Forecasting climate change impacts on distribution and abundance of jack mackerel around Korean waters

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Contents

• Variations of ocean environments around Korean waters
• Influence of environmental variations to recruitment of jack mackerel
• Selection of environmental stock-recruit relationships
• Forecasting abundance and distribution of jack mackerel
Currents around Korean waters
Ocean currents

yrs 1980s

yrs 1990s
Sea Level Pressure in the ECS

(Data from: Oh et al., 2004)

SST in the southern Yellow Sea

(from Lee, 2006)
Abundance of Jack mackerel
Transporting larvae/juvenile of jack mackerel by the Kuroshio Current

Spawnig ground

Nursery ground

April 11-30

February 27-March 10

After Sassa et al. (2005)

After Lee (2005)
Spawning biomass of jack mackerel

Recruitment of jack mackerel

(from Lee et al., 2005)
Growth and Maturation of jack mackerel

- Growth rate ($K/L_{\infty}$) :
  - $0.006$ (yr 66-70) $< 0.029$ (yr 99-04)
Recruitment estimates (1)

<table>
<thead>
<tr>
<th>Year</th>
<th>Recruitment estimates (I)</th>
<th>Recruitment estimates (I)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>One regime</td>
<td>Three regimes</td>
</tr>
<tr>
<td></td>
<td>Ricker</td>
<td>B-H</td>
</tr>
<tr>
<td>r</td>
<td>0.289</td>
<td>0.171</td>
</tr>
<tr>
<td>P-value</td>
<td>&lt;0.05</td>
<td>n/s</td>
</tr>
</tbody>
</table>
Spawner-Recruit Relationships of jack mackerel

(from Lee et al., 2005)
## Analysis of deviance of the fitted GAM

<table>
<thead>
<tr>
<th>Models</th>
<th>Residual df</th>
<th>Deviance</th>
<th>AIC</th>
<th>rsq</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n = 15</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>null deviance =</td>
<td>0.4380993</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Response: InR</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>1 lnS</td>
<td>13</td>
<td>0.3159742</td>
<td>26.3159742</td>
<td>0.27876109</td>
</tr>
<tr>
<td>2 lo(S,Z,Pdo)</td>
<td>4.030774</td>
<td>0.0485814</td>
<td>8.1101294</td>
<td>0.89395129</td>
</tr>
<tr>
<td>3 lnS+lo(Z,Pdo)</td>
<td>4.604726</td>
<td>0.0529183</td>
<td>9.2623703</td>
<td>0.87938396</td>
</tr>
<tr>
<td>4 lo(S,Z)</td>
<td>5.201238</td>
<td>0.1085168</td>
<td>10.5109928</td>
<td>0.76024637</td>
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<tr>
<td>5 lo(S,Pdo)</td>
<td>5.604726</td>
<td>0.0560394</td>
<td>11.2654914</td>
<td>0.8721641</td>
</tr>
<tr>
<td>6 lnS+lo(Z)</td>
<td>7.637916</td>
<td>0.124454</td>
<td>15.400286</td>
<td>0.71700909</td>
</tr>
<tr>
<td>7 lnS+lo(Pdo)</td>
<td>9.224373</td>
<td>0.1338425</td>
<td>18.5825885</td>
<td>0.70871962</td>
</tr>
</tbody>
</table>
Recruitment estimates (II)

\[ \ln(R) \sim \log(S, Z, \text{PDO}, \text{span}=0.75, \text{degree}=1) \]
Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global mean sea level.
Linear trend of temperature change (°C) in the land and sea surface (1968-2005)
Temperature changes in Korea

- From 1968 to 2005, air temperatures increased on average by 1.3°C, and SSTs by 1°C.
- Additional increase by $1.3 - 1.0 = 0.3$°C in the land may have been caused by local factors such as industrialization and urban heat-island effect.
- The increasing trend diminished with water depth.
Monthly air temperature and SST over Korean Peninsula

Overall: $y = 0.72 + 0.55x$ ($r^2 = 0.93$, $p < 0.001$)

- Aug.: $y = 19.39 + 0.27x$ ($r^2 = 0.08$, $p = 0.046$)
- Oct.: $y = 13.46 + 0.38x$ ($r^2 = 0.25$, $p < 0.001$)
- Jun.: $y = 9.02 + 0.58x$ ($r^2 = 0.16$, $p = 0.008$)
- Dec.: $y = 12.61 + 0.34x$ ($r^2 = 0.31$, $p < 0.001$)
- Apr.: $y = 10.60 + 0.34x$ ($r^2 = 0.39$, $p < 0.001$)
- Feb.: $y = 11.77 + 0.36x$ ($r^2 = 0.64$, $p < 0.001$)
Air temperature forecast over Korean Peninsula (based on IPCC SRES A2 CO₂ emission scenario)

Warming rate (from Kim et al., 2007)
0.61 degree/decade, 5.5 degree/century
Mean Spring Winds

Forecast Cross-Shelf Wind

Bering Sea cross-shelf wind by N. Bond

Zonal WIND forecasting
(nursery ground of jack mackerel)

Recruitment forecasting
(Steepness vs. Carrying capacity)
Distribution of jack mackerel
Geographical distribution of mean surface temperature in April in each period separated by regime shifts.
Geographical distribution of mean zooplankton biomass in each period separated by regime shifts.
Spatial distributions of jack mackerel around Korean waters

1971-79

1980-87

1990-96
Joint confident regions in the habitat of major small pelagics in Korean waters during the periods of (a) pre- and (b) post-1988 CRS (Zhang, Yoon and Lee, 2006).
Summary

- Temperature and zonal wind in the nursery ground of jack mackerel are major environmental factors to forecast future her abundance and distribution.
- In Korean waters, the increase of temperature by 1°C in both of the land and sea seems to be related with global factors, but 2 x higher than the global mean reported by IPCC.
- Favorable ocean environmental shifts influenced growth and reproductions of jack mackerel, and in the short-term future her distribution would be extended northward.