The influence of the environment on horizontal and vertical bigeye tuna movements investigated by analysis of archival tag records and ecosystem model outputs

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Objectives

1. Develop an individually-based model for BET movements where fish will be able to ‘swim through’ environmental data
2. in order to simulate spatial dynamics from individual to population scale

Archival tag records:
13 classic, 4 pop-up
(WPO, CSIRO-SPC, 1999-2004)

Ocean models outputs:
Physical-biogeochemical model
(ESSIC)
Ecosystem model
(SEAPODYM)

Data
- temperature (water, body)
- depth
- light
- position

Scales
- minutes
- to days
- H : 0.5 °
- V : m

investigate relationships + scale issues
build validate IBMs
Horizontal movements
On a seasonal scale: migration timing and routes in the Coral Sea

Kalman-filtered tracks of 2 tagged individuals
(cf. Sibert et al. 2003)

‘Migration route’
= area for data extraction from ocean model

Evolution of ecosystem parameters in the area (space average)
On a monthly scale: validation of ‘bigeye habitat’ in SEAPODYM (Lehodey 2004)
On a monthly scale: comparison between tag records and ocean model estimations

1. Comparison between surface temperatures:
   - recorded by a tag (boxplot)
   - extracted from the model (point = space average)

2. Correction of latitude values in order to reduce the discrepancies between tag and model values
Vertical movements

Behaviour types:

'classic' (74%)
'mixed' (24%)
'surface' (1%)
'deep dive' (1%)

cf. Schaefer & Fuller 2002
Musyl 2003

Duration:
hours to weeks

Factors:
temperature
light (sun/moon)
food
physiology
age...

Track
(Kalman-filtered)

Space-averaged
monthly parameters
extracted from
the ecosystem
model
**Vertical movements**

Common time scale between tag records and ocean model outputs = \textit{month}

Variables calculated from tag depth records:
- mean depth
- depth variance
- \% of time spent >500m
- \% of time spent <200m

\textit{mean depth during the day} during the day
\textit{mean depth during the night} during the night

representative of the proportion of 'classic' vs 'mixed' vertical behaviour
BET mean depth during the day would:
increase with temperature at 400m
decrease with migrant mesopelagic forage biomass
increase with deep mesopelagic forage biomass

Generalized Additive Model:
stepwise selection of covariates among ecosystem parameters

Model selected:
\[ \text{mean.depth.day} \sim s(t400m) + s(Fb.migr) + s(Fb.deep) \]

> summary(gam5)

Family: gaussian
Link function: identity

Formula:
\[ \text{mean.depth.day} \sim s(t400m) + s(Fbiom2) + s(Fbiom1) \]

Parametric coefficients:

| Estimate  | std. err. | t ratio | Pr(>|t|) |
|-----------|-----------|---------|----------|
| constant  | 349.02    | 4.408   | 79.18    | < 2.22e-16 |

Approximate significance of smooth terms:

<table>
<thead>
<tr>
<th>edf</th>
<th>chi.sq</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>s(t400m)</td>
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<td>0.00039621</td>
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<tr>
<td>s(Fbiom2)</td>
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<td>0.0083612</td>
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<tr>
<td>s(Fbiom1)</td>
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<td>0.016734</td>
</tr>
</tbody>
</table>

R-sq.(adj) = 0.174  Deviance explained = 20.9%
GCV score = 2133.2  Scale est. = 2020.8  n = 104
Conclusion

Critical points:
- tagging data quality + quantity
- position estimates (i.e. link between tag records and ocean models):
  improve by latitudinal temperature or other method
- gap between tag and model scales:
  reduced in a higher resolution to come
  (10 days : scale of vertical behaviour changes)
- validation of forage distribution

Perspectives:
- use this approach to build rule-based IBMs (Allain et al. 2004) /
  validate more theoretical IBMs (Kirby et al. 2003)
- examine the link between horizontal (speed) and vertical movements (behaviour)
  + identify feeding events (visceral warming)
- simulation of BET spatial dynamics from individual to population scale