Tuna and tuna forage: reconciling modeling and observation in a spatial mixed-resolution ecosystem model

Patrick Lehodey
Oceanic Fisheries Programme
Secretariat of the Pacific Community
Noumea, New Caledonia
Conclusion

• Existing data on tuna and the pelagic ecosystem are numerous but at multiple temporal and spatial scales

• Using them to parameterize and evaluate an ecosystem model requires to develop a model that produces predictions at these same multiple temporal and spatial scales
Top-to-bottom integrated food web in marine ecosystem

Level of information (observation and knowledge) available for the pelagic ecosystem

marine ecosystem information

Top Pred.
- Catch and effort, length freq., large scale tagging exp, individual trackings, biology, physiology, stat. pop. Dyn. Mod.

Interm. TL.
- Catch cruises, biology
- cruises, OPC, mesocosm...
- physiology, dynamics...

Zoopk.
- Satellites, cruises, moorings...
- photosynthesis, physiology, dynamics...

Prod I
- Satellites, scientific cruises and ship of opportunity network, arrays of moorings...
- physical laws (Navier-Stoke, …)

Phys.

Evaluation

marine ecosystem model(s)

Basin scale spatial pop. dyn. mod.

Functional group (s)
- NPZD
- 3D NPZD
- 3D GCM

same level of details

Obs. ↔ Pred.
Pelagic ecosystem

Figure 1. A top to bottom schematic view of the pelagic food web. Most of the organisms in the meso- and deep-pelagic layers have nycthemeral migration patterns leading to higher concentration in the upper layer at night and in the deeper layer during the day.
Vertical structure of the pelagic food web

Figure 2. The different daily vertical distribution patterns of the micronekton in the tropical pelagic ecosystem. 1, epipelagic; 2, mesopelagic migrant; 3, mesopelagic non-migrant; 4, bathy-pelagic migrant; 5, bathypelagic non-migrant. Group 4 can be detailed into bathypelagic migrant into the intermediate layer (4a) or the surface layer (4b).

Figure 3. Five typical vertical movement behaviours simulated using a 3-layer and 2-type of prey pelagic system (adapted from Dagorn et al. 2000):

1- epipelagic predators (e.g., skipjack, marlins and sailfish);
2- predators moving between the surface and intermediate layers during the day (e.g., yellowfin tuna);
3- predators mainly in the intermediate layer during the day (e.g., albacore tuna);
4- predators moving between deep and intermediate layer during the day (e.g., blue shark);
5- predators mainly in the deep layer during the day (e.g., bigeye tuna and swordfish).
Modelling forage components:

3-layer 6-forage functional groups

Day Length (DL) as a function of latitude and date

Total primary production

T°C & currents in the 0-200m layer

T°C & currents in the 200-500m layer

T°C & currents in the 500-1000m layer

day

sunset, sunrise

night
Forage functional groups: modelling forage as multi-species populations

2-layer, 3-component forage

Epipelagic forage
Migrant mesopelagic forage
Deep mesopelagic forage

Top: La Niña
Bottom: El Niño
Spatial forage biomass

Day: 0-200m

Night: 0-200m

Day concentrations (ml / 1000 m³) of “skipjack forage” measured during the EASTROPAC cruise (left) and biomass of epi-pelagic forage predicted by the model for the same period (February-March 1967). (Blackburn and Laurs, 1972)
Spatial forage biomass

- Acoustic data

(A. Bertrand, E. Josse)
Biomass time series

Predicted biomass of forage components in eastern and western equatorial regions.
# Structure of the tuna population

<table>
<thead>
<tr>
<th>Time / age structure</th>
<th>Spawning</th>
<th>Larvae</th>
<th>Juvenile</th>
<th>Young</th>
<th>Adult</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>t0</td>
<td>1&lt;sup&gt;st&lt;/sup&gt; month</td>
<td>2&lt;sup&gt;nd&lt;/sup&gt; and 3&lt;sup&gt;rd&lt;/sup&gt; month</td>
<td>2&lt;sup&gt;nd&lt;/sup&gt; quarter to age of 1&lt;sup&gt;st&lt;/sup&gt; maturity</td>
<td>1&lt;sup&gt;st&lt;/sup&gt; maturity to last quarter</td>
</tr>
<tr>
<td>Size</td>
<td>2 mm</td>
<td>2 mm -5 cm</td>
<td>5-15 cm</td>
<td>15 - &gt; 40 cm</td>
<td>&gt; 40 cm</td>
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</tbody>
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1- Habitat based movement

2- Proportional to fish size

3- Decreasing with increasing habitat

4- Impact of currents?

<table>
<thead>
<tr>
<th>Transport / movement (advection-diffusion)</th>
<th>Spawning</th>
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<th>Juvenile</th>
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<th>Adult</th>
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Currents in upper layer

<table>
<thead>
<tr>
<th>Habitat factors</th>
<th>Spawning</th>
<th>Larvae</th>
<th>Juvenile</th>
<th>Young</th>
<th>Adult</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T°, Food (P), Predators (F)</td>
<td>T°, Food (Zpk), Predators (all largest tuna)</td>
<td>T°, Oxygen, Food (F), Predators (all adult tuna)</td>
<td>T°, Oxygen, Food (F), spawning seasonality</td>
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<th>Natural mortality</th>
<th>Independent estimates + habitat-related variability</th>
</tr>
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</table>

| Growth | Independent estimates (+ habitat-related variability) |
Spawning Habitat: (Temperature, Food, Predators, currents)

distribution of skipjack larvae

Jun 1971
Fisheries: Pred. vs Obs.

Spatially-disaggregated monthly catch

Length-frequency distribution (by fishery, time and space)
Accessibility to forage components

By species, age, space and time

- Build up a database to classify all tuna prey species according to these 6 groups
Adult Habitat: (temperature, food, spawning seasonality)

Bigeye tuna (FL = 80 cm) habitat Jun 1999
Observed individual movements and predicted habitat

Predicted movement (arrows) of bigeye tuna (FL ~ 80 cm) based on the gradient of habitat (background colour) combining forage, temperature and oxygen, and estimated track of a bigeye released with an archival tag during the same period.

Nov 1999
Mixed resolution (PFRP project)
Mixed resolution (PFRP project)

Physical-biogeochemical outputs:
ESSIC (R. Murtugudde, Univ. Maryland)
  - 1950-present
  - ½ deg spatial resolution
  - 10 day time resolution

Forage and tuna:
SEAPODYM
  - 6 forage components (production and biomass)
  - Tuna species (Larvae, juveniles, young, adults, total biomass)
  - Tuna fisheries (many)
Visualization software: SeapodymView:

- Replay the simulations
- Extract/aggregate data

- Can be distributed with files of predicted variables to colleagues interested to compare their results/observations to these predictions