Species replacement between Japanese sardine and Pacific saury in relation to variation in feeding environment

Haruka Nishikawa and Ichiro Yasuda

Ocean Research Institute, University of Tokyo
Species replacement in the Northwestern Pacific

- Species replacement goes on saury & anchovy, mackerels, and sardine, in that order
- Fluctuation of sardine resources is drastic
- Recent replacement occurred in 1988 from sardine to saury

Catches of small pelagic fishes
(Kawasaki, 1993)
Previous works on sardine and saury fluctuation

- Japanese sardine larval mortality is significantly correlated with winter SST in the Kuroshio Extension and the southern recirculation zone (Noto and Yasuda, 1999)
- Pacific saury abundance is significantly correlated with SST in the Kuroshio region, Kuroshio-Oyashio transition zone and Oyashio region (Tian et al., 2003)

Both sardine and saury can be under the influence of environmental variation in the northwestern Pacific
Sardine and saury larva distribution

Kuroshio Extension is the wintering place of saury larva and can be migration route of sardine larva in spring
Mixed layer depth in the Kuroshio Extension

Winter mixed layer depth in KE varied from 100m to 250m

Spring chlorophyll density has a tendency to increase when winter ML is deep

Environmental variation in KE could influence on sardine and saury through their food

MLD data: White (2003), Chl data: SeaWiFS
Questions

- Why dominant species of northwestern Pacific changed from Japanese sardine to Pacific saury since 1988?
- Why Japanese sardine resources fluctuates drastically?
Data and method

Correlation analysis
To find the relationship between environmental factor and sardine, saury resources by using observational data

Model analysis
To compare the estimated plankton density with sardine, saury resources
The model is NEMURO (Kishi et al., 2001) and tuned to KE

Observational data
- Mortality coefficient anomaly of Japanese sardine…Kishida et al. (1994)
- Large and medium saury abundance…Tian et al. (2003)
- Mixed layer depth…White (2003)
- Sea surface temperature…GISST
- Shortwave radiation…NCEP/NCAR reanalysis data
- Nitrate and silicate…World Ocean Atlas 2001
Correlation with winter MLD

**Japanese sardine**
Larvae could not survive in the year of shallow winter MLD.

**Pacific saury**

**Large**
Abundance rose in the year of shallow winter MLD.

**Medium**
Abundance didn’t have any correlation with winter MLD in sardine dominated years. But they had positive correlation in saury dominated years.
Correlation with winter MLD

- Winter MLD in the KE could affect both sardine and saury
- Correlation with sardine resources was positive while large saury was negative in 1980s
  - 1988’s species replacement occurred between sardine and large saury
- Medium saury had positive correlation on condition sardine resources were small
  - Medium saury might compete with sardine for food
- These results are consistent with previous works because winter MLD variation corresponds to winter SST variation
Winter/spring zooplankton density increase/decrease in 1988 corresponding to large saury/sardine increase/decrease
Deep winter MLD inhibits photosynthesis in winter and causes spring phytoplankton bloom (-1987)

Shallow winter MLD causes winter phytoplankton bloom (1988-)

MLD regime shift in 1988 might change the spring/winter food availability of sardine/large saury
## Discussion 1

### Species replacement in 1988

<table>
<thead>
<tr>
<th>Year</th>
<th>Winter</th>
<th>Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>1987</td>
<td>Sardine dominated</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>○</strong></td>
<td></td>
</tr>
<tr>
<td>1988</td>
<td>Sardine decreased, L-Saury increased</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>×</strong></td>
<td><strong>○</strong></td>
</tr>
</tbody>
</table>

Deep winter MLD set bloom in spring in the Kuroshio Extension and sardine could match the bloom.

Shallow winter MLD set bloom in winter. Large saury could match the winter bloom while sardine mismatched the bloom.
## Discussion 2
Fluctuation pattern

<table>
<thead>
<tr>
<th></th>
<th>Japanese sardine</th>
<th>Pacific saury</th>
</tr>
</thead>
<tbody>
<tr>
<td>main spawning season</td>
<td>short February to March</td>
<td>long November to May</td>
</tr>
<tr>
<td>environmental change influence</td>
<td>Most of year class</td>
<td>Part of year class</td>
</tr>
<tr>
<td>resources fluctuation</td>
<td>drastic</td>
<td>moderate</td>
</tr>
</tbody>
</table>