Application of SEAPODYM to the Pacific Pelagic Ecosystem. Recent results and perspectives

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SEAPODYM: Spatial model driven by physical and “simplified” food-web interactions

Climate/environment variability

- Temperature
- Currents
- Oxygen
- Primary production

Interactions

- Mid-trophic levels
  = predators forage

Predators
  = Tunas, billfish ...

Interactions

Fishing impact

Fisheries
2004-05 achievements

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- Executable with documentation (cf. reference manual: ME IP 1), associated softwares and files needed to run simulation will be released on a dedicated web site
Running forage model alone:

Turn-over of forage component is based on a relationship between temperature and age of maturity of organisms (Q10’s rule)

-> this can be considered as a dynamic equilibrium state of the system

-> and then provides a limit of the carrying capacity of the ecosystem mid-trophic levels for top predators species
Results: mid-trophic levels

Epi-pelagic layer
(0-100m)

Meso-pelagic layer
(100-400m)

Bathy-pelagic layer
(400-1000m)

Simulation outputs: Forage. 1948-2004, 10 days, 0.5 deg²
Results: prey-predator coupling

➢ it is possible to have from zero to N predators species explicitly described in the model.

Over the “specific predator area”, the mean forage mortality (for a given component) is the sum of the mortalities due to the predator species described in the model + a residual mortality $\lambda'$ due to all other predators.

Locally, in each cell, the forage mortality due to food requirements of described predators, $\omega_{ij}$ is calculated according to physical accessibility of the predator species (age) to the forage component considered and to their daily ration (% of body mass).

If sum of $\omega_{sp}$ above $\bar{\lambda}$ -> ERROR:
biomass of predators cannot be sustained by the forage component

Outside specific predator area,
forage $m = \lambda(\text{temperature})$

Inside specific predator area
forage $m = \omega_{ij} + \lambda'$
Application to skipjack, yellowfin and bigeye tuna
Table 2. Parameterisation of the populations structure in SEAPODYM

<table>
<thead>
<tr>
<th></th>
<th>skipjack</th>
<th>yellowfin</th>
<th>Bigeye</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of age classes (quarter) after juvenile phase</td>
<td>16</td>
<td>28</td>
<td>40</td>
</tr>
<tr>
<td>Age at first maturity (quarter)</td>
<td>4</td>
<td>7</td>
<td>11</td>
</tr>
<tr>
<td>Age (quarter) at recruitment</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

Length-at-age and weight-at-age coefficients estimated from MFCL analyses (crosses) and functions (curves) used to define the coefficient used in SEAPODYM simulations
<table>
<thead>
<tr>
<th>Category code</th>
<th>Description / source / resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PURSE SEINE</strong></td>
<td></td>
</tr>
<tr>
<td>WPSASS</td>
<td>Aggregated data of purse seine fisheries in the WCPO Sets associated to animals, log or FAD</td>
</tr>
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<td>Aggregated data of purse seine fisheries in the WCPO Unassociated sets (i.e. free schools)</td>
</tr>
<tr>
<td>EPSASS</td>
<td>Aggregated data of purse seine fisheries in the EPO Sets associated to animals, log or FAD</td>
</tr>
<tr>
<td>EPSUNA</td>
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</tr>
<tr>
<td><strong>POLE-AND-LINE</strong></td>
<td></td>
</tr>
<tr>
<td>PLTRO</td>
<td>Aggregated data of tropical (25°N-25°S) pole-and-line fisheries data</td>
</tr>
<tr>
<td>PLSUB</td>
<td>Aggregated data of sub-tropical pole-and-line fisheries (mostly Japanese domestic fleets)</td>
</tr>
<tr>
<td><strong>LONGLINE</strong></td>
<td></td>
</tr>
<tr>
<td>LLP80</td>
<td>Aggregated data of longline fisheries before 1980 (The pre-1980/post-1980 categories was to (very roughly) define the change from targeting yellowfin to targeting bigeye)</td>
</tr>
<tr>
<td>LLSHW</td>
<td>Aggregated data of longline shallow after 1980 (mainly TW and mainland Chinese LL offshore fleets)</td>
</tr>
<tr>
<td>LLDEEP</td>
<td>Aggregated data of deep longline fisheries after 1980</td>
</tr>
<tr>
<td>LLMIX</td>
<td>Aggregated data of “mixed” longline fisheries after 1980</td>
</tr>
<tr>
<td><strong>DIVERSE</strong></td>
<td></td>
</tr>
<tr>
<td>RINGNET</td>
<td>Aggregated data of ringnet fisheries (mainly Philippines, Indonesia)</td>
</tr>
<tr>
<td>ARTSURF</td>
<td>Aggregated data of artisanal surface fisheries (including ringnet, mainly Philippines, Indonesia)</td>
</tr>
<tr>
<td>COMMHL</td>
<td>Aggregated data of commercial handline fisheries (Philippines, Indonesia, PNG, US)</td>
</tr>
<tr>
<td>GILLNET</td>
<td>Aggregated data of gillnet fisheries</td>
</tr>
<tr>
<td>TROLL</td>
<td>Aggregated data of troll fisheries</td>
</tr>
</tbody>
</table>
Spawning Habitat

\[
H_s = R_s \cdot I_{\theta_s} \cdot e^{\alpha \cdot \log \left[ 1 + \frac{P}{F_i} \right]}
\]

Average predicted distribution of skipjack larvae-juvenile (age-2-3 months) for 1950-75

Distribution of skipjack larvae (Nishikawa et al, 1985)
Predicted biomass of juvenile (age 2-3 mo) yellowfin

(Nishikawa et al.)

Predicted biomass of juvenile (age 2-3mo) Bigeye
Average predicted distribution of juvenile (age 2-3 months) biomass during decadal period 1950-75 and 1976-98
Average predicted distribution of total biomass during decadal period 1950-75 and 1976-98
Skipjack anomaly (1976-98) – (1950-75)

Yellowfin anomaly (1976-98) – (1950-75)

Bigeye anomaly (1976-98) – (1950-75)
Average forage consumption by species (all age classes) based on accessibility to forage components
Running single vs multi-species simulations with SEAPODYM: What are the effect of interaction between top predator species like tuna?

- Change in abundance of predators
- Change in natural mortality (if ε > 0)
- Change in Spatial distribution
- Change in Spawning Habitat (P/F)
- Change in Feeding Habitat
- Change in forage mortality
Some more results on bigeye...
Selectivity

bigeye
Predicted and observed CPUE

- CPUE PLSUB Obs BET
- CPUE PLSUB Pred BET
- CPUE WPSASS Obs BET
- CPUE WPSASS Pred BET
- CPUE WPSUNA Obs BET
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**BET**

**Observed total catch (t)**

Blue = LL
Orange = Others (surf. Gears)

High level of catch by surface gears in 1994-97 not predicted
BET - WCPO

Adult total biomass

SEAPODYM (3-species simulation) estimates with (red) and without (blue) fishing

Black curve: MULTIFAN-CL estimate (with fishing)
Conclusions

• In absence of an optimization function, a reasonable parameterization for 3 species (skj, yft and bet) and their fisheries was obtained.

• The model capture important changes in the population dynamics that explain a large part of time space variability in the catch and CPUE.

• Multi-species simulations make big differences and produce better results.

• Decline in bigeye stock in the late 1950’s and during 1960’s is reproduced by the model and predicted to be largely due to natural variability AND species interactions.

• You can do it yourself: www.seapodym.org
Perspectives

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- Test management scenarios.
- Export the model to other Ocean: GLOBEC CLIOTOP Modelling working group.
- Test first simulation with climate change scenario (1860-2100).

-> Exploratory analysis to identify main mechanisms that need more studies (for WG 1 2 3 in CLIOTOP).