Geographical shifts in the spatial distribution of Northeast Pacific groundfish populations

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Objectives

- Quantify changes in spatial distribution of demersal fish and invertebrates in the Northeast Pacific Ocean
  - Bering Sea (59 taxa)
  - (Gulf of Alaska, U.S. West Coast)
- Examine potential causes
  - Bottom temperature
  - Abundance (density dependence)
  - Residual long-term trends
- Test for northward shift in response to warming trend?
Data: CPUE from bottom trawl survey

Eastern Bering Sea
1982-2004

Gulf of Alaska
1984-2003

Anchorage
Juneau
Kodiak I.
Approach: quantifying shifts in distribution

- Estimate & remove average spatial pattern
  - Anomalies in probability of occurrence
  - Anomalies in CPUE-where-present
- Quantify spatial gradients in anomalies for each survey year
  - Latitude / alongshore distance
  - Depth
- Estimate trends in gradients over time
Total CPUE: average spatial pattern 1982-2004

fourth-root transformed CPUE

Longitude

Latitude

Alaska
Distribution by depth / time of year

fourth-root transformed CPUE

Julian Day

Depth (m)
Annual means: Total CPUE

fourth-root transformed CPUE

Year

CPUE anomalies for two periods

1982 - 1986

2000 - 2004
Difference in anomalies among periods


Alaska
Differences in anomalies and SE

Differences:

2 x Standard errors
Smooth trends by latitude and depth

- CPUE anomaly vs. (rotated) latitude
- CPUE anomaly vs. Depth

- 1982 - 1986
- 2000 - 2004

- south
- north
- shallow
- deep
Smooth trends by latitude and depth

(Anomalies relative to 1982-2004 means)
Annual gradients in total CPUE by latitude and depth

(latitudinal anomaly) (depth anomaly)

(± 2 SE confidence intervals TOO NARROW as they DO NOT account for spatial autocorrelation)
Indices for individual taxa

- **Probability of occurrence**
  - Model presence / absence as function of latitude, longitude, bottom depth, Julian day, net width, and **tow duration**
  - Residuals (logit-scale) as indicators of anomalies in probability of occurrence

- **CPUE-where-present**
  - Model as function of latitude, longitude, bottom depth, Julian day, net width
  - Residuals (log-scale) as indicators of spatial anomalies in CPUE-where-present
Trends in latitudinal anomalies across species

Highly mobile taxa

Sessile / limited mobility

Linear trend in latitudinal anomalies, 1982-2004
# Trends in latitudinal anomalies (CPUE) selected taxa

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Slope</th>
<th>P-value</th>
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<tbody>
<tr>
<td>Lepidopsetta sp. rock sole</td>
<td>1.53</td>
<td>0.000</td>
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<tr>
<td>Theragra chalcogramma walleye pollock</td>
<td>1.01</td>
<td>0.000</td>
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<tr>
<td>Scyphozoa jellyfish</td>
<td>0.84</td>
<td>0.002</td>
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<tr>
<td>Limanda aspera yellowfin sole</td>
<td>0.76</td>
<td>0.001</td>
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<tr>
<td>Rajidae skates</td>
<td>0.65</td>
<td>0.000</td>
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<tr>
<td>Lycodes brevipes shortfin eelpout</td>
<td>0.57</td>
<td>0.033</td>
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<tr>
<td>Hippoglossus stenolepis Pacific halibut</td>
<td>0.47</td>
<td>0.018</td>
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<tr>
<td>Bathymasteridae ronquils</td>
<td>0.42</td>
<td>0.011</td>
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<tr>
<td>Holothuroidea sea cucumbers</td>
<td>0.37</td>
<td>0.035</td>
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<tr>
<td>tunicates</td>
<td>0.21</td>
<td>0.010</td>
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<tr>
<td>Podothecus acipenserinus sturgeon poacher</td>
<td>0.18</td>
<td>0.027</td>
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<tr>
<td>Glyptocephalus zachirus rex sole</td>
<td>-0.17</td>
<td>0.005</td>
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<tr>
<td>Myoxocephalus spp</td>
<td>-0.32</td>
<td>0.037</td>
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<tr>
<td>Hemilepidotus papilio butterfly sculpin</td>
<td>-0.46</td>
<td>0.001</td>
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</tbody>
</table>
**Average latitudinal anomalies**

Highly mobile taxa

Sessile / limited mobility

-6 -4 -2 0 2 4 6

Mean slope


1999
Potential causes of latitudinal shifts

• Temperatures
  • Estimated average bottom temperature within survey area by year

• Changes in abundance
  • Average CPUE by year for each species
Trends in latitudinal anomalies

Trends with temperature

Trends with mean CPUE

Number of taxa

Slope

Highly mobile taxa

Sessile / limited mobility

Highly mobile taxa
Residual time trends in latitudinal anomalies

Significant trends (p < 0.05), 1982-2004:

Northward shift
- Pacific halibut (*Hippoglossus stenolepis*)
- Bering flounder (*Hippoglossoides robustus*)
- Yellowfin sole (*Limanda aspera*)
- Ronquils (*Bathymasteridae*)
- Tunicates

Southward shift
- Arrowtooth flounder (*Atheresthes stomias*)
- Pacific cod (*Gadus macrocephalus*)
- Rex sole (*Glyptocephalus zachirus*)
Summary and conclusions

• Significant northward shifts in center of distribution of numerous demersal taxa on the eastern Bering Sea shelf over the last 20+ years
• Shifts related to changes in bottom temperature and abundance
• If current warming trend continues, biomass on northeastern Bering Sea shelf is likely to increase relative to the southeast
• Range extensions are likely because several species are near northern limit of their distribution
Acknowledgements

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