Marine Plankton Community Modeling
Scott Doney
Woods Hole Oceanographic Institution
NCAR ASP Colloquium 2013

Supported by:
Size Matters

![Diagram showing size matters in materials and methods.](Diagram)

- **Materials**
  - POC: Zooplankton, Phytoplankton, Bacteria, Viruses, Macromolecules
  - DOC: Colloidal, Truly dissolved

- **Methods**
  - Flow cytometers
  - Sieves and filters
  - Ultrafilters

- **Size (m)**
  - mm
  - μm
  - nm

- **Molecular mass**
  - $10^{-2}$ to $10^{1}$
## Model Elements Depend on Science Questions

<table>
<thead>
<tr>
<th>Carbon Cycle &amp; Biogeochemistry</th>
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</thead>
<tbody>
<tr>
<td>Ecology &amp; Food-webs</td>
</tr>
<tr>
<td>• Phytoplankton, zooplankton, bacteria, ...</td>
</tr>
<tr>
<td>• Biological interactions (growth, predation, competition, disease, vertical migration, ...)</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Biodiversity</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Variability within populations</td>
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<tr>
<td>• Species diversity</td>
</tr>
<tr>
<td>• Community ecology</td>
</tr>
</tbody>
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<table>
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<th>Fisheries &amp; Conservation</th>
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<tr>
<td>• Higher trophic levels</td>
</tr>
<tr>
<td>• Demography, size &amp; age-structure, ...</td>
</tr>
<tr>
<td>• Swimming, behavior (individual-based models)</td>
</tr>
</tbody>
</table>
-Aggregate into trophic levels/functional groups/size classes

Size-class & Functional Group Variations

Model PFTs blend size & geochemistry (e.g. formation of CaCO3, opal, nitrogen fixation)

LeQuere et al. Global Change Biology 2005
Factors Governing Phytoplankton Competition

Differential growth, nutrient & light limitation, grazing and mortality among PFTs

LeQuere et al. Global Change Biology 2005
A) Diatom Growth Limitation 1990s

Nutrient Limitation

Moore et al.
J. Climate
In press
Diatom Fraction in Blooms

Hashioka et al.
Biogeosciences submitted
Diatom Fraction vs. Bloom Magnitude

Hashioka et al.
Biogeosciences
submitted
Phytoplankton Growth: Diatom/small Ratio

\[ \ln\left( \frac{\mu_{\text{diatom}}}{\mu_{\text{small}}} \right) \]

(a) PISCES

(b) NEMURO

(c) PlankTOM5

(d) CCSM-BEC

+diatom/small

-diatom/small
### Summary of Model Factors: Diatom/small Ratio

<table>
<thead>
<tr>
<th></th>
<th>PISCES</th>
<th>NEMURO</th>
<th>PlankTOM5</th>
<th>CCSM-BEC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bottom-up</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_{\text{max}}$</td>
<td>$-$</td>
<td>$\text{UP}$</td>
<td>$\text{UP}$</td>
<td>$-$</td>
</tr>
<tr>
<td>Nutrient limit.</td>
<td>$\text{Down}$</td>
<td>$\text{Down}$</td>
<td>$\text{Down}$</td>
<td>$\text{Down}$ (NA)</td>
</tr>
<tr>
<td>Light limit.</td>
<td>$-$</td>
<td>$-$</td>
<td>$\text{Down}$</td>
<td>$\text{UP}$ (NA, SO)</td>
</tr>
<tr>
<td>Temp. dep.</td>
<td>$-$</td>
<td>$-$</td>
<td>$-$</td>
<td>$-$</td>
</tr>
<tr>
<td>Top-down</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grazing by</td>
<td>$\text{UP}$</td>
<td>$\text{UP}$</td>
<td>$\text{UP}$</td>
<td>$\text{UP}$</td>
</tr>
<tr>
<td>Zooplankton</td>
<td>$\text{Down}$</td>
<td>$\text{Meso/Macro}$</td>
<td>$\text{Mesozoo}$</td>
<td>$\text{Up}$ (NP)</td>
</tr>
</tbody>
</table>

**+diatom/small**

**-diatom/small**

Hashioka et al. Biogeosciences submitted
Plankton Niches

Dominant Phytoplankton Group

Voigt et al.
Biogeosciences
In prep.
# Model Food-webs & Interaction Strengths

<table>
<thead>
<tr>
<th>CCSM</th>
<th>PISCES</th>
<th>NEMURO</th>
<th>PlankTOM5</th>
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</table>

**Intended Food-webs (heavy lines strong interactions)**

**Obtained Food-webs**

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Sailley et al.
Ecological Modelling
2013
MAREDAT - Towards a world atlas of MARine ecosystem DATa

(a) Global

- Macrozooplankton: 9.3 (0.2) ± 67.7
- Mesozooplankton: 6.0 (2.8) ± 13.6
- Microzooplankton: 9.3 (3.1) ± 17.1
- Diatoms: 16.5 (1.7) ± 104.7
- Coccolithophores: 0.4 (0.05) ± 2.4
- Picophyto plankton: 12.7 (5.5) ± 22.1
- Pteropods: 2.9 (0.005) ± 67.7
- Foraminifers: 0.03 (0.008) ± 0.05
- Pico heterotrophs: 8.1 (6.6) ± 6.0
- Phaeocystis: 28.3 (2.2) ± 96.0
- Diazotrophs: 5.5 (0.03) ± 27.4

Buitenhuis et al.
Earth System Science Data 2013
Total Diazotrophs Nitrogen Fixation = 129.69 Tg N y\(^{-1}\)

Everything is Everywhere but Environment Selects

Bruggeman & Kooijman
Limnol. Ocean. 2007
Follows et al.
Science 2007
Biodiversity & Biogeography

Barton et al. Science 2010
Trait-based Modeling & Energetic Trade-offs

Litchman et al.
Ecol. Lett. 2007
Litchman & Klausmeier
Cell Physiology/Allocation Modeling

Monod Uptake

Droop Quota

Biochemical Components

Shuter J. Theor. Biol. 1979
Klausmeier et al. Nature 2004
Discrete versus Continuous Size Classes

Discrete Classes

Continuous Spectral Representation

Armstrong Deep-Sea Res. II 2003