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The spatial footprint of biological re-organization in a demersal community

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Outline

1. **Temporal variability in the Northeast Pacific: An update of Hare & Mantua's (2000) regime shift analysis**
2. **The spatial footprint of temporal variability in groundfish abundances: Examples from the Eastern Bering Sea**
   a. **Can we construct a meaningful index that captures variability in spatial distribution?**
   b. **What does it indicate about past changes?**
   c. **Can we predict future changes in spatial distribution?**
   d. **Do changes in relative spatial distribution affect recruitment?**

100 time series of Hare & Mantua (2000)

(98 time series updated through 2006: 31 climate, 67 biology)

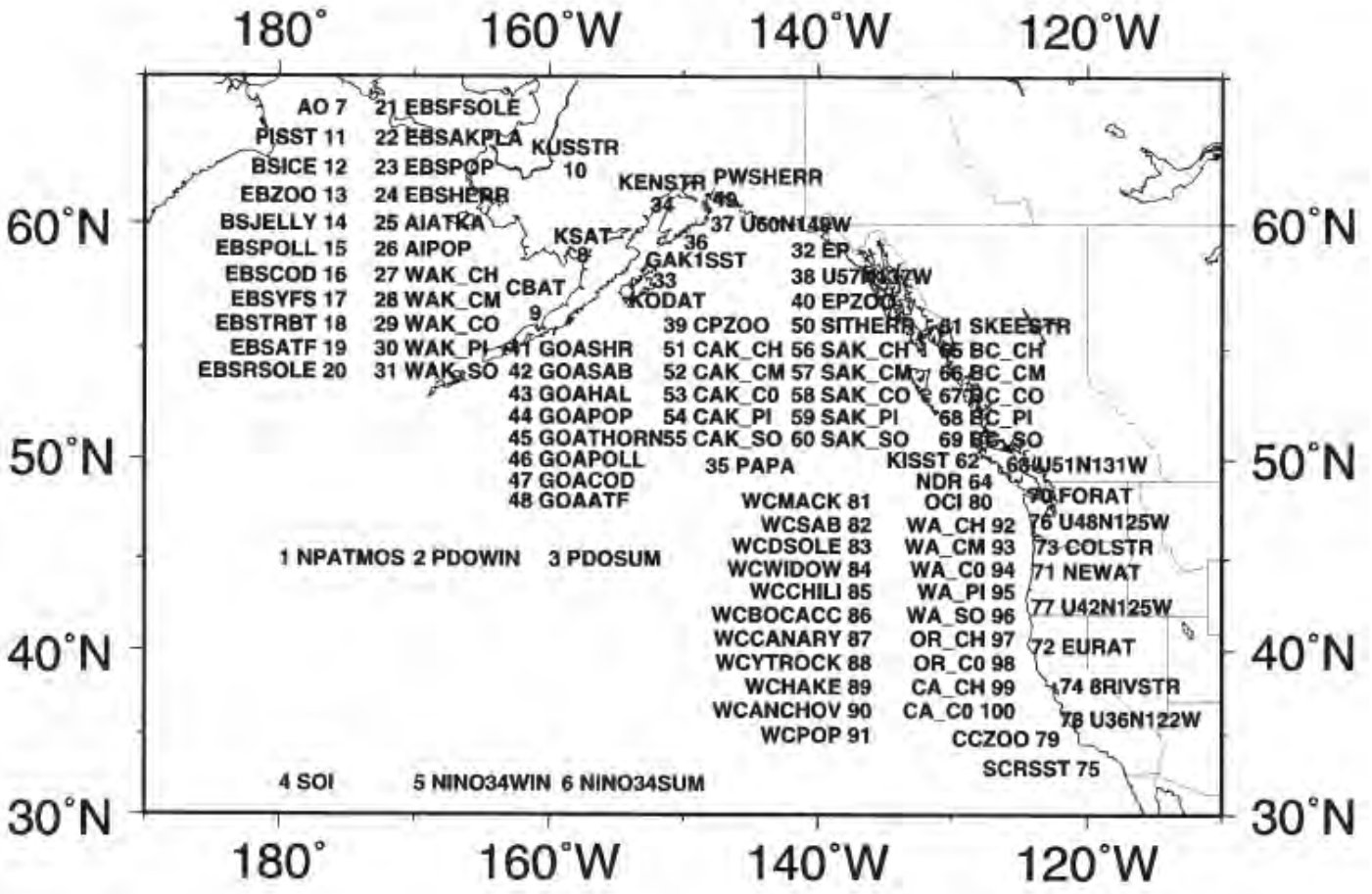
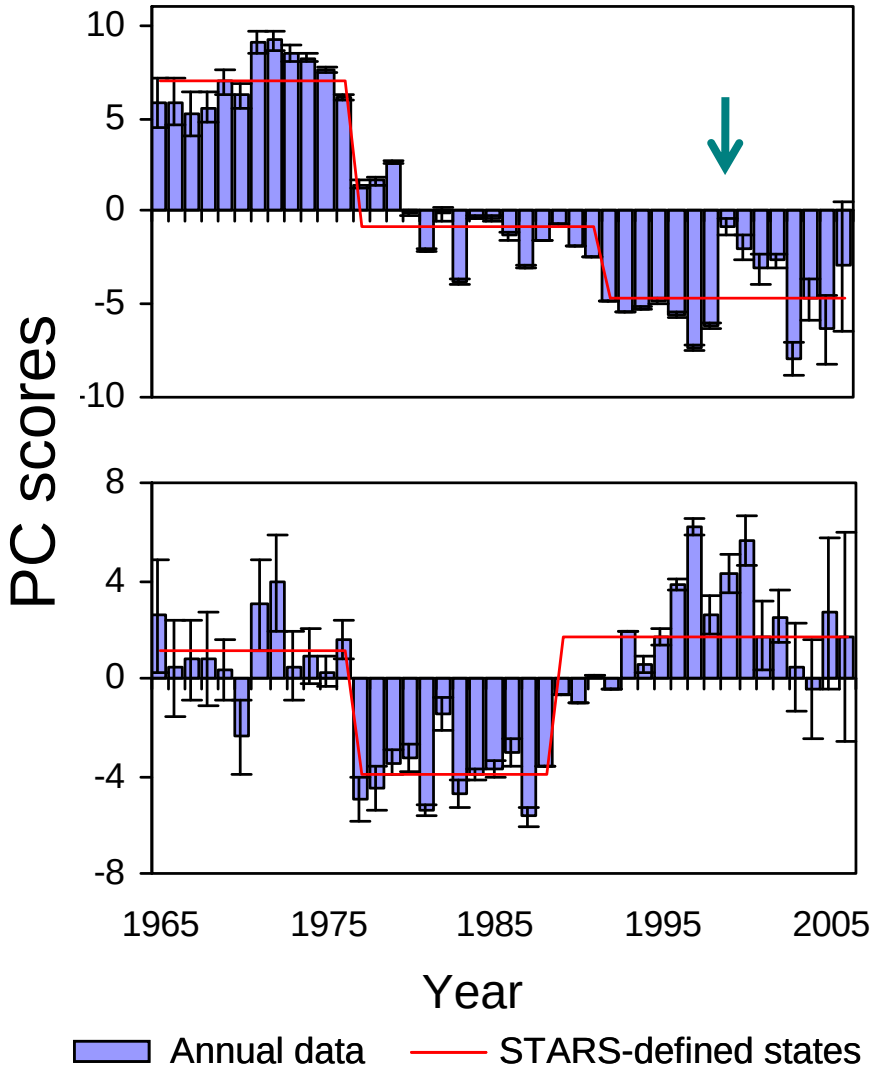


Fig. 1. Numeric and alphabetic abbreviations for the 100 time series used in this study. Geographical

Fig. 1 from Hare & Mantua with approximate locations of 100 indices

Time series of major modes of Northeast Pacific variability



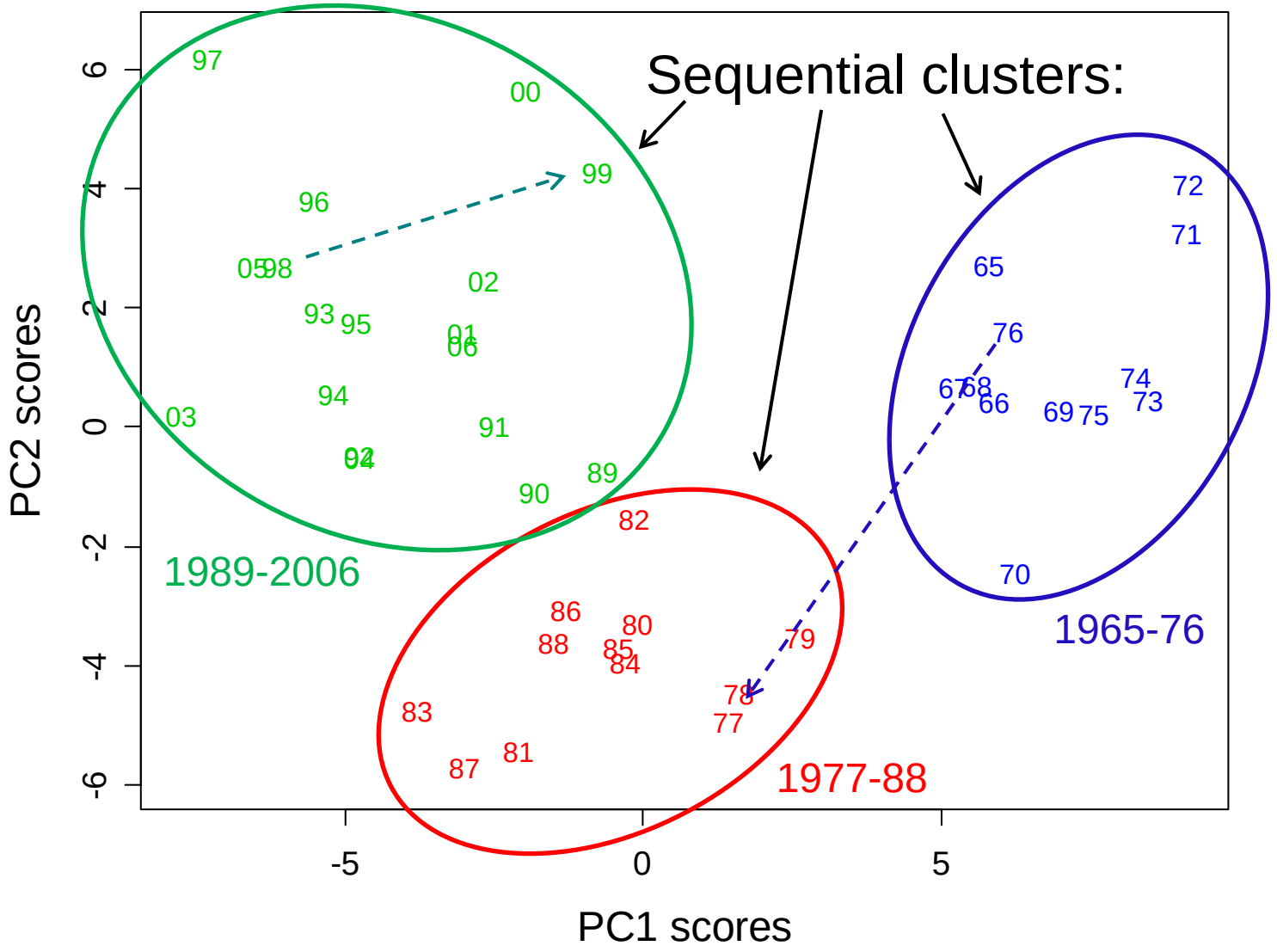
First Principle Component:

- 23.4 % of total variability
- Step changes in 76/77 and 91-92 ($p < 0.001$, STARS analysis)
- Large shift in 98/99, quick reversal to 1990s condition

Second Principle Component:

- 9.6 % of total variability
- Step changes in 76/77 and 88-89 ($p < 0.001$, STARS analysis)

First 2 major modes of variability: (33% of total variability)

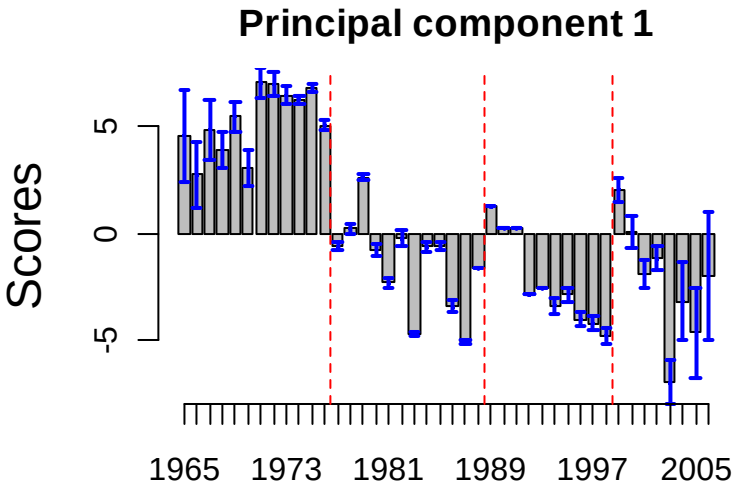


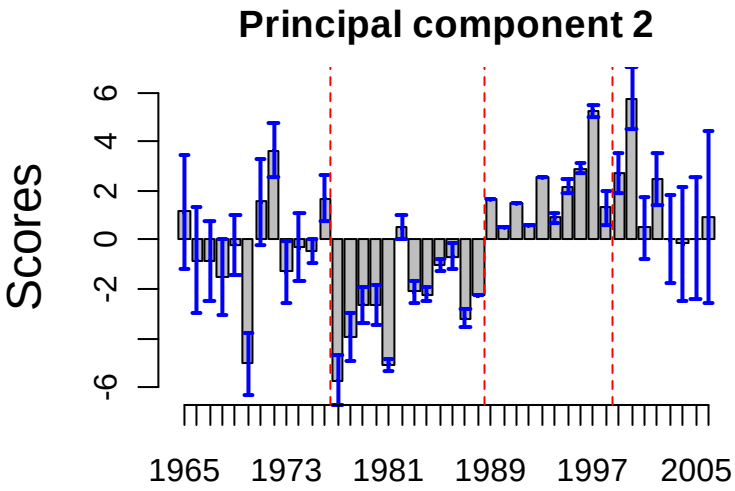
How robust are these patterns?

Sensitivity analyses:

- **Eliminating up to 60% of the data series had little effect on major step changes, in particular 76/77 and 98/99 changes were very robust (1998/99 change generally short-lived)**
- **Excluding all 31 salmon series resulted in very similar patterns with strong shifts in 76/77 and short-lived shift in1998/99**

Excluding salmon:





Summary: Hare & Mantua update

- **Long-term directional trend in major modes of biological variability (three successive "states")**
- **Apparent large shift in 1999**
  - **Unusual climate conditions in 1999**
  - **Short-lived response rather than a change to a new state (Ecosystem resilience?)**

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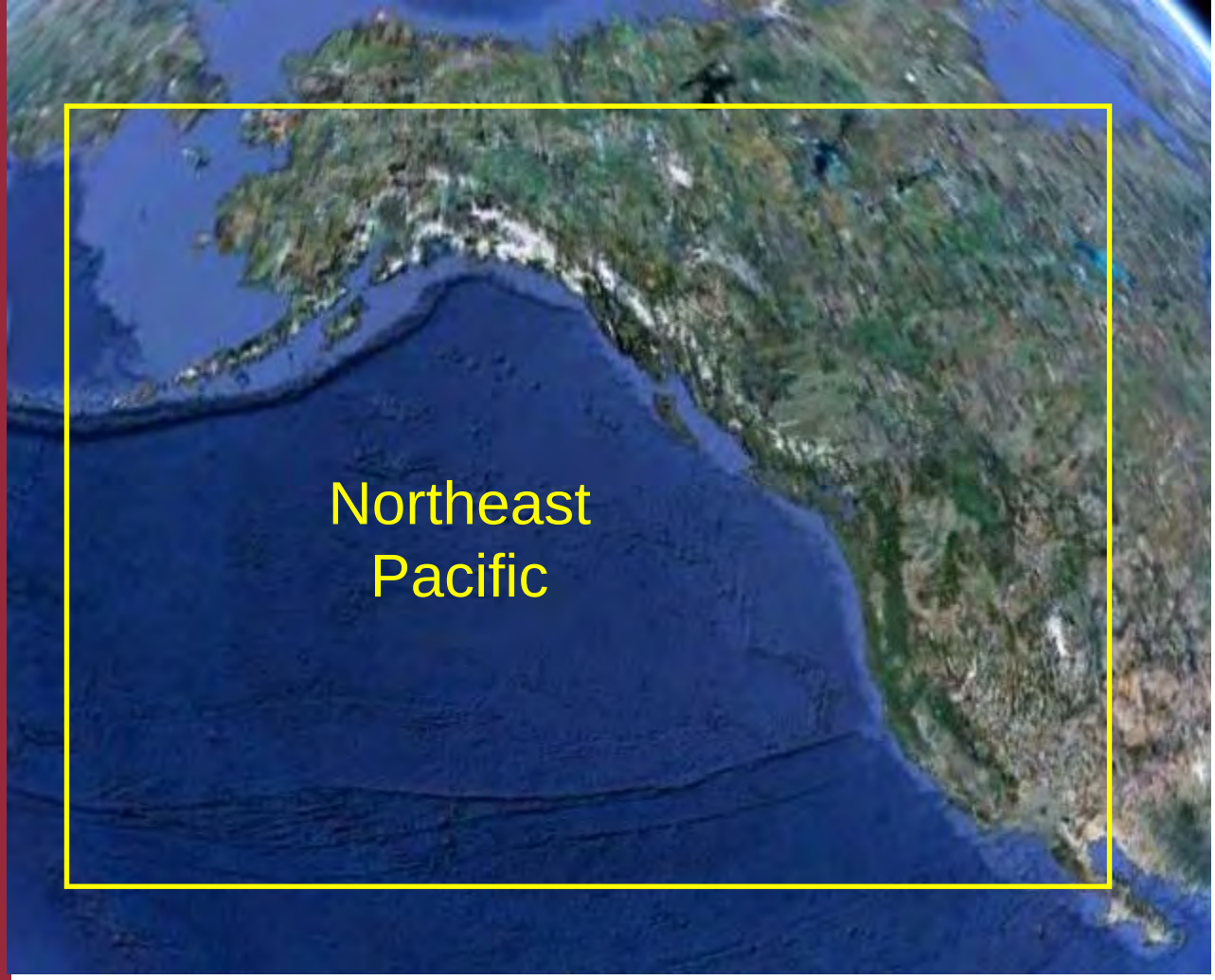

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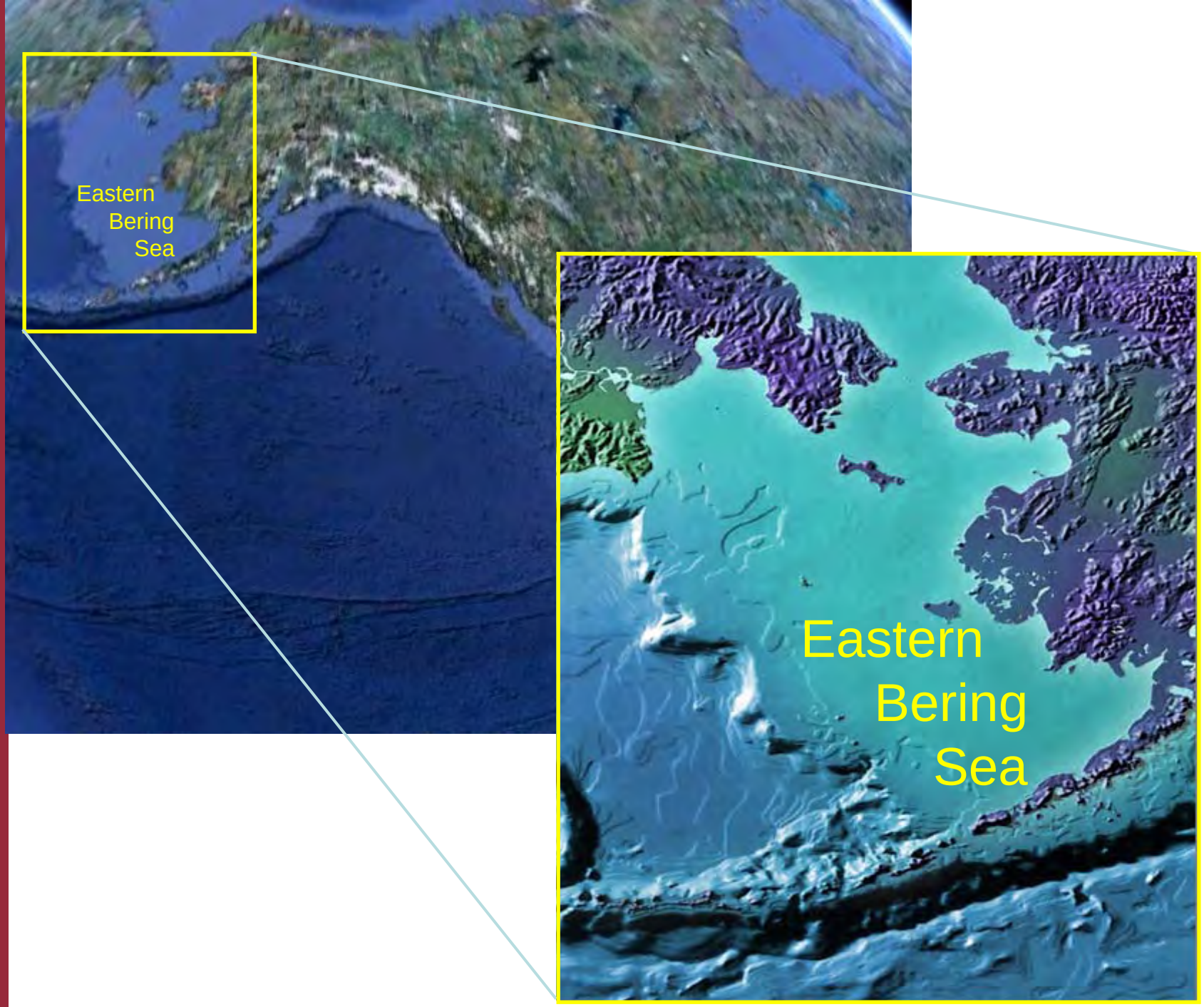
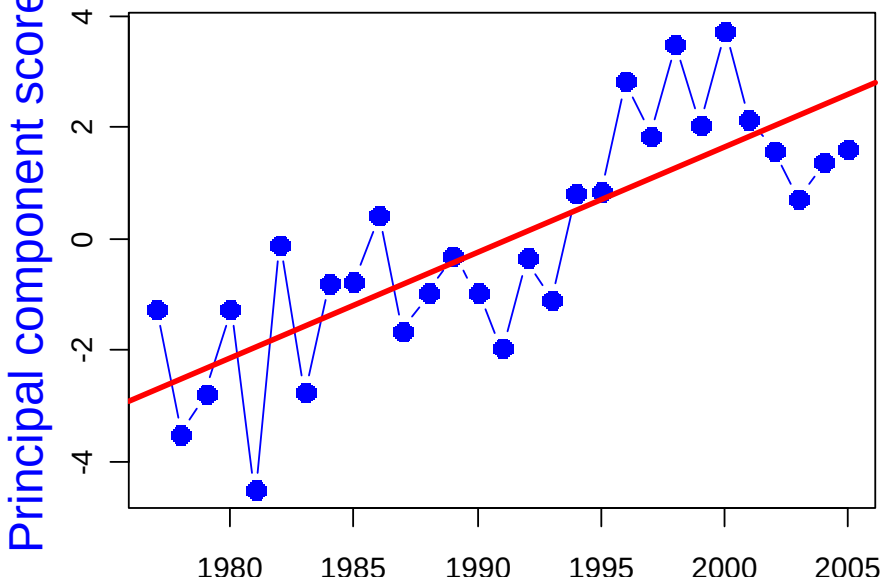
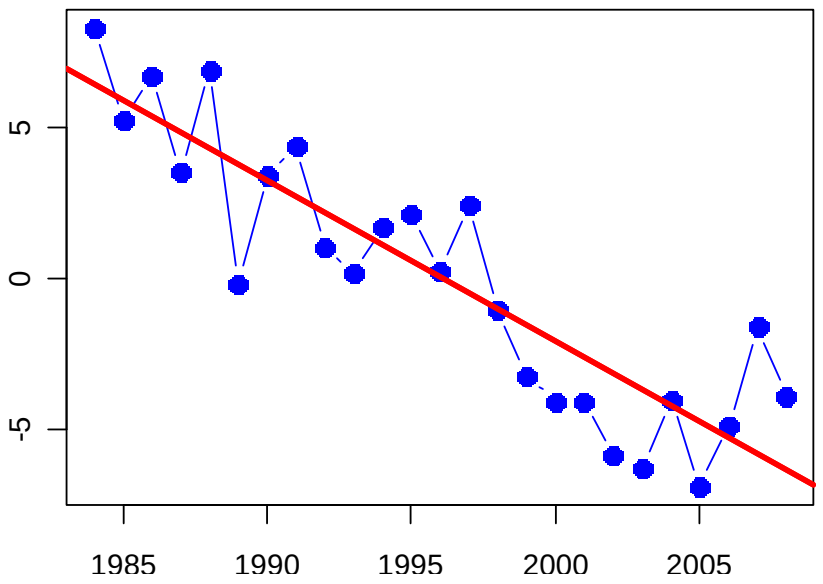


Eastern Bering Sea: Major modes of variability

18 biological productivity series
(demersal & pelagic fish, seabirds)
(23% of total variance)



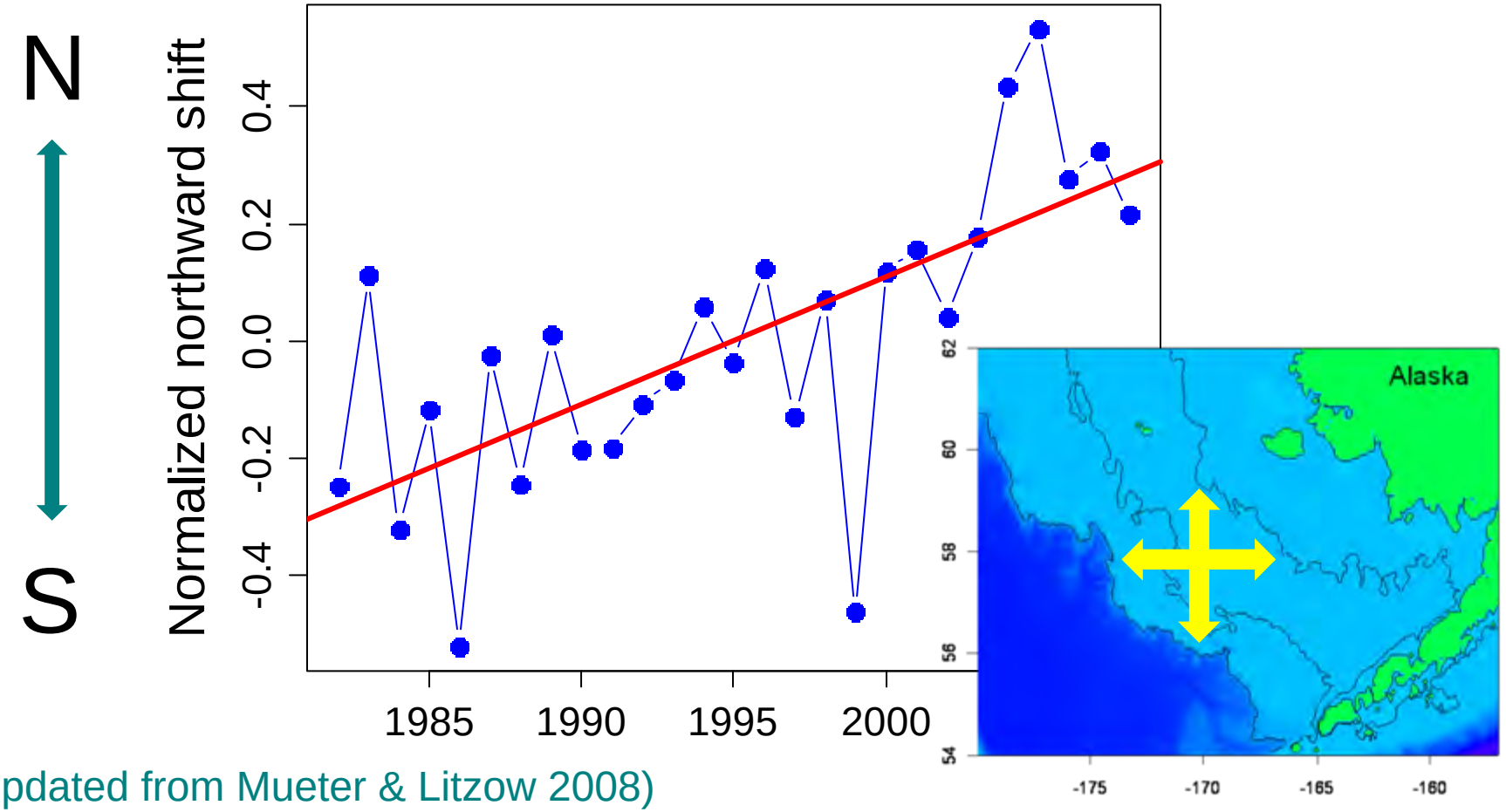
Abundances of 46 fish & shellfish taxa
In summer bottom trawl surveys
(21% of total variance)



→ Strong directional changes over 25+ years

Eastern Bering Sea: Major modes of spatial variability

Average North-South displacement (Center of gravity) across 41 demersal fish & shellfish taxa, 1982-2008



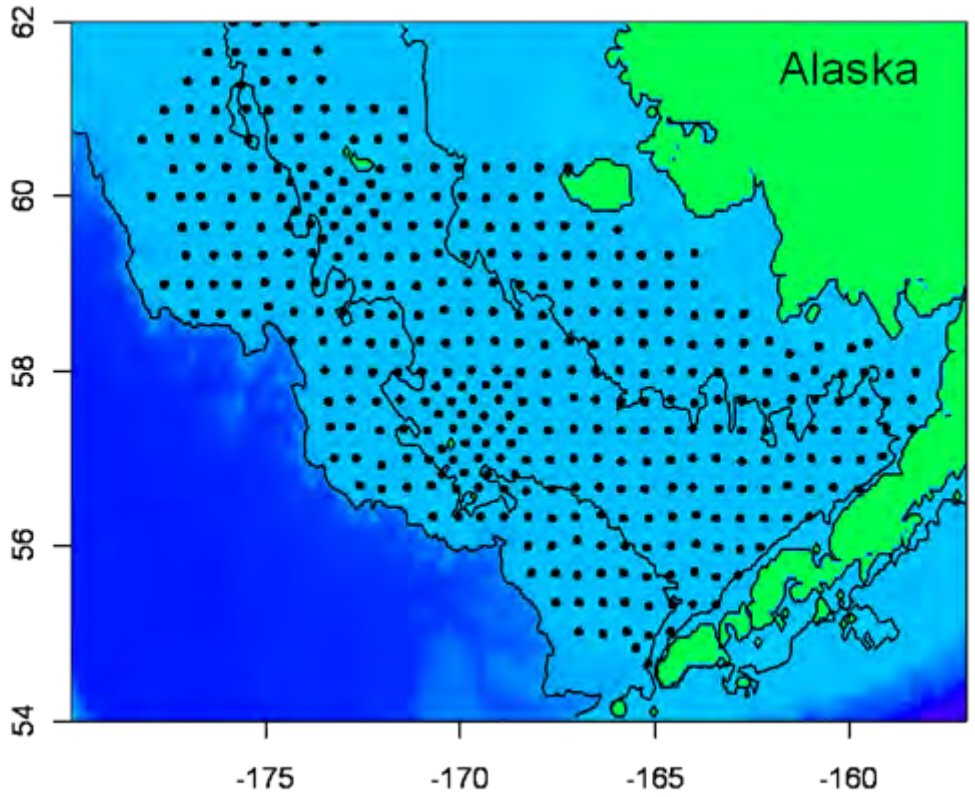
Updated from Mueter & Litzow 2008)

Spatial indicators

- **Center of gravity**
- **Inertia**
- **Anisotropy**
- **Positive area**
- **Spreading area**
- **Equivalent area**
- **Number of spatial patches**
- **Microstructure index**

after Woillez et al 2009

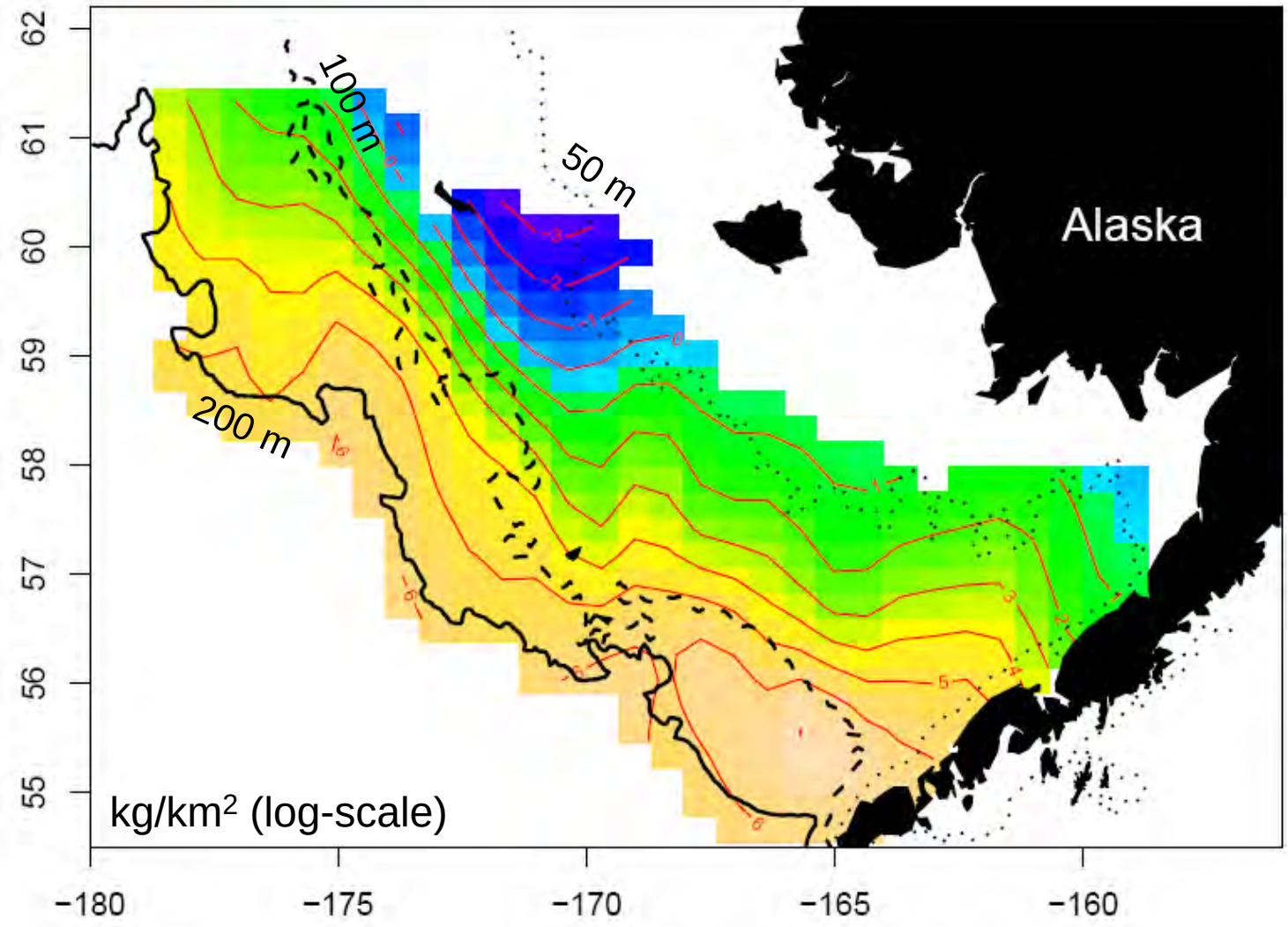
Eastern Bering Sea bottom trawl survey sampling grid



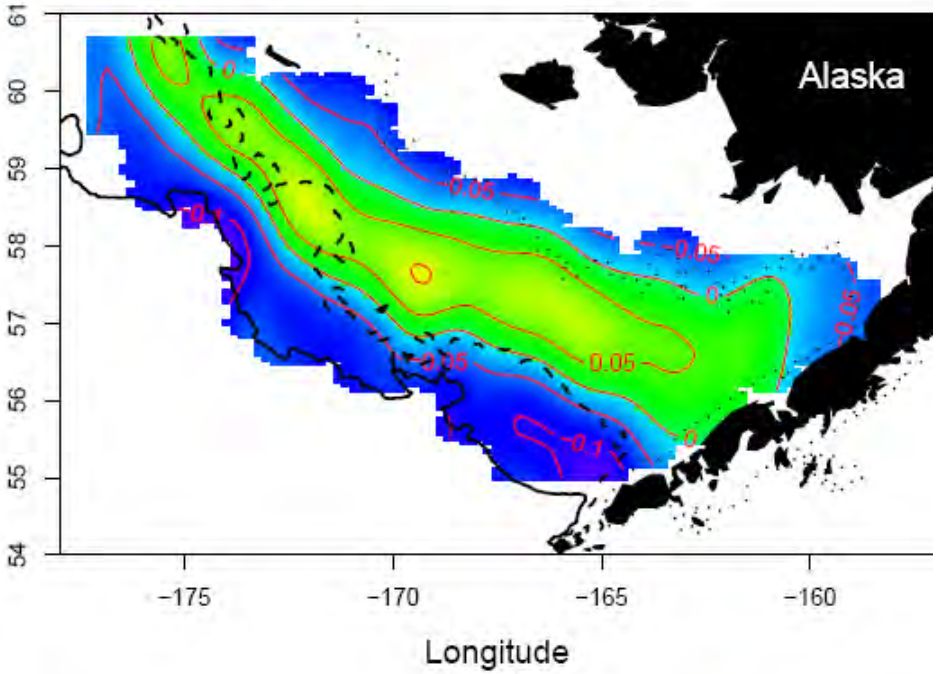
Principal Components Analysis (EOF) of time series of abundances at each station, 1982-2008

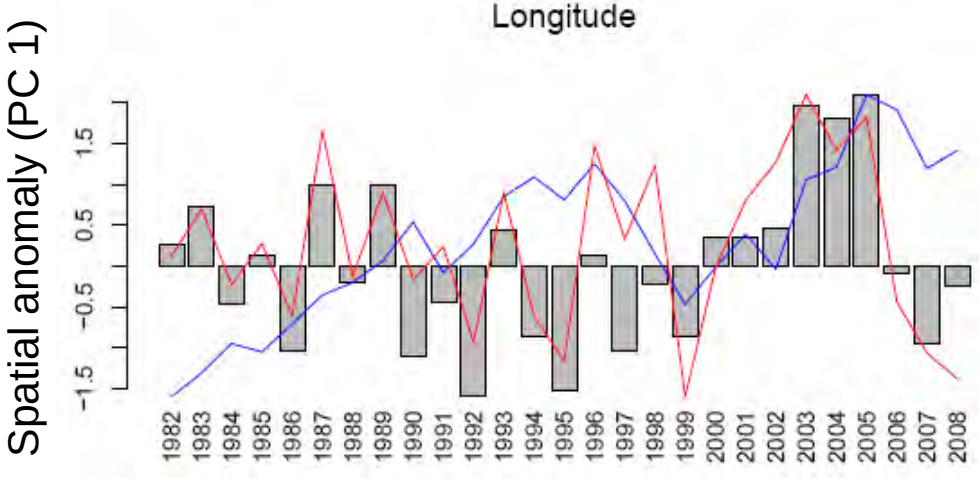
For survey description, see Lauth & Acuna (2007, NOAA Tech Memo, AFSC)

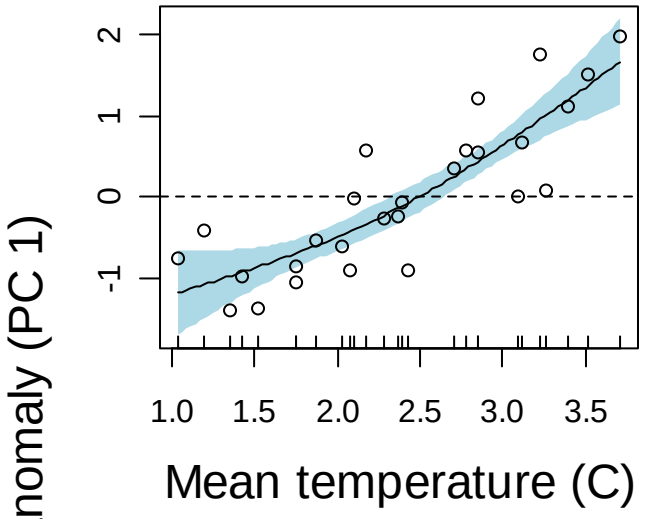
Arrowtooth flounder (Atheresthes spp.): Mean densities (1982-2008)

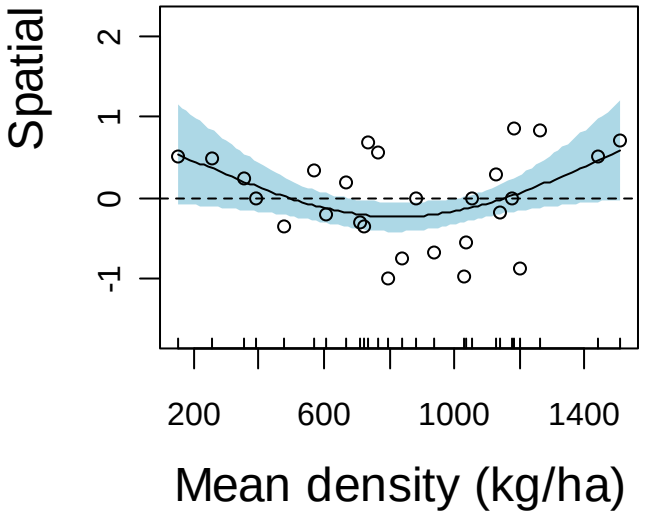


Spatial anomalies:
Arrowtooth flounder (Atheresthes spp.)

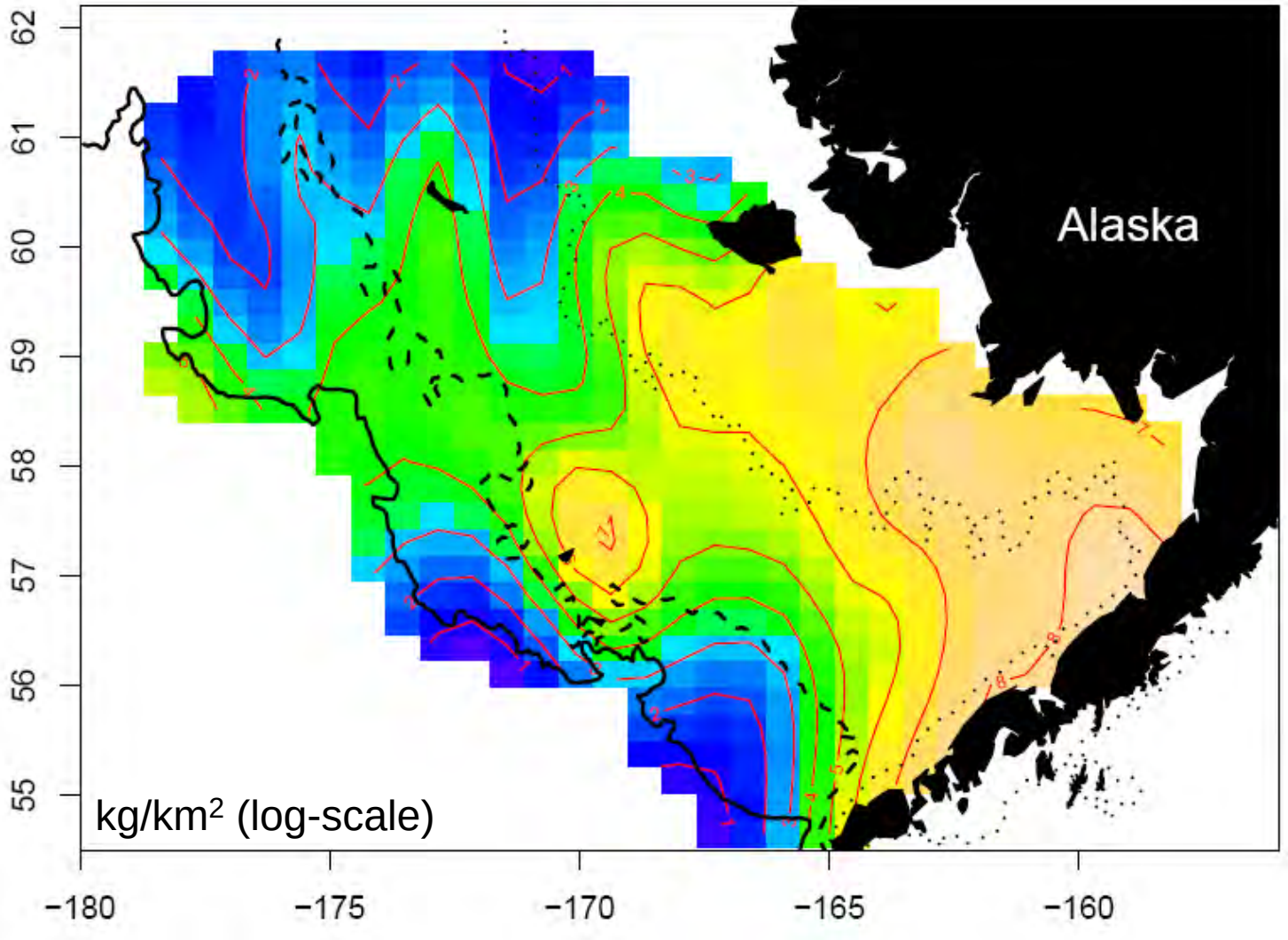








Rock sole (Lepidopsetta spp.): Mean densities (1982-2008)



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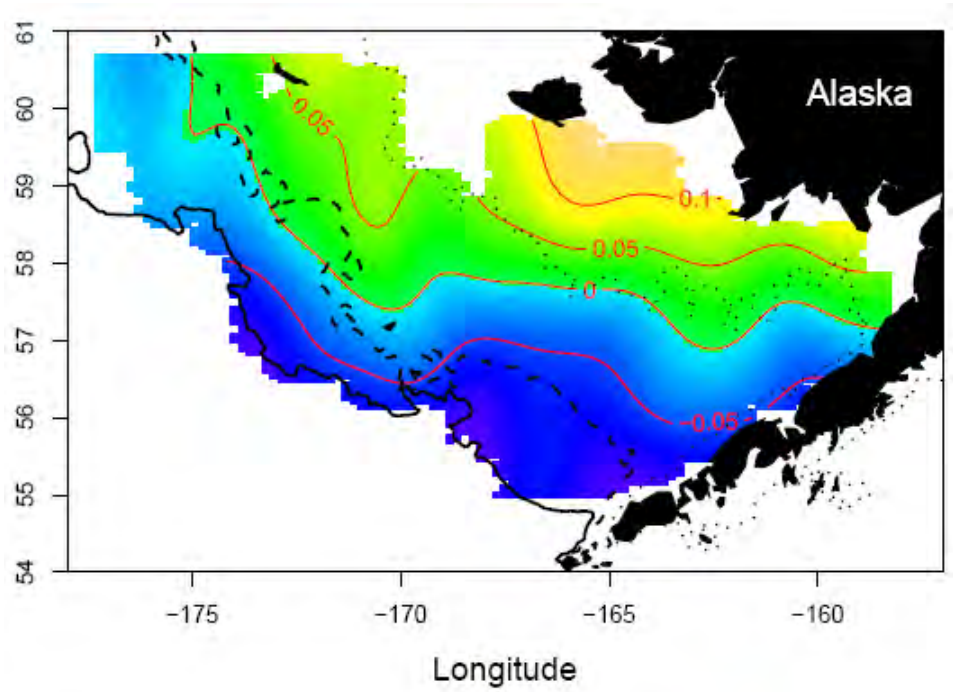
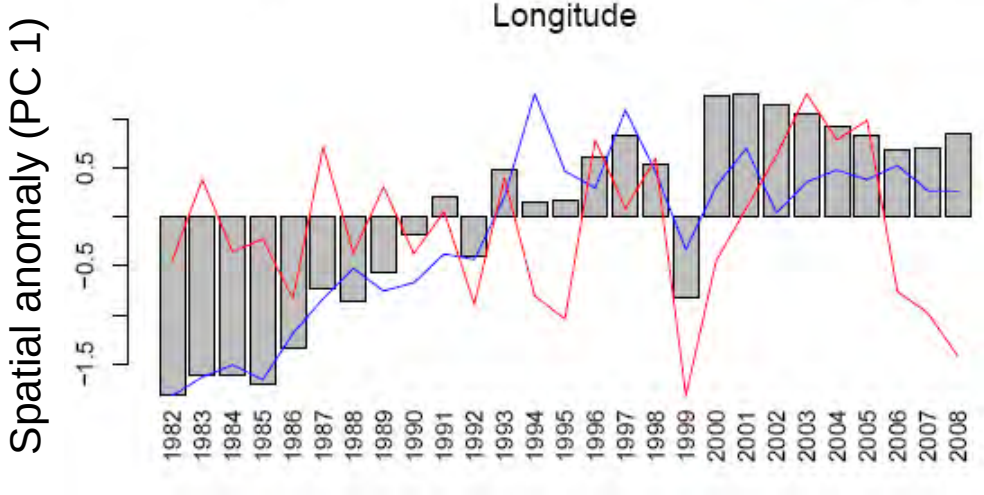
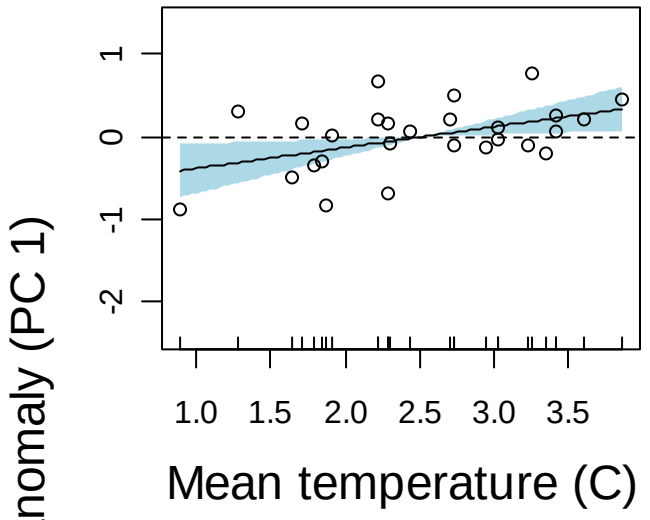
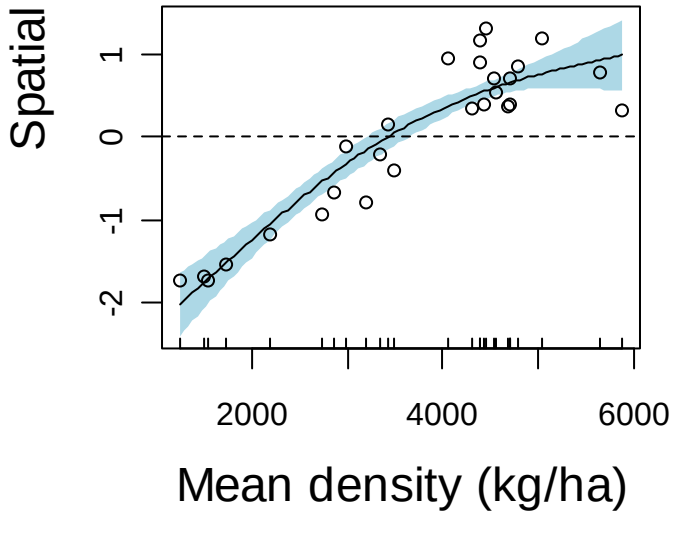








Summary results (46 taxa)

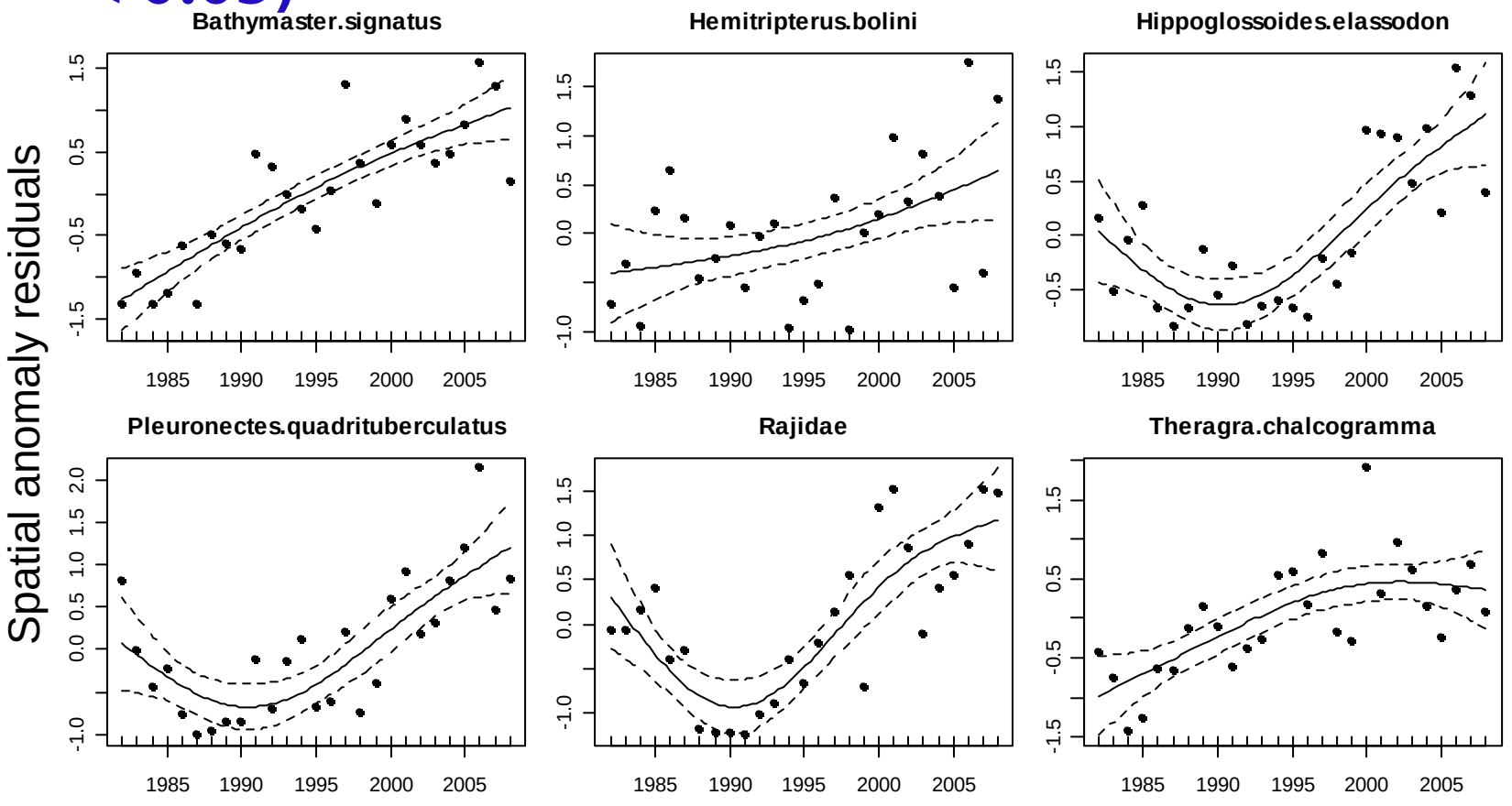
- **First Principal Components accounted for 9-43% of total variance in spatial anomalies**
- **Temperature and/or abundance accounted for a significant proportion of variance in first PC for 39 of 46 species**
- **Temperature and / or abundance accounted for > 70% of variability in first PC for 12 species**

Modeling spatial anomalies

Species	R^2	Significance of effect	
		Temperature	Abundance
Ammodytes hexapterus	0.74	0.351	**0.000**
Anoplopoma fimbria	0.94	0.210	**0.000**
Atheresthes sp	0.73	**0.000**	0.063
Boreogadus saida	0.74	**0.007**	**0.001**
Chionoecetes opilio	0.72	0.588	**0.000**
Eleginus gracilis	0.88	0.859	**0.000**
Hemilepidotus papilio	0.76	0.887	**0.000**
Lepidopsetta sp	0.85	**0.018**	**0.000**
Lycodes raridens	0.84	0.945	**0.000**
Pandalus goniurus	0.87	0.868	**0.000**
Paralithodes platypus	0.77	0.477	**0.000**
Platichthys stellatus	0.75	**0.045**	**0.000**

Strong residual trends over time

- **After accounting for effects of temperature variability and abundance, 27 of 46 taxa showed significant residual trends over time ($p < 0.05$)**



Predicting spatial distribution

- **Future projections of spatial patterns of distribution under different climate scenarios are possible for some species**
  - **Need projected abundances (Population dynamics model)**
  - **Need average regional temperatures (downscaling from IPCC models)**

Predict index of spatial anomaly:

f(temperature, abundance)

Predict abundances by location:

Annual mean + spatial mean + spatial anomaly + ε

Conclusions

- **There has been a (currently unexplained) directional shift in biological communities in the Northeast Pacific and, specifically, in the eastern Bering Sea over the past 25-30 years (exceeding decadal scales of variability).**
- **Directional changes in spatial distribution are associated with both changes in temperature and changes in abundance. In addition, many species show strong residual shifts in distribution**
- **Changes in the relative spatial distribution of different species affect trophic interactions and hence future abundances, potentially**

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