APECOSM *(Apex Predators ECOSystem Model)*

*Quick overview and application to scenarios development*

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Global changes are pushing oceans’ ecosystems toward unknown states with no-analogues in the past.

This creates an urgent need for

- Anticipating future threats and opportunities.
- Elaborating mitigation and adaptation strategies,
- Factoring long-term issues into present day governance.

We lack a robust theory that would keep valid beyond observed states with minimal stationarity assumptions.

APECOSM seeks for a mechanistic theory based on first principles to formalize ecosystem dynamics

- Understand, interpret and generalize observations,
- Guide and stimulate empirical studies,
- Provide sound basis to applications: conservation, resource management, scenarios & projections.

Conceive and think the complexity of ecosystems’ dynamics and evolution
Formulate individual dynamics from invariant properties,
- Predation, metabolism (DEB) (Maury et al., 2007; Maury et Poggiale, 2013)
- Behaviour: 3D movements (Faugeras et Maury, 2007)
- Effects of schools dynamics (Maury, 2017)

Upscale the individual model to population level
- Population dynamics based on individual processes (Maury, 2010)
- Eulerian state equation
- Individual flux through a 7D state-space

Upscale the population model to the community level
- Considers the functional importance of species’ size and individuals’ size (Maury et al., in press)
Formulate individual dynamics from invariant properties,

- Predation, metabolism (DEB) \((\text{Maury et al., 2007; Maury et Poggiale, 2013})\)
- Behaviour: 3D movements \((\text{Faugeras et Maury, 2007})\)
- Effects of schools dynamics \((\text{Maury, 2017})\)

Upscale the individual model to population level

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- Individual flux through a 7D state-space

Upscale the population model to the community level

- Considers the functional importance of species’ size and individuals’ size \((\text{Maury et al., in press})\)
- Trait-based approach \((\text{Maury et Poggiale, 2013})\)
- Eulerian 4D state equation \((\text{Guiet, 2016})\)

Consistency between organization levels

Inter-dependence of the state equations at each level of organization

Individuals, populations & communities share the same parameters
APECOSM, an E2E model of marine ecosystems

- Mechanistic model articulating individual, population and community levels

- APECOSM represents 3 pelagic communities (x, y, z, l, Lm)
Mechanistic model articulating individual, population and community levels

APECOSM represents 3 pelagic communities (x, y, z, l, Lm)

For studying processes

For projections and scenarios

Guiet et al., 2016

Lefort et al., 2015
APECOSM simulates marine ecosystems

- Articulates species and communities

- Global horizontal grid ORCA2 (x=180 y=148 z=46)
- Size V=100 size classes [1mm, 2m]
- 3 generic communities
  => 6,6.10^8 grid points; 2 time steps / day
Communities in APECOSM: 5D numerical grid

Epipelagic 4mm

Epipelagic 25cm

Size $V^{1/3}$

Depth $z$
APECOSM is coupled to the IPSL Earth System Model
Projections:

Climate change impacts on global marine ecosystems (Lefort et al., 2015)

Projected global averaged change from 1860 to 2100

Size integrated anomalies of biomass (1mm to 2m) (2096-2105)-(2006-2015)
Process studies

Temperature and primary production effects on marine communities (Guiet et al., 2016)
Climate impacts on tunas (Dueri et al., 2014)

Exploitable biomass - no fishing

Total biomass - no fishing

Biomass Indian Ocean (equatorial transect)
Feedbacks from ecosystems to biogeochemistry, carbon cycle and climate
APECOSM can be coupled 2-ways to NEMO-PISCES

- **Biomass (log)**
  - **PISCES**
    - Nano-phytoplankton: 1-10 \( \mu m \)
    - Diatoms: 10-100 \( \mu m \)
    - Micro-zooplankton: 20-200 \( \mu m \)
    - Meso-zooplankton: 200-2000 \( \mu m \)
    - SPOM-I POM: 100-5000 \( \mu m \)

- **NEMO**
  - "u, v, d, T"

- **APECOSM**
  - "O\(_2\), PAR"
  - "Predation"
  - "Epipelagic migratory mesopelagic"

- **Gases**
  - NH\(_4^+\)
  - NO\(_3^-\)

- **DOM**
  - "Excretion"
  - "Egestion"

- **Mortality**
Feedback of ecosystems to the carbon cycle in the IPSL-CM5 earth system model

Active export / POC at 150m (annual mean)

Global Budget in GtC/yr (150m)

<table>
<thead>
<tr>
<th></th>
<th>Flux (GtC/yr)</th>
<th>Contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>POC flux</td>
<td>5.1</td>
<td>68%</td>
</tr>
<tr>
<td>DOC flux</td>
<td>1.1</td>
<td>15%</td>
</tr>
<tr>
<td>Active flux</td>
<td>1.3</td>
<td>17% (20%)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>7.5</strong></td>
<td><strong>100%</strong></td>
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Aumont et al., in review
Integration from climate to fishing
Governance strategies (APECOSM-E; RCP8.5 / SSP3)

Dueri et al., 2016

2010

- Catches maximisation
- Profit maximisation
- No regulation

2095

- Catches maximisation
- Profit maximisation
- No regulation

Conservation

Skipjack price

Food security

Employment

Profit of companies

Rent

Profit / vessel

No regulation

Rent

Profit of companies

Food security

Employment

Skipjack price

Conservation

No regulation

Rent

Profit of companies

Food security

Employment

Skipjack price

Conservation

Profit of companies

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Rent
Conclusion

APECOSM: a tentative to progress a mechanistic theory of marine ecosystems,
- Articulates individual, population and community levels,
- Represents socio-ecosystems through coupling with physics, biogeochemistry and bio-economy

APECOSM contributed to FISHMIP phase 1
- Couldn’t run with GFDL forcing that was provided 2D
- Had tremendous problems with IPSL-CM forcing’s due to problems with the regridded files provided
  ➞ Recommend using native grids for forcing files

FishMIP phase 2 has a great potential but great challenges ahead
- Extend OSPs (SSPs) to represent global fisheries including quantitative effort pathways
- Develop a set of contrasted global marine ecosystems & fisheries scenarios by combining compatible RCPs and OSPs
- Undertake an actual comparison of models
- Synoptic observations are critically lacking for calibrating, assessing & improving the models
  ➞ Promote global acoustic data collection and compilation
Building scenarios for global marine socio-ecosystems

From «Shared Socio-economic Pathways (SSPs)» to «Oceanic System Pathways»

Maury et al., 2017

Faire de la construction de scénarios une démarche participative impliquant les acteurs

- CLIOTOP, RFMOs, NGOs, industrie, FAO, ...
- Réintégrer le long terme à la gestion,
- Elaborer des stratégies de gouvernance vers la durabilité
- Evaluer les alternatives et les options