Geographic variation in fish growth responses to regime shifts in the North Pacific using a fish growth - ecosystem coupled model NEMURO.FISH

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1. An example of geographical comparison of biological response to climate changes
2. Link to marine mammals and seabirds as prey (small pelagic fishes)
NEMURO
North Pacific Ecosystem Model for Understanding Regional Oceanography

Kishi et al. (2001), Kishi et al. (in press)
Ito et al. (2004), Megrey et al. (in press), Ito et al. (in press) etc.
Bioenergetics Model for herring and saury

\[
\frac{dW}{W \cdot dt} = \left[ C - (R + S + F + E + P) \right] \cdot \frac{CAL_z}{CAL_f}
\]
Today's Contents

0. 3D-NEMURO (zooplankton)
   lower trophic level ecosystem response

1. 3D-NEMURO (zooplankton)
   + NEMURO.FISH (herring)
   geographical comparison of fish response

2. 3D-NEMURO (zooplankton)
   + NEMURO.FISH (saury & herring)
   geographical & species comparison of fish response
3D-NEMURO
Aita et al. (2003), Yamanaka et al. (2003), Aita et al. (in press)

**Physical model**
CCSR Ocean Component Model 3.4

**Resolution**
Horizontal: 1 degree by 1degree (360x180)
Vertical: 54 levels from the surface to 5000 m

**Real climate forcing since 1948**
daily surface heat flux
fresh water flux
wind stress
light intensity
NCEP reanalysis
Winter mixed layer depth in 3D-NEMURO

1956-1975

1977-1996


Increase in CP coastal GA
Decrease in WP GA

Aita et al. (in press)
SST & upwelling in 3D-NEMURO


SST: colder in CP & warmer in other area similar to observation

upwelling: enhanced in north of 30N

Aita et al. (in press)
Primary production in 3D-NEMURO


PP:  
- there is negative bias  
- increase in CP: consistent with observation  
- decrease in GA: consistent with observation  
- increase in BS: inconsistent with observation

Aita et al. (in press)
Comparison with observation (C. Pacific)

Much smaller than observational values. However, the variability is consistent with observation. The variability shows high correlation with PDO (>0.6).

Aita et al. (in press)
Correlation coefficients between PP and PDO

Positive in C. Pacific.
Negative along eastern boundary of Pacific.

Aita et al. (in press)
Geographical comparison of herring

Integrate NEMURO.FISH using zooplankton & temp. of 3D-NEMURO (one-way static linkage).

Partly reported in Rose et al. (in press)
In 3D-NEMURO, the zooplankton density is much smaller than observation. Therefore, the herring cannot grow sufficient. Need to calibrate bioenergetics model parameters.

Automated calibration software PEST to calibrate parameters.

Weights-at-age from:
Schweigert et al. (2004)
Lassuy (1980)
Herring growth by NEMURO.FISH

Weight of age-4 herring on March 1 of each year

Growth in weight from age-4 to age-5 of each year
Cluster analysis for wet weight of herring

Use complete connection method with standardized Euclidian distance
EOF for wet weight
EOF1 38.1%
EOF2 19.4%

EOF1  EOF2
group 1  –  +
group 2  +  +
group 3  +  –

Time series of score
EOF1:
EOF2:
  1953-54, 68-69,
  81-82, 89-90
Cluster analysis for wet weight change of herring

Dendrogram for delta wet weight

- peter-4-deltaw
- sak-4-deltaw
- W-Ber-4-deltaw
- Togiak-4-deltaw
- PWS-4-deltaw
- SeaofO-4-deltaw
- WCVI-4-deltaw
- CA-4-deltaw

Use complete connection method with standardized Euclidian distance
**EOF for weight change**

**EOF1** 35.2%

**EOF2** 24.7%

**EOF1**  **EOF2**

- **group 1**   +   +
- **group 2**   +   +
- **group 3**   +   -
- **group 4**   +   -

**Time series of score**

**EOF1:**


**EOF2**

noisy
1. We should be careful about the meaning of data. weight & weight increment show different result
2. Model result showed basin scale synchronicity & east & Sea of O vs Bering & west asynchronicity
Life History of Pacific Saury with Oceanographic Features

Modified from Watanabe et al. (1989)
### Table 2. Life stages of Pacific saury in the saruy bioenergetics model

<table>
<thead>
<tr>
<th>Stage</th>
<th>Region</th>
</tr>
</thead>
<tbody>
<tr>
<td>larvae</td>
<td>Kuroshio</td>
</tr>
<tr>
<td>juvenile &amp; young</td>
<td>mixed region</td>
</tr>
<tr>
<td>small</td>
<td>Oyashio</td>
</tr>
<tr>
<td>adult</td>
<td>mixed region</td>
</tr>
<tr>
<td>adult matured</td>
<td>Kuroshio</td>
</tr>
<tr>
<td>adult</td>
<td>mixed region</td>
</tr>
<tr>
<td>adult</td>
<td>Oyashio</td>
</tr>
<tr>
<td>adult matured</td>
<td>Kuroshio</td>
</tr>
</tbody>
</table>

9 life stages

- Ito et al. (2004)
- Ito et al. (in press)
- Mukai et al. (in press)
Species comparison between saury and herring

Herring is assumed to live in the northernmost box, even though they do not live there in nature (virtual comparison). For saury, the geographical comparison is realistic.

Megrey et al. (in press)
Ito et al. (in prep.)
Saury and herring show synchronicity in East.

Megrey et al. (in press)
Saury vs Herring, West vs East (Model)

Zooplankton
  synchronized in subarctic and transition in east
  asynchronized in subarctic and transition in west

Saury and Herring
  synchronized in east
  asynchronized in west

Saury
  saury migrate from subtropical to subarctic
  Ito et al. (in press): zoo in transition & SST in subarctic are important
  complicated because integrating signals in wide area.

Herring
  complicated because integrating signals during several years

  The response depends on both location and life history.
Conclusion and Future perspectives

1. The biological response depends on both location and life history.

2. To make geographical comparison, time derivative data is useful.

3. Model approaches are immature to compare with realistic variations. However, those will become powerful tools to understand the biological responses. Therefore, we will continue.

4. Biological nesting “rhomboidal” approaches (deYoung et al., 2004) seems to be appropriate way to model marine ecosystems.
   - increase resolution near target species, and decrease resolutions up and down trophic ecosystem levels.

Drive marine mammals & seabirds model based on NEMURO.FISH seems interesting.