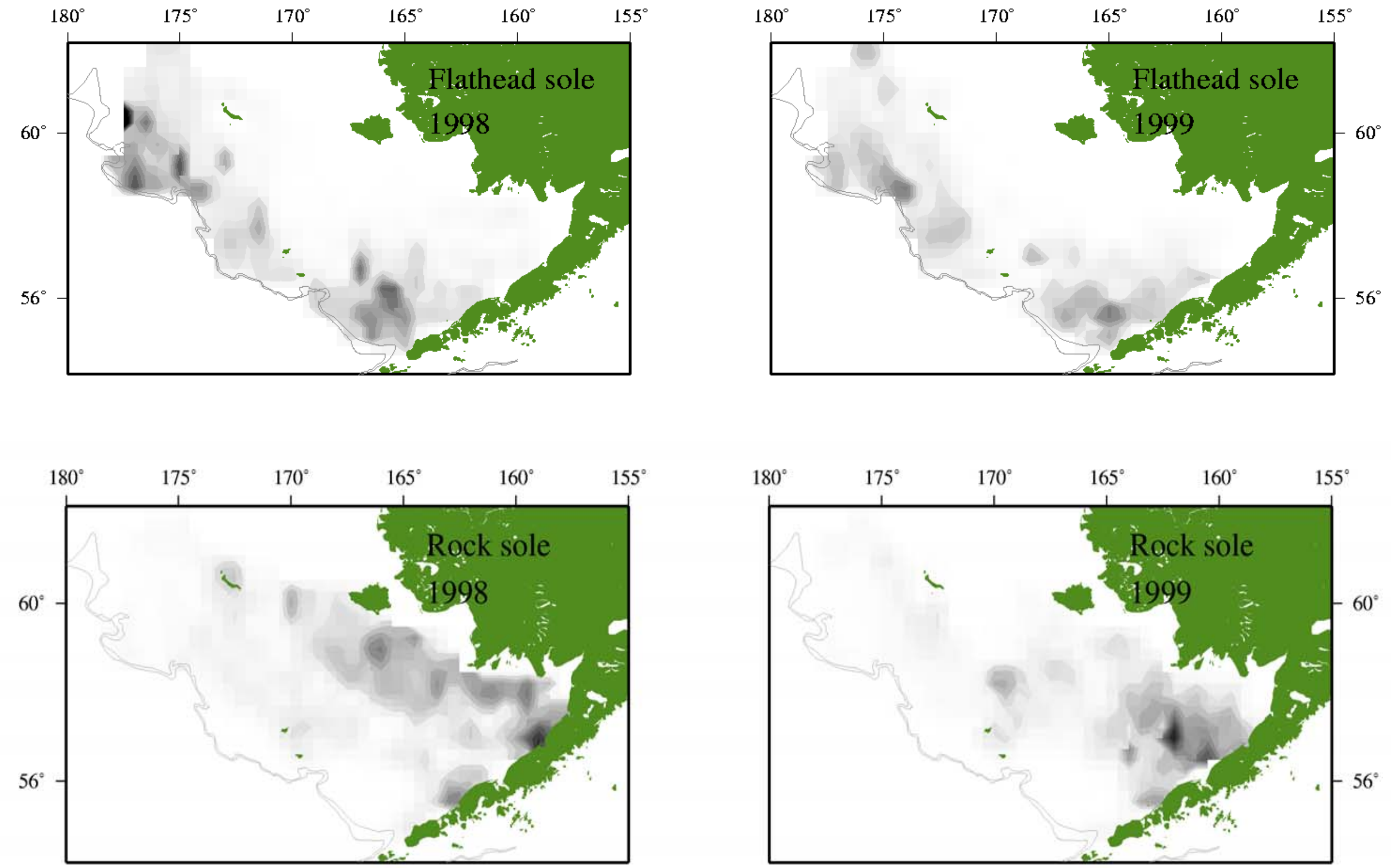
Compute centroids of flatfish distributions by year

Average latitude and longitude of stations where a species is found, weighted by catch per unit effort (CPUE)

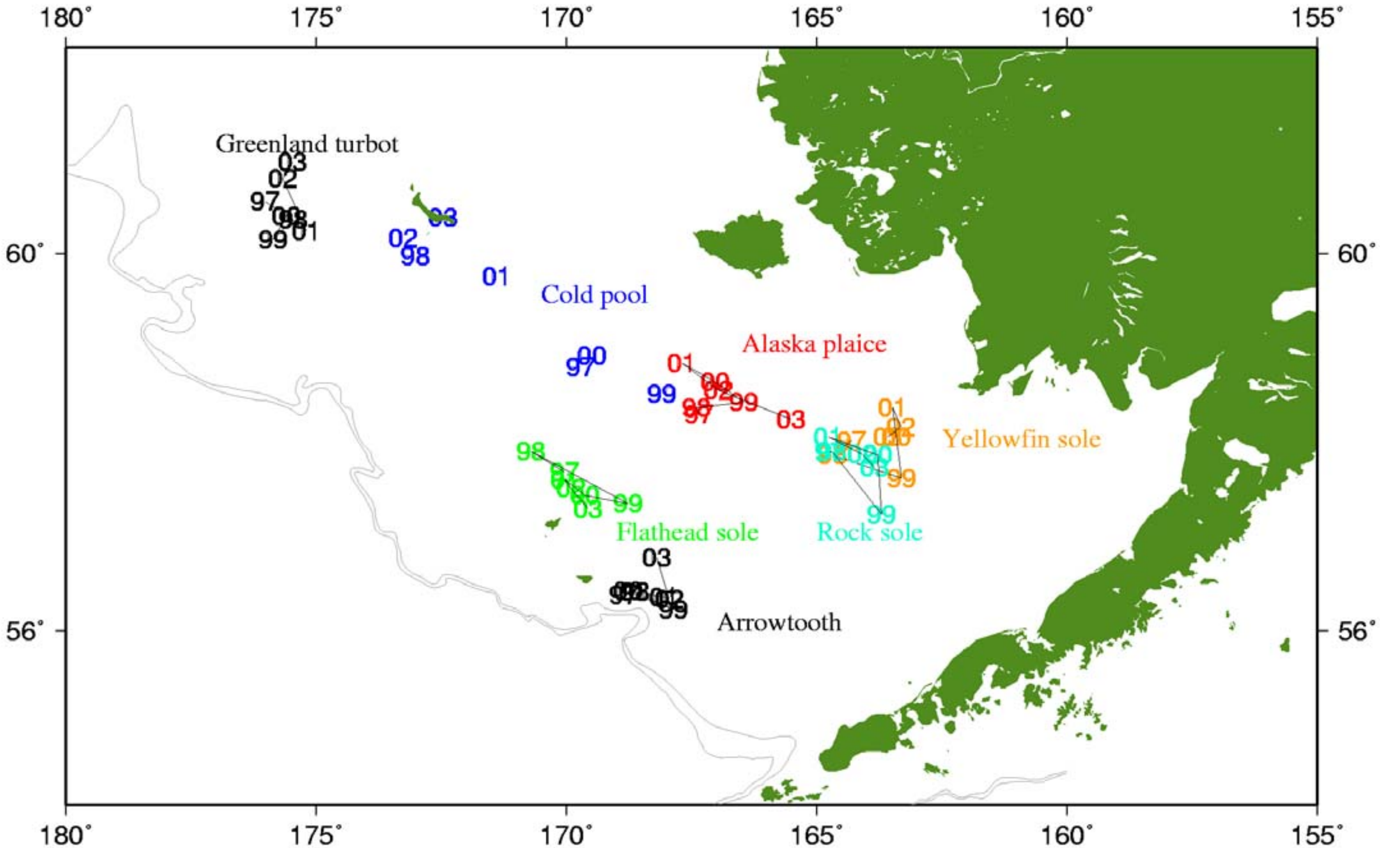
Compute ellipses encompassing 50% of the flatfish distribution

Fit bivariate normal curves to the spatial distributions

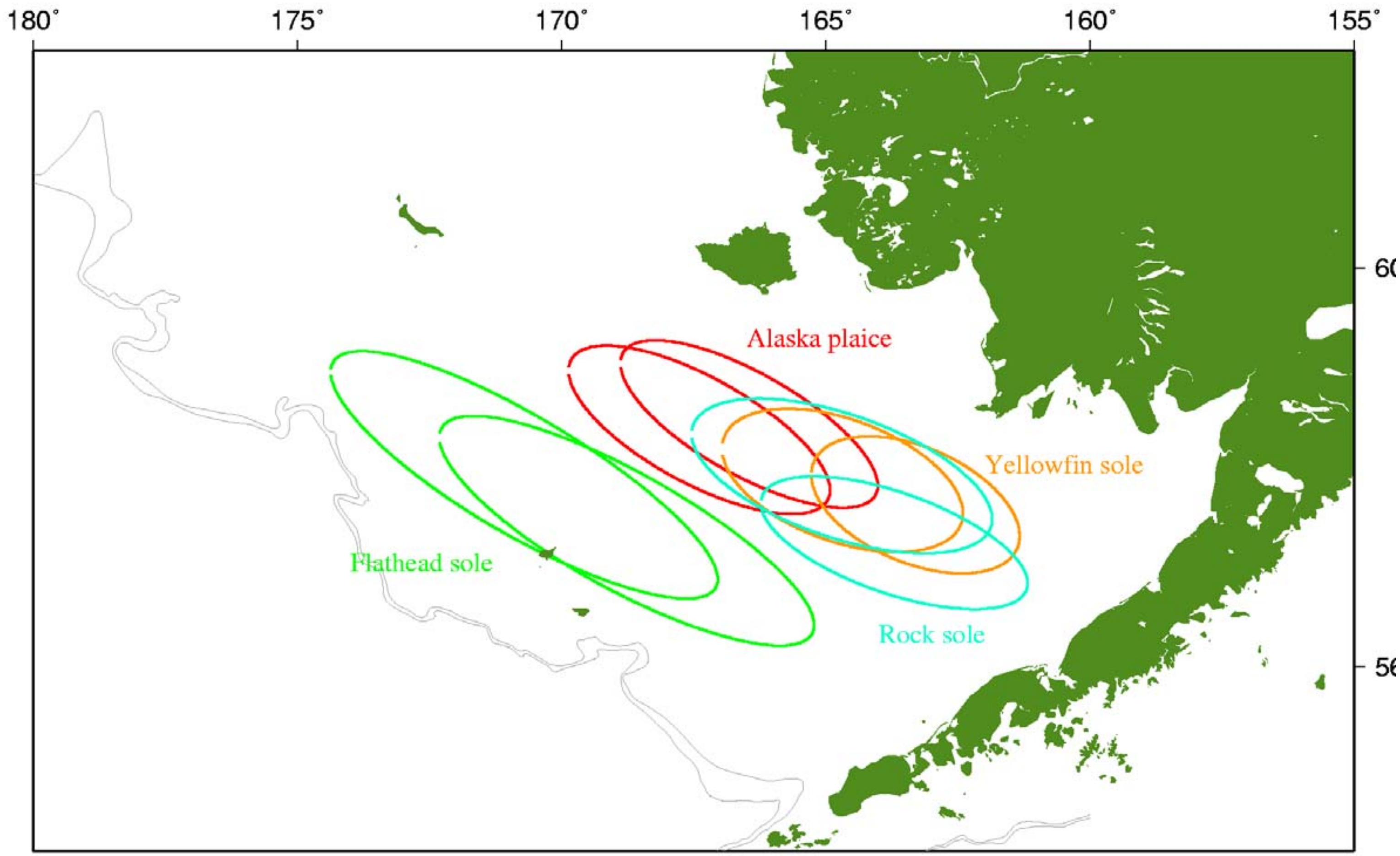
Contour plots of distributions, 1998-1999



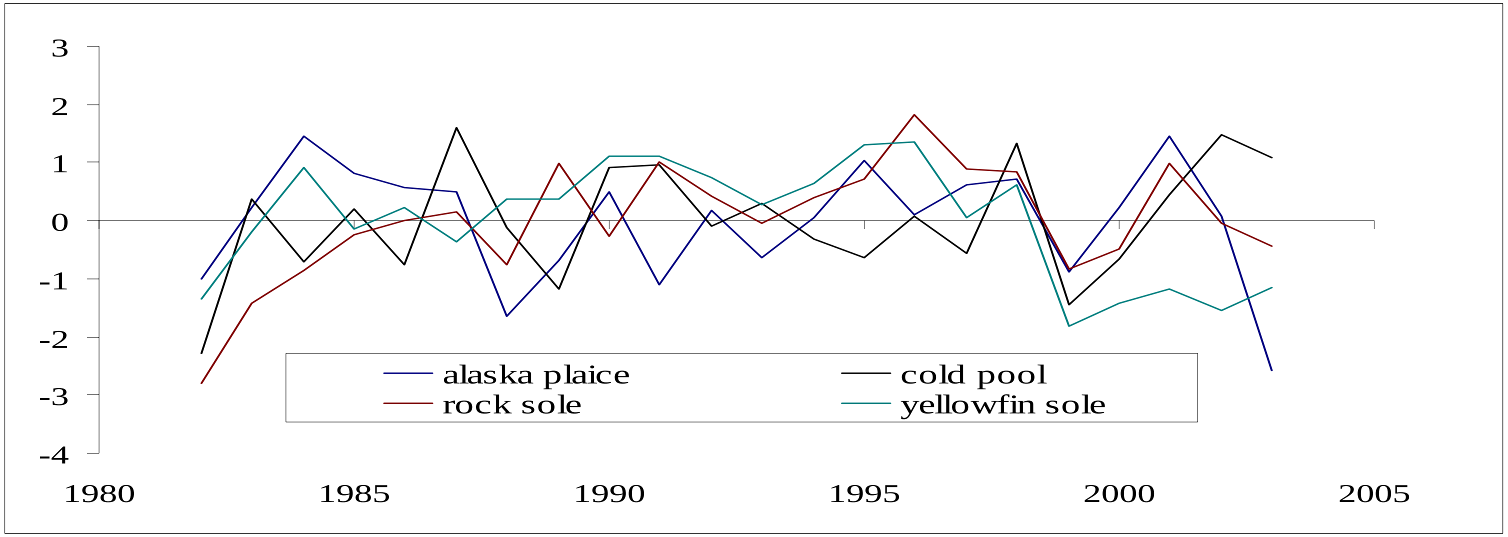
Flathead sole and cold pool centroids, 1998-2003

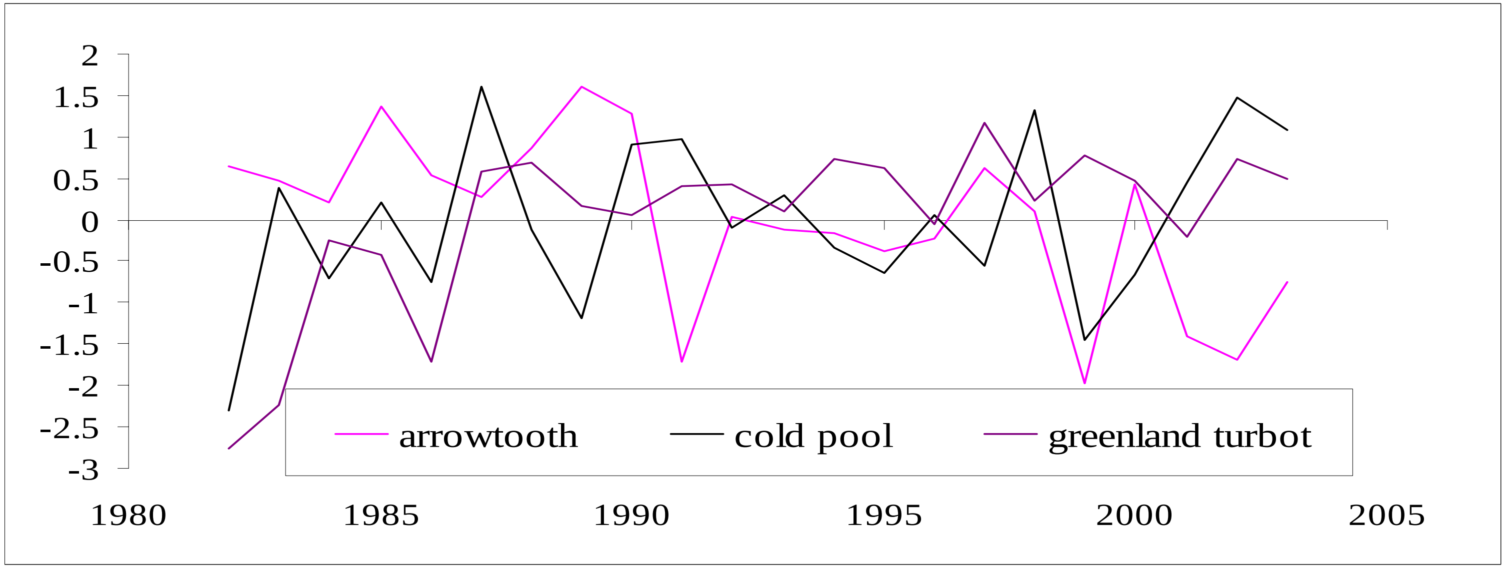


Flathead sole distributions, 1998-1999

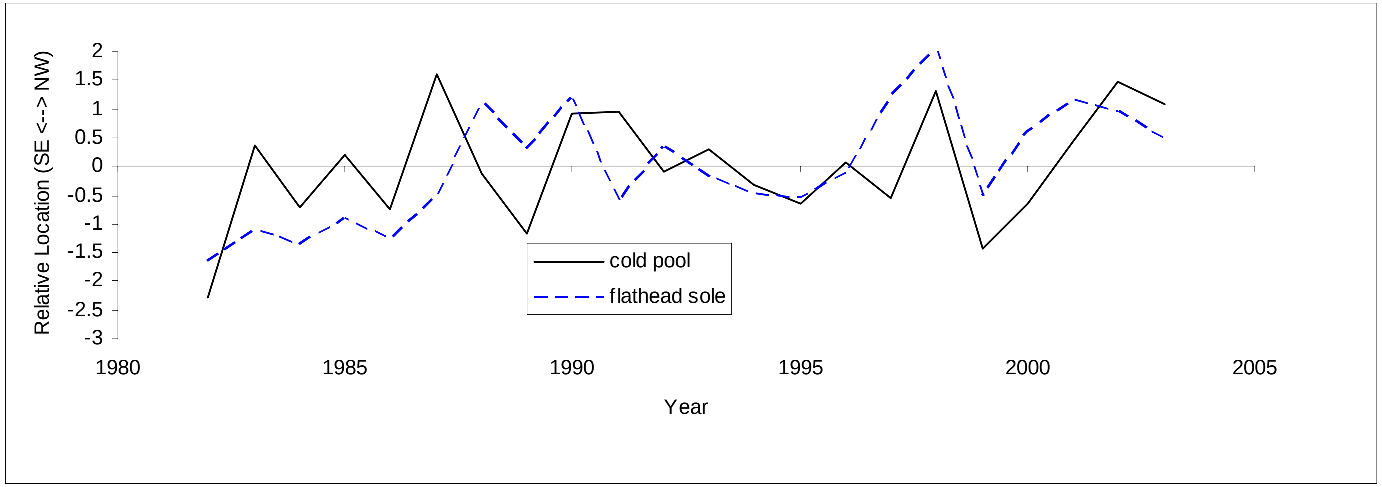


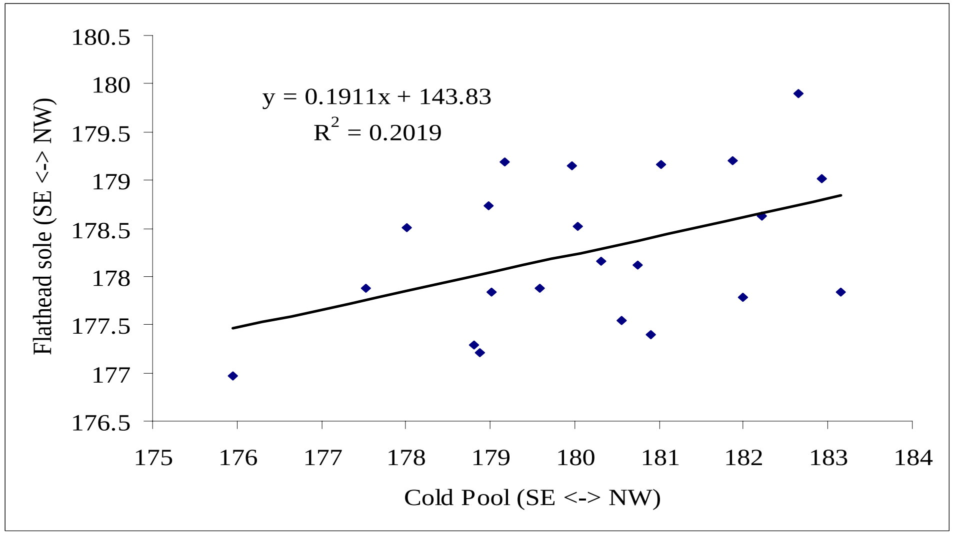
Changes in flatfish distributions in relation to the cold pool





Changes in flathead sole in relation to the cold pool





Other studies relating the cold pool to EBS fish distributions

Wyllie-Echevarria and Wooster (1998)

- Artic cod – Generally found in the cold pool in both warm and cool years
- Walleye pollock – Seldom found in the cold pool; on the outer shelf during cool years and more widespread during warm years.

Swartzman et al. (1994)

- Used Generalized Additive Modeling (GAM) to suggest that the summer spatial distribution of walleye pollock is associated with temperature and depth of the thermocline.

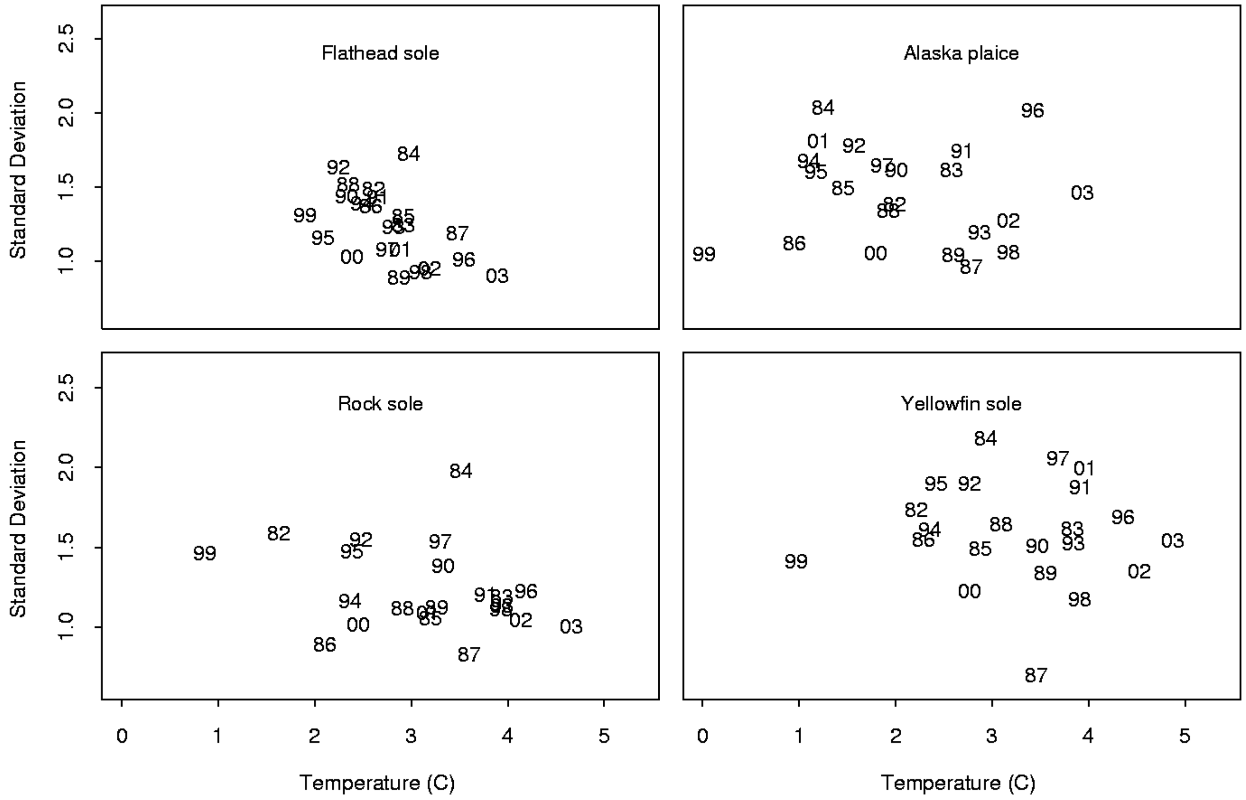
Hypotheses

1) The diet of flathead sole has a larger proportion of fish than some other small flatfish – they could be responding to prey distributions

2) The optimal temperature constraints for flathead sole may be more restricting than for other small flatfish

Mean temperature and standard deviation for flatfish species

Alaska plaice – presence of antifreeze peptide proteins that prevents the formation of ice crystals (Knight et al. 1991)



What are the resource management implications of shifting populations?

1) The catchability and availability of our surveys are affected

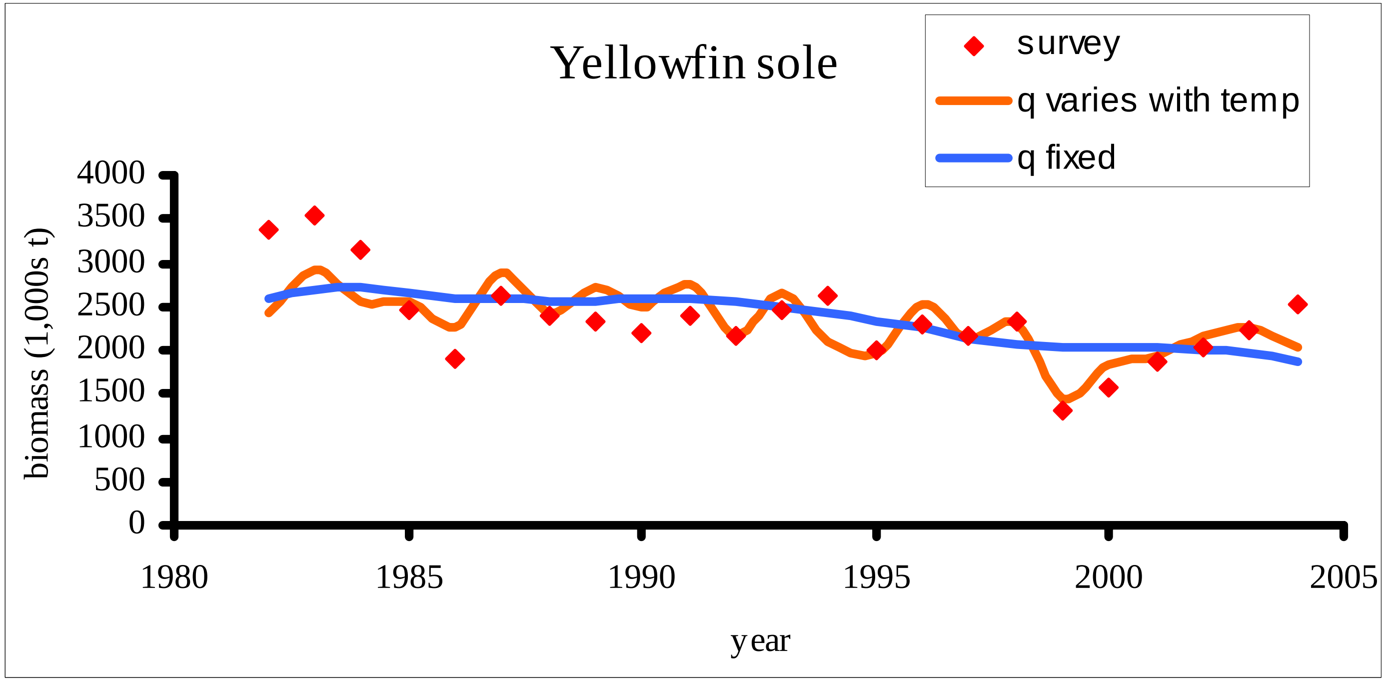
Catchability – refers to fish that are available to be captured by the *gear* but are not selected (i.e. changes in behavior)

Availability – refers to the extent to which fish are available to the survey *gear* (i.e. changes in distribution)

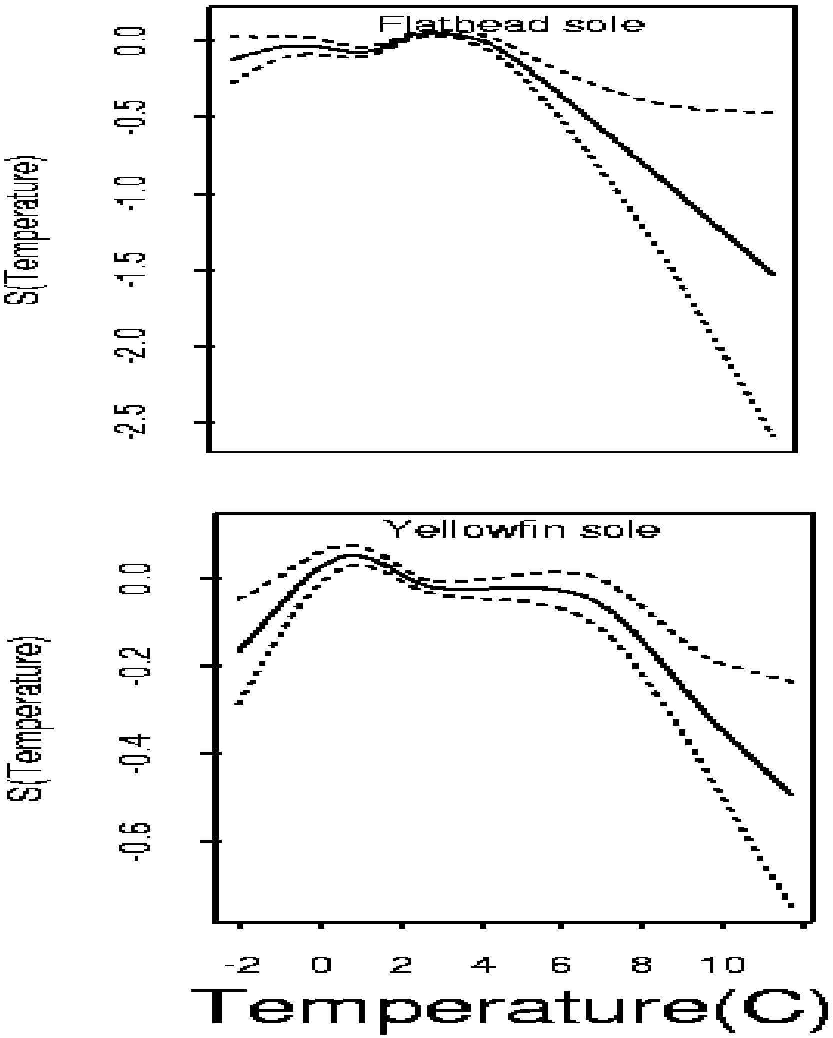
Both things are encompassed in the the catchability parameter *q*

$$\tilde{B} = q \sum_a s_a N_a W_a \qquad\qquad q = e^{(\alpha + \beta T)}$$

Example of estimating temperature-dependent catchability



Habitat use of flatfish is likely mediated by environmental variability, but perhaps the signal is more subtle than observed in pelagic species



GAM model of habitat use

$$\ln\{E(CPUE)\}$$
$$= year + S(T) + S(D)$$
$$+ S(Sed) + S(Lat)$$
$$+ S(Long)$$

Conclusions and items for future work

1) The distributions of several flatfish species on the EBS shelf shifted southward in 1999, which was an unusually cold year

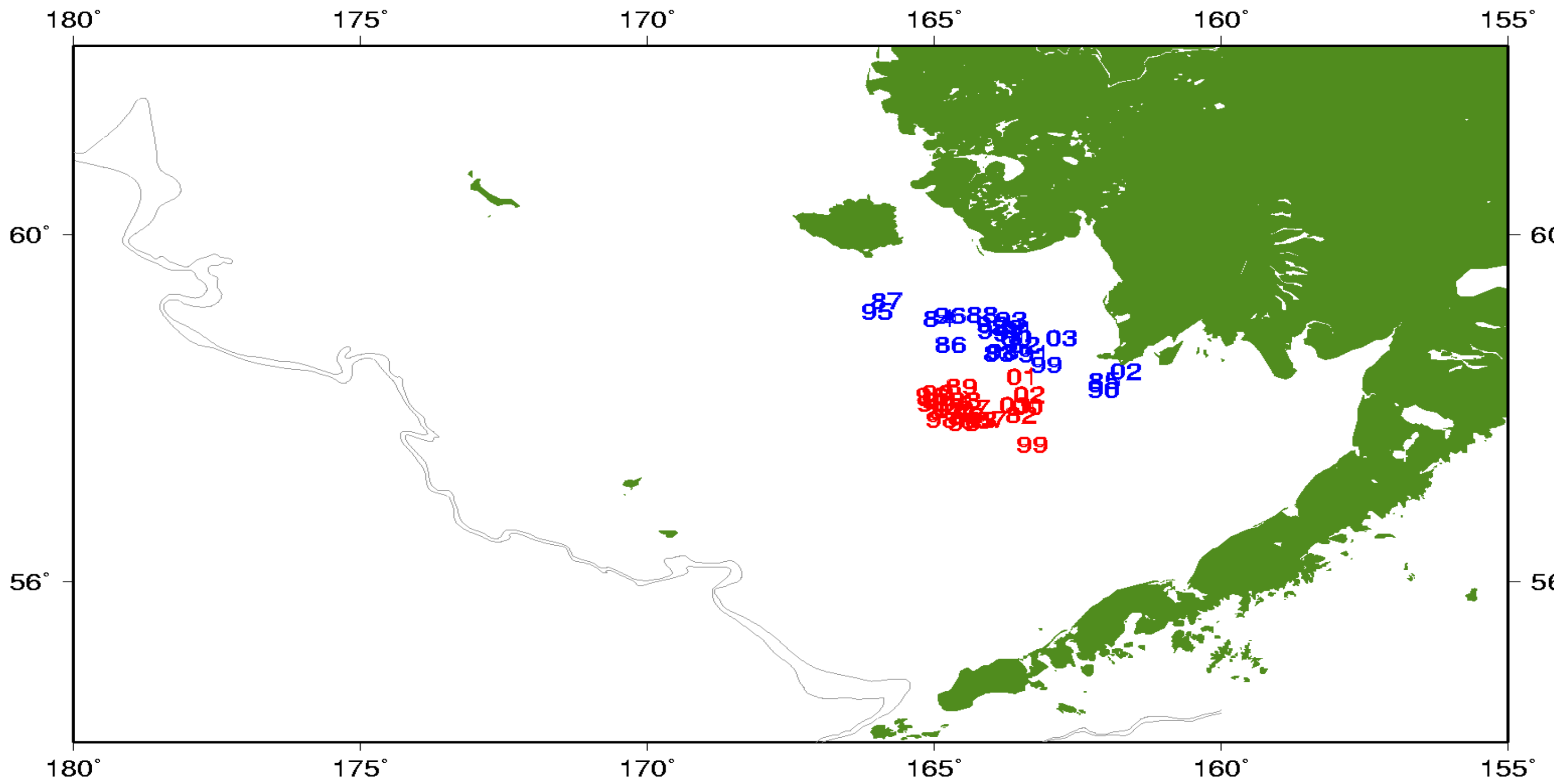
2) The mechanism for this shift is not entirely clear – is this a response to the physiological effect of cold temperature or is temperature a proxy for benthic productivity?

3) The shifting of population distributions in response to can have important management implications, both in terms of assessing population size and habitat use.

4) Habitat models for flatfish have generally not considered the effect of environmental variability, but these factors may be important (particularly in years corresponding to unusual events)

Ontogenetic shifts in spatial distribution may be part of the story

Yellowfin sole centroids by size (breakpoint is 12 cm)



Relation between flathead sole location and juvenile walleye pollock (<20 cm) locations