Influence of biotic and abiotic environment on large pelagic fish distribution in American Samoa

Mathieu Doray
Joint Institute of Marine and Atmospheric Research, University of Hawaii

Réka Domokos, Michael Seki, Jeffrey J. Polovina
Pacific Islands Fisheries Science Center, NMFS, NOAA
Motivations

- Influence of environment (eddy activity) on declining domestic fisheries CPUEs
- Fishery independent survey
  - Acoustic monitoring of large pelagic fish distribution
  - Abiotic and biotic environment monitoring
- GAM model to test influence of available in-situ and remote sensing environment descriptors on distribution of large pelagic fish acoustic targets
Materials and Methods
Methods: sound scattering layers characterisation

- Sound scattering layers (SSLs) acoustic data pre-processing
  - 38 kHz, echo-integration min. thr. = -90 dB, 0-700 m
  - 2 NM x 50 m integration cells
    - no spatial correlation between elementary sampling units (ESUs)
    - reduce vertical variance
  - Number of shoals per ESU

- SSL structure synthetic descriptors:
  - PCA/clustering on ESUs acoustic density profiles
  - Number of shoals and SSLs principal components (SSL.PCn) as synthetic descriptors
Methods: hydrological environment characterisation

- In-situ data
  - Spatial merging of acoustic and CTD data
  - Synthetic descriptors of CTD profiles
    - PCA/clustering on vertical profiles of CTD variables (resolution: 50 m, range = 0-700 m)
    - PCs as synthetic descriptors (CTD.PCn)
- Remote sensing data
  - Sea level anomaly (SLA): weekly, gradient, eddy kinetic energy (EKE), cruise average and standard deviation (SD)
  - Sea surface temperature (SST): cruise average, gradient and SD
Methods: large pelagic fish target selection

- Acoustic target selection
  - Targets tracked over 3 pings
  - Minimum Target Strength threshold (Bertrand and Josse, 2000)
  - Manual validation of all targets
  - Detections only in daytime

- Target counts
  - Target abundance biased in presence of aggregative structures
  - Presence/absence in 60 m ESUs
  - NBF = Number of presence in 2 NM ESUs
Results: big fish detections and environmental patterns

- Higher SLA
- Lower sub-surface salinity
- Higher SSL density
- Low number of shoals

- Lower SLA
- Higher sub-surface salinity
- Lower SSL density
- High number of shoals
Results: GAMs with \textit{in-situ} variables

- No spatial correlation between ESUs
- Family: negative binomial
- Model checking
  - \textit{GCV criterion for optimal smoothing (Wood, 06)}
  - \textit{AIC for model comparison}
  - \textit{Randomized quantile residuals (Dunn & Smyth, 96)}

<table>
<thead>
<tr>
<th>Model</th>
<th>df</th>
<th>% deviance explained</th>
<th>AIC</th>
<th>GCV.UBRE</th>
</tr>
</thead>
<tbody>
<tr>
<td>NBF ~ s(SSL.PC1)</td>
<td>4.59</td>
<td>26%</td>
<td>175.06</td>
<td>1.02</td>
</tr>
<tr>
<td>NBF ~ s(SSL.PC1) + s(CTD.PC1)</td>
<td>5.3</td>
<td>31%</td>
<td>170.22</td>
<td>1.03</td>
</tr>
<tr>
<td>NBF ~ s(SSL.PC1) + s(SSL.PC3) + s(CTD.PC1)</td>
<td>8.01</td>
<td>42%</td>
<td>161.12</td>
<td>1.04</td>
</tr>
<tr>
<td>NBF ~ s(SSL.PC1) + s(SSL.PC3) + s(CTD.PC1) + CTD.PC2</td>
<td>9.69</td>
<td>47%</td>
<td>156.96</td>
<td>1.01</td>
</tr>
<tr>
<td>NBF ~ s(SSL.PC1) + s(SSL.PC2) + s(SSL.PC3) + s(SSL.PC4) + s(CTD.PC1) + s(CTD.PC2) + s(CTD.PC3) + s(CTD.PC4)</td>
<td>19.84</td>
<td>64%</td>
<td>150.31</td>
<td>0.71</td>
</tr>
<tr>
<td>NBF ~ s(SSL.PC1) + s(SSL.PC2) + s(SSL.PC3) + s(SSL.PC4) + s(CTD.PC1) + s(CTD.PC2) + s(CTD.PC3) + s(CTD.PC4)</td>
<td>19.41</td>
<td>63%</td>
<td>150.21</td>
<td>0.71</td>
</tr>
<tr>
<td>NBF ~ s(SSL.PC1) + s(SSL.PC2) + s(SSL.PC3) + s(CTD.PC1) + s(CTD.PC2) + s(CTD.PC3)</td>
<td>17.97</td>
<td>62%</td>
<td>149.09</td>
<td>0.74</td>
</tr>
<tr>
<td>NBF ~ s(SSL.PC1) + s(SSL.PC3) + s(CTD.PC1) + s(CTD.PC2) + s(CTD.PC3)</td>
<td>16.33</td>
<td>61%</td>
<td>148.23</td>
<td>0.72</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Term</th>
<th>df</th>
<th>% deviance explained</th>
</tr>
</thead>
<tbody>
<tr>
<td>s(SSL.PC3)</td>
<td>0.71</td>
<td>5%</td>
</tr>
<tr>
<td>CTD.PC2</td>
<td>1.68</td>
<td>5%</td>
</tr>
<tr>
<td>s(CTD.PC1)</td>
<td>2.71</td>
<td>11%</td>
</tr>
<tr>
<td>s(CTD.PC3)</td>
<td>6.64</td>
<td>14%</td>
</tr>
<tr>
<td>s(SSL.PC1)</td>
<td>4.59</td>
<td>26%</td>
</tr>
</tbody>
</table>
Results: GAMs with *in-situ* variables

Deviance expl.: 26%

SSL PC1

11%

CTD PC1

5%

SSL PC3

14%

CTD PC2

5%

CTD PC3
Results: GAMs with \textit{in-situ} variables

Observed big fish densities

Modelled big fish densities
## Results: GAMs with remote sensing variables

<table>
<thead>
<tr>
<th>Model</th>
<th>df</th>
<th>% deviance expl.</th>
<th>AIC</th>
<th>GCV.UBRE</th>
</tr>
</thead>
<tbody>
<tr>
<td>NBF ~ s(gmSLA)</td>
<td>2</td>
<td>8.97E-008</td>
<td>193.07</td>
<td>1.01</td>
</tr>
<tr>
<td>NBF ~ s(SLA, k = 10)</td>
<td>2</td>
<td>0</td>
<td>193.06</td>
<td>1.02</td>
</tr>
<tr>
<td>NBF ~ s(sdSST)</td>
<td>2.01</td>
<td>0</td>
<td>193.03</td>
<td>1.01</td>
</tr>
<tr>
<td>NBF ~ s(gsdSST)</td>
<td>2</td>
<td>0</td>
<td>192.79</td>
<td>1.02</td>
</tr>
<tr>
<td>NBF ~ s(gradSLA)</td>
<td>2</td>
<td>0.04</td>
<td>189.83</td>
<td>1.01</td>
</tr>
<tr>
<td>NBF ~ te(SLA, gradSLA)</td>
<td>7.74</td>
<td>0.22</td>
<td>188.53</td>
<td>1.04</td>
</tr>
<tr>
<td>NBF ~ te(mSLA, gsdSLA, k = 10)</td>
<td>4.67</td>
<td>0.13</td>
<td>188.06</td>
<td>1.04</td>
</tr>
<tr>
<td>NBF ~ s(sdSLA)</td>
<td>3.34</td>
<td>0.11</td>
<td>187.57</td>
<td>1.02</td>
</tr>
<tr>
<td>NBF ~ s(SLA)</td>
<td>2</td>
<td>0.08</td>
<td>187.24</td>
<td>1.01</td>
</tr>
<tr>
<td>NBF ~ s(mSST)</td>
<td>2</td>
<td>0.08</td>
<td>187.24</td>
<td>1.01</td>
</tr>
<tr>
<td>NBF ~ s(gmSST)</td>
<td>2</td>
<td>0.07</td>
<td>187.22</td>
<td>1.01</td>
</tr>
<tr>
<td>NBF ~ te(mSLA, gmSLA)</td>
<td>4.39</td>
<td>0.13</td>
<td>186.93</td>
<td>1.04</td>
</tr>
<tr>
<td>NBF ~ te(mSLA, mgSLA)</td>
<td>6.09</td>
<td>0.18</td>
<td>186.91</td>
<td>1.03</td>
</tr>
<tr>
<td>NBF ~ s(mgSLA)</td>
<td>3.81</td>
<td>0.13</td>
<td>186.55</td>
<td>1.03</td>
</tr>
<tr>
<td>NBF ~ te(mSLA, sdSLA, k = 10)</td>
<td>4.77</td>
<td>0.16</td>
<td>186.18</td>
<td>1.04</td>
</tr>
<tr>
<td>NBF ~ te(SLA, eke)</td>
<td>4</td>
<td>0.15</td>
<td>185.23</td>
<td>1.02</td>
</tr>
<tr>
<td>NBF ~ s(gsdSLA)</td>
<td>2</td>
<td>0.1</td>
<td>185.08</td>
<td>1.01</td>
</tr>
<tr>
<td>NBF ~ s(SLA) + s(mSLA) + s(gradSLA) + s(sdSLA) + s(mgSLA) + s(mSST) + s(sdSST) + s(gmSST)</td>
<td>11.9</td>
<td>0.32</td>
<td>185.08</td>
<td>1.02</td>
</tr>
<tr>
<td>NBF ~ s(mSST)</td>
<td>3.07</td>
<td>0.13</td>
<td>184.44</td>
<td>1.03</td>
</tr>
<tr>
<td>NBF ~ s(SLA) + s(mSLA) + s(gradSLA) + s(sdSLA) + s(mgSLA) + s(eke) + s(mSST) + s(gmSST) + te(SLA, gradSLA)</td>
<td>11.45</td>
<td>0.33</td>
<td>182.85</td>
<td>0.99</td>
</tr>
<tr>
<td>NBF ~ s(eke)</td>
<td>2</td>
<td>0.13</td>
<td>182.73</td>
<td>1.02</td>
</tr>
<tr>
<td>NBF ~ s(mSST) + s(gmSST) + te(SLA, gradSLA)</td>
<td>10.8</td>
<td>0.33</td>
<td>181.3</td>
<td>0.91</td>
</tr>
</tbody>
</table>
Results: GAMs with remote sensing variables

- Under anticyclonic conditions, large pelagics density higher in weak geostrophic currents areas (convergence)
- Remote-sensing variables non significant when added into GAM with in-situ variables
Discussion and Conclusions (1)

- Acoustic sampling
  - Acoustics allows for the study of deep scattered large pelagics and their preys
  - Target identification?
- Data processing
  - PCs useful to represent environment vertical structure
  - GAM convenient tool to quantitatively explore and compare influences of environmental covariates
- Best in-situ model explain 2 times more variance than best remote-sensing model (61% vs 29%) and are more significant
  - Remote sensing data limited to surface layer and lower trophic levels
  - Valuable data to describe the SLA landscape in which biological production occurs
Discussion and Conclusions (2)

- Micronekton density
  - Explains highest amount of variability
  - Proven positive correlation with big fish abundance at mesoscale
  - Need for a network of instrumented buoys for continuous SSLs sampling

- Hydrology
  - Explains as much variance as SSL density
  - Hydrological conditions not limitant for tuna -> water masses of different origins?

- SLA
  - Highest tuna and micronekton densities in weak geostrophic current areas -> convergence?
Regional oceanography

Mean SLA 02/17/06 to 03/03/06

Equatorial upwelling

SEC

SECC

SEC

STCC
Results: PCA on CTD
Results: PCA on SSLs
Results: big fish targets distribution

Depth distribution of big fish acoustic targets