Changes in Sablefish Recruitment in Response to Oceanographic Conditions

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Overview

- Sablefish stock-recruitment and its problems
- Early life history characteristics of sablefish
- Use of the General Additive Model (GAM)
- Seasonal behavior of the predictive oceanographic variables (north and east Ekman transport, sea level) and GAM fits to these variables
- Resampling via bootstrap to quantify bias and error around estimates of coefficient
- Incorporation of environmental parameters into the stock assessment model
The US west coast sablefish assessment covers from the US/Canadian border in the north to the US/Mexico border in the south.
Stock-Recruit data does not fit traditional Ricker or Beverton-Holt models well

\[ R = \frac{1}{(\alpha + \beta / \text{SSB})} \]
Sablefish egg/larvae abundance at surface peaks from February to April

(CalCOFI data, reproduced from Moser et al. 1994)

<table>
<thead>
<tr>
<th>REGION</th>
<th>JAN</th>
<th>FEB</th>
<th>MAR</th>
<th>APR</th>
<th>MAY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Washington</td>
<td>0</td>
<td>-</td>
<td>37.8</td>
<td>158.1</td>
<td>16.4</td>
</tr>
<tr>
<td>Northern Oregon</td>
<td>0</td>
<td>-</td>
<td>25.4</td>
<td>87.9</td>
<td>20.9</td>
</tr>
<tr>
<td>Southern Oregon</td>
<td>0</td>
<td>-</td>
<td>45.2</td>
<td>22.4</td>
<td>17.8</td>
</tr>
<tr>
<td>Northern Calif.</td>
<td>0</td>
<td>-</td>
<td>21.9</td>
<td>11.4</td>
<td>2.1</td>
</tr>
<tr>
<td>Central Calif.</td>
<td>0</td>
<td>5.2</td>
<td>1.4</td>
<td>1.1</td>
<td>0</td>
</tr>
</tbody>
</table>
The General Linear Model (GLM) vs. The General Additive Model (GAM)

- The GAM does not necessarily impose a rigid parametric dependence of recruitment on the environment.
- A GAM lets the data show us the appropriate functional form through the use of scatterplot smoothers while at the same time maintains the predictive power of a more rigid model.
- Terms can be modeled non-parametrically or parametrically or both forms combined into a semi-parametric model.
Oceanographic data was obtained from the NOAA CO-OPS web site and the NOAA Pacific Fisheries Environmental Lab “Live Access Server”

http://co-ops.nos.noaa.gov/data_res.html

http://las.pfeg.noaa.gov/las/
**Northward Ekman Transport (NET) at 48 ° Lat in February alternates between north(+) and south(-)**

- **Bar Chart**
  - Y-axis: NET (values from -300 to 0)
  - X-axis: Month (1 to 12)
  - Data points for each month indicate the NET value.

- **Graph**
  - X-axis: Z-score
  - Y-axis: Partial Residuals
  - Trend line with P = 0.0004

- **Legend**
  - Bar colors represent months.
Eastward Ekman Transport (EET) at 45° in June is an index of summer upwelling and is generally west(-)
Sea Level (SL) at 42° in July is an indicator of Along Shore Transport (< sea level = > transport)

(bs(sl.42.7, knots=7.3, degree=1)

P = 0.0007
The most parsimonious model was chosen using stepwise selection and Akaike’s Information Criteria (AIC)

\[ \text{AIC} = -2 \times \ln(\text{likelihood}) + 2\times K \]

Where \( K \) is the number of parameters in the model. The AIC statistic accounts simultaneously for the degrees of freedom used and the goodness of fit: more parsimonious models have a lower AIC.
### Resulting Model

\[ R = SSB + SL.42^\circ.7 + NET.48^\circ.2 + EET.45^\circ.6 \]

<table>
<thead>
<tr>
<th>Model</th>
<th>Res SE</th>
<th>AIC</th>
<th>F</th>
<th>Pr(F)</th>
<th>R^2</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSB</td>
<td>13010</td>
<td>4.91E+9</td>
<td>1.107</td>
<td>0.3010</td>
<td>0.0420</td>
</tr>
<tr>
<td>SSB + SL</td>
<td>10830</td>
<td>4.06E+9</td>
<td>4.881</td>
<td>0.0090</td>
<td>0.3890</td>
</tr>
<tr>
<td>SSB + SL + NET</td>
<td>9412</td>
<td>3.65E+9</td>
<td>6.696</td>
<td>0.0009</td>
<td>0.5589</td>
</tr>
<tr>
<td>SSB + SL + NET + EET</td>
<td>8014</td>
<td>3.39E+9</td>
<td>9.559</td>
<td>&lt;0.0001</td>
<td>0.6948</td>
</tr>
</tbody>
</table>
The GAM with environmental covariates explained 69% of the variation in recruitment.
Bootstrap analysis strongly suggests normality in the distribution of error around the estimated means of the coefficients.
Stability was tested by successively deleting one year of data for the last five years (1996-2000), refitting the model, and predicting deleted years as well as 2001 and 2002.
Possible Explanations for Observations

- Increased negative northern Ekman transport in February may transport eggs/larvae from more northern areas (Vancouver Island area)
- Increased negative eastern Ekman transport in June is associated with increased spring upwelling which is a generally better condition for juvenile sablefish
- Increased along shore transport may work with spring upwelling to bring more nutrients into the system
Recruitment may be related to Northern vs. Southern copepod anomalies

Data from Mackas et al. 2001
Current Direction of the Work

Recruitment is fit internal to the stock-assessment model by using a log-likelihood function and modeling the deviates $Re$ from $Rs$ with the equation below

$$Re = Rs \ast \exp(mx)$$

where:
$Re = \text{recruits from the environmental model}$
$Rs = \text{recruits from the stock/recruit model}$
$m_i = \text{fitted parameter}$
$x_i = \text{environmental effect anomaly (centered at 0)}$
Much more of the variance is accounted for when using the stock-environmental-recruit model.
Advantages to fitting within the stock assessment model

• Keeps the fitting process and parameter estimates internally consistent
• Allows for each years recruitment to be treated individually with regard to standard error
• Allows for gaps in the data
• Allows improvements to the stock assessment fit to be quantified
Conclusions

- Estimates of recruitment for a given year may be possible by August via oceanographic variables.
- Estimates of historical (pre-survey) recruitment may be possible, which could lead to inferences with regard to “virgin” state ($B0$).
- Fitting the recruitment relationship internal to the stock assessment model will allow for fitting, hind casting, and forecasting to be done simultaneously.