

**What is needed is an integrated modeling framework that can:**

- 1. synthesize this information for multiple species and processes;**
- 2. do so in a spatially explicit way;**
- 3. analyze potential community and ecosystem responses;**
- 4. identify key processes that govern ecosystem condition**

# A spatially-explicit ecosystem model to examine the effects of fisheries management alternatives in the California Current

Chris J. Harvey, Isaac C. Kaplan, Emily J. Brand,  
M. Elizabeth Clarke, and Phillip S. Levin

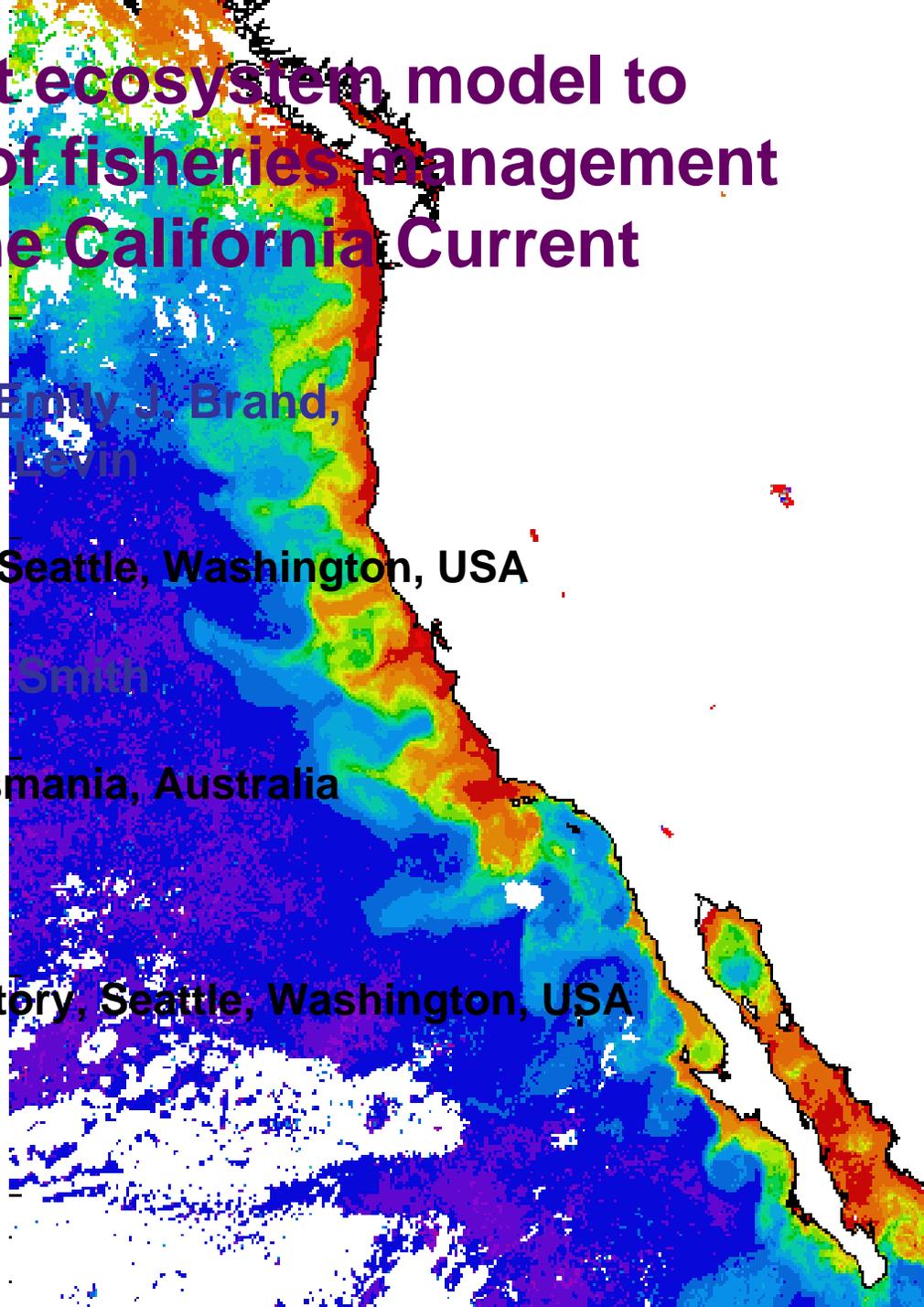
Northwest Fisheries Science Center, Seattle, Washington, USA

Elizabeth A. Fulton, Anthony D.M. Smith

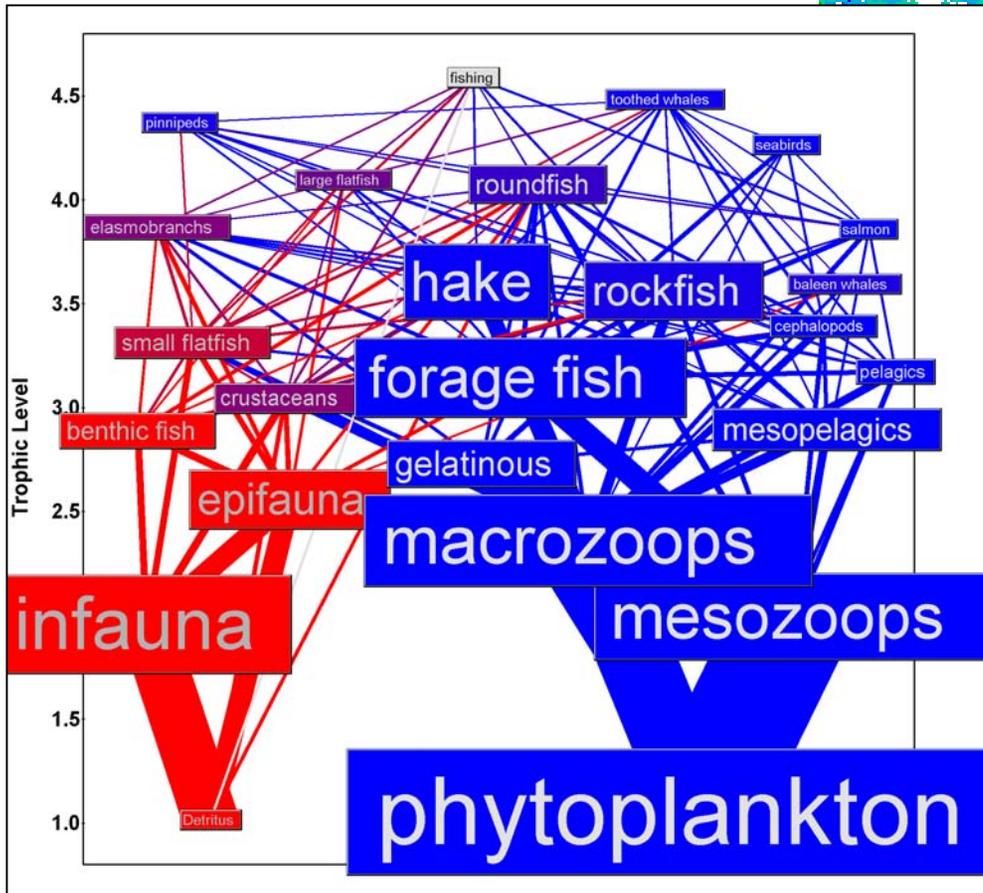
CSIRO–Marine Research, Hobart, Tasmania, Australia

Albert J. Hermann

Pacific Marine Environmental Laboratory, Seattle, Washington, USA



# Previous modeling work by Field—Ecopath/Ecosim



Conceptual food web of the California Current ecosystem. Blue = supported by pelagic production. Red = supported by benthic production. (Field, 2004)

## What's next:

Three-dimensional spatial heterogeneity

Detailed age structure

Oceanography, climate, and biogeochemistry

Habitat

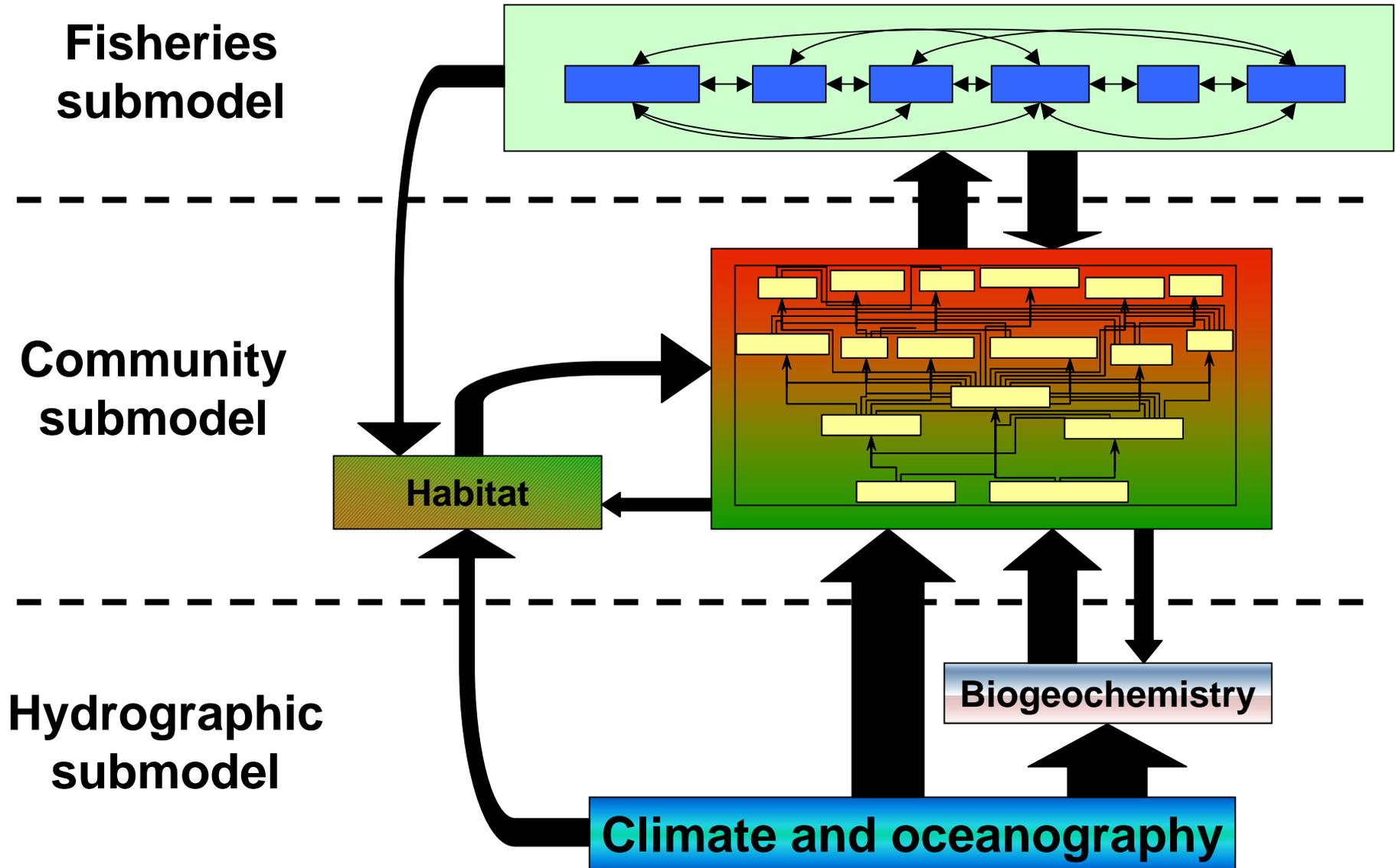
Migration and behavior

Fleet dynamics and management decisions based on decision rules

# **Atlantis** (Fulton et al. 2004, Ecol. Model. 173:371-406)

- **Biological and physical dynamics**
  - main processes and groups thought important in temperate marine ecosystems
- **Human impacts**
  - fishing
  - other (e.g., eutrophication)
- **Fleet dynamics and management**
  - multiple fleets
  - management activities
- **Monitoring and assessment**
  - data from surveys and fisheries records (with error)
  - common assessment models and index estimation
- **Plus other options, depending on needs and preferences**

# Atlantis (Fulton et al. 2004, Ecol. Model. 173:371-406)



# Atlantis model of the California Current Ecosystem

62 polygons

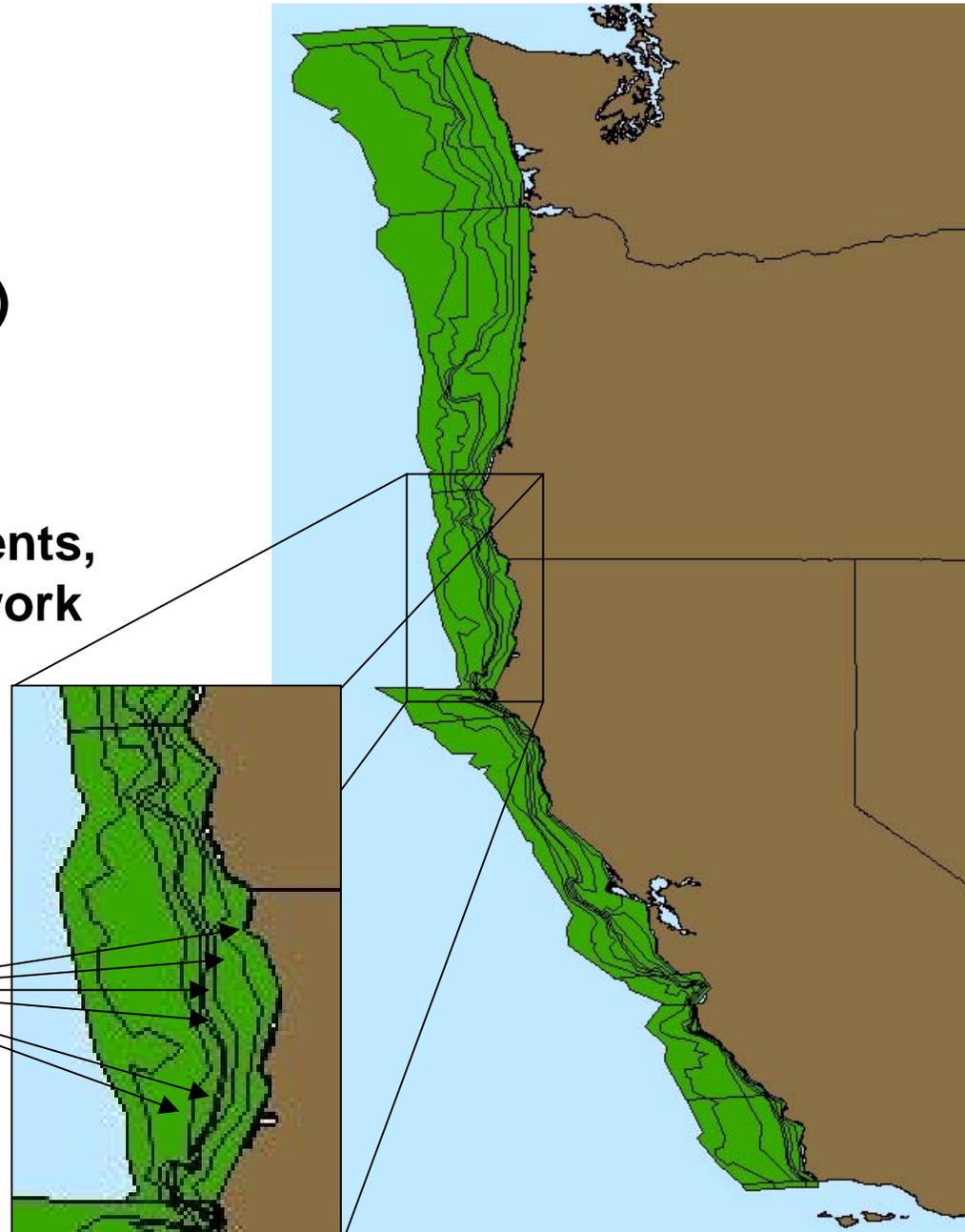
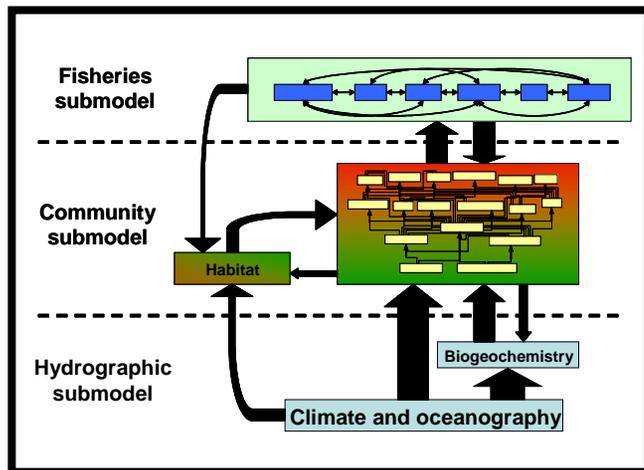
≤ 8 vertical layers per polygon

Oceanographic forcing (10x10 km)

61 functional groups

29 fishing “fleets”

Draws from monitoring, assessments,  
life history studies, John Field’s work



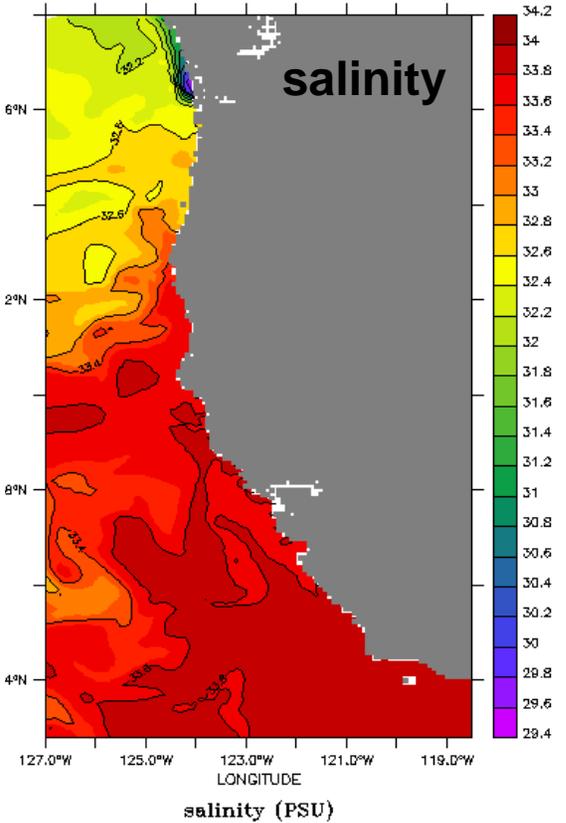
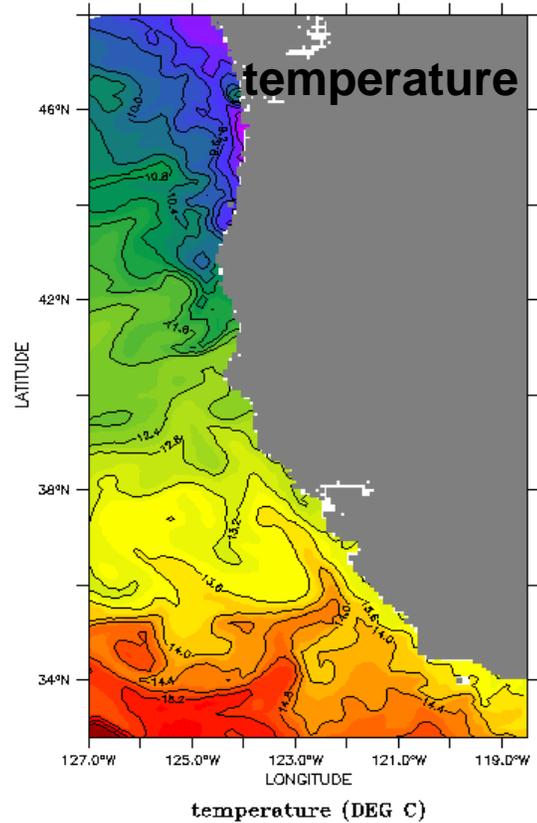
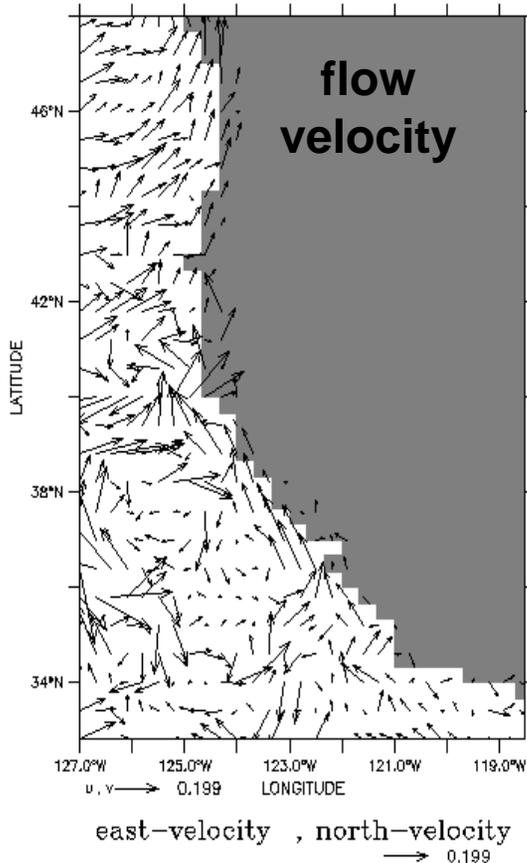
# Oceanographic forcing: 10-km grid, 12-hr time step (ROMS model projections—A. Hermann et al.)



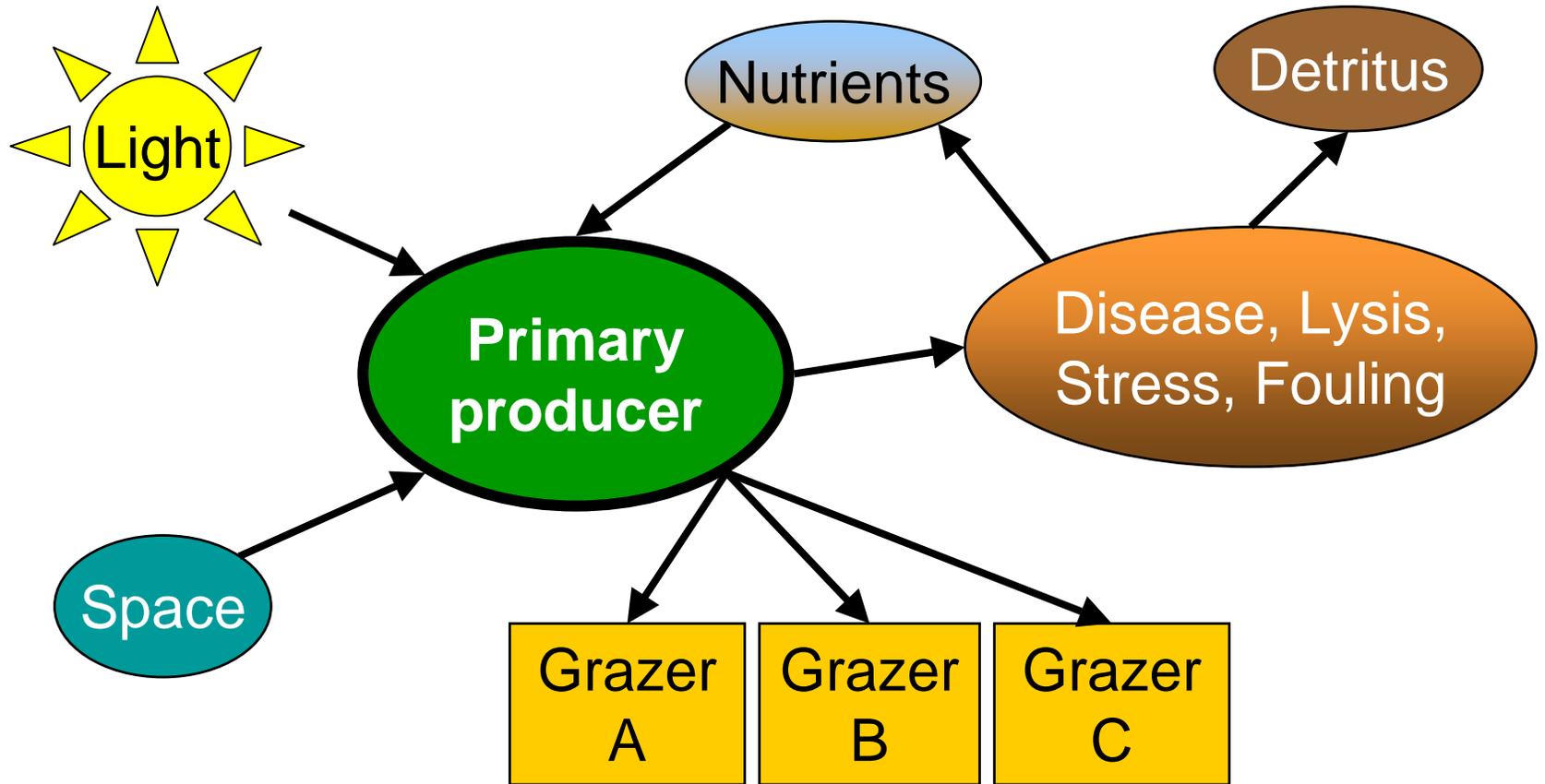
LAS 6.4.0/Ferret 5.81 -- NOAA/PMEL  
DEPTH (m) : 10  
TIME : 03-JAN-2002 12:00  
DATA SET: nep\_c

LAS 6.4.0/Ferret 5.81 -- NOAA/PMEL  
DEPTH (m) : 10  
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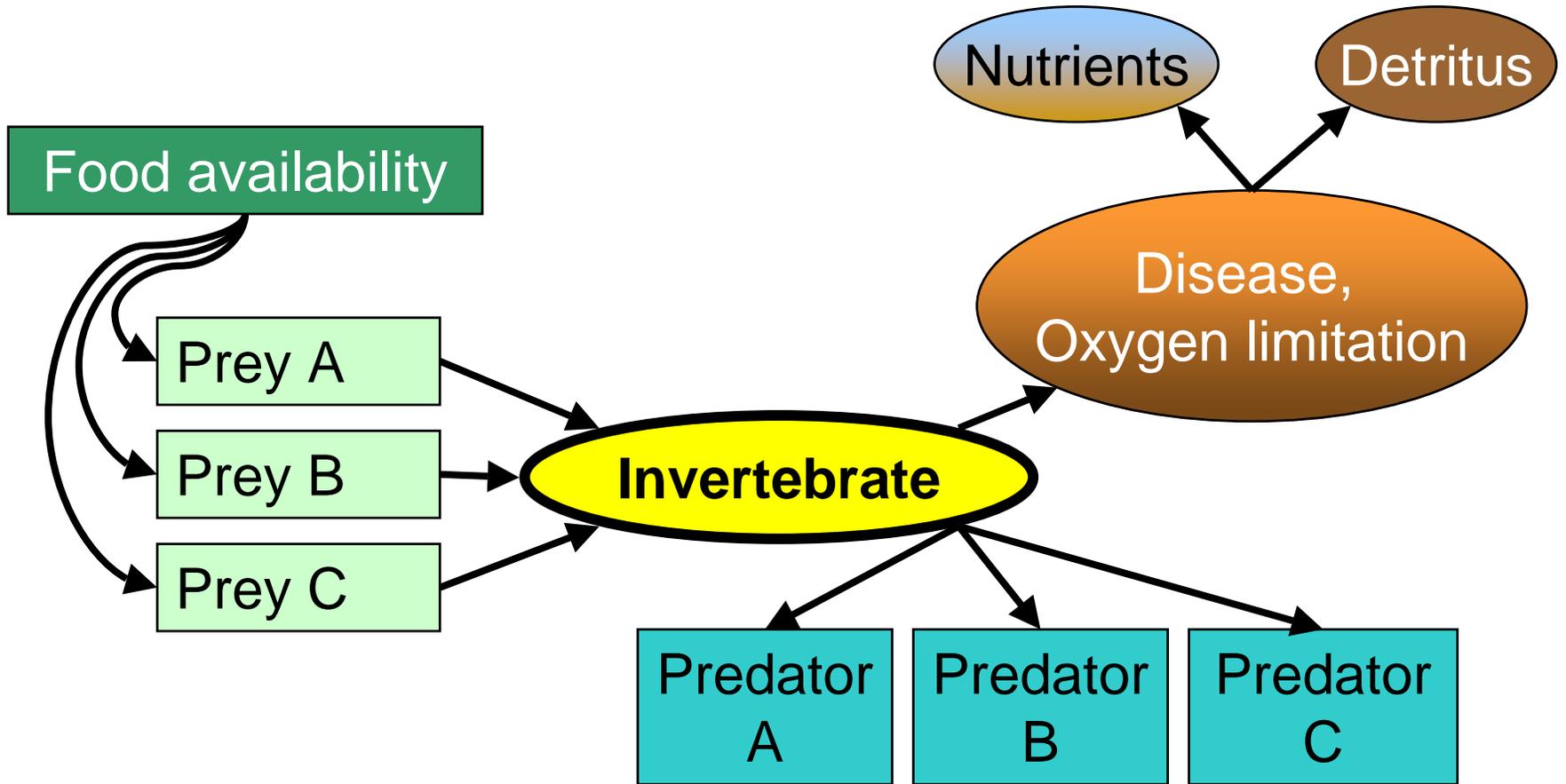


# Primary producers



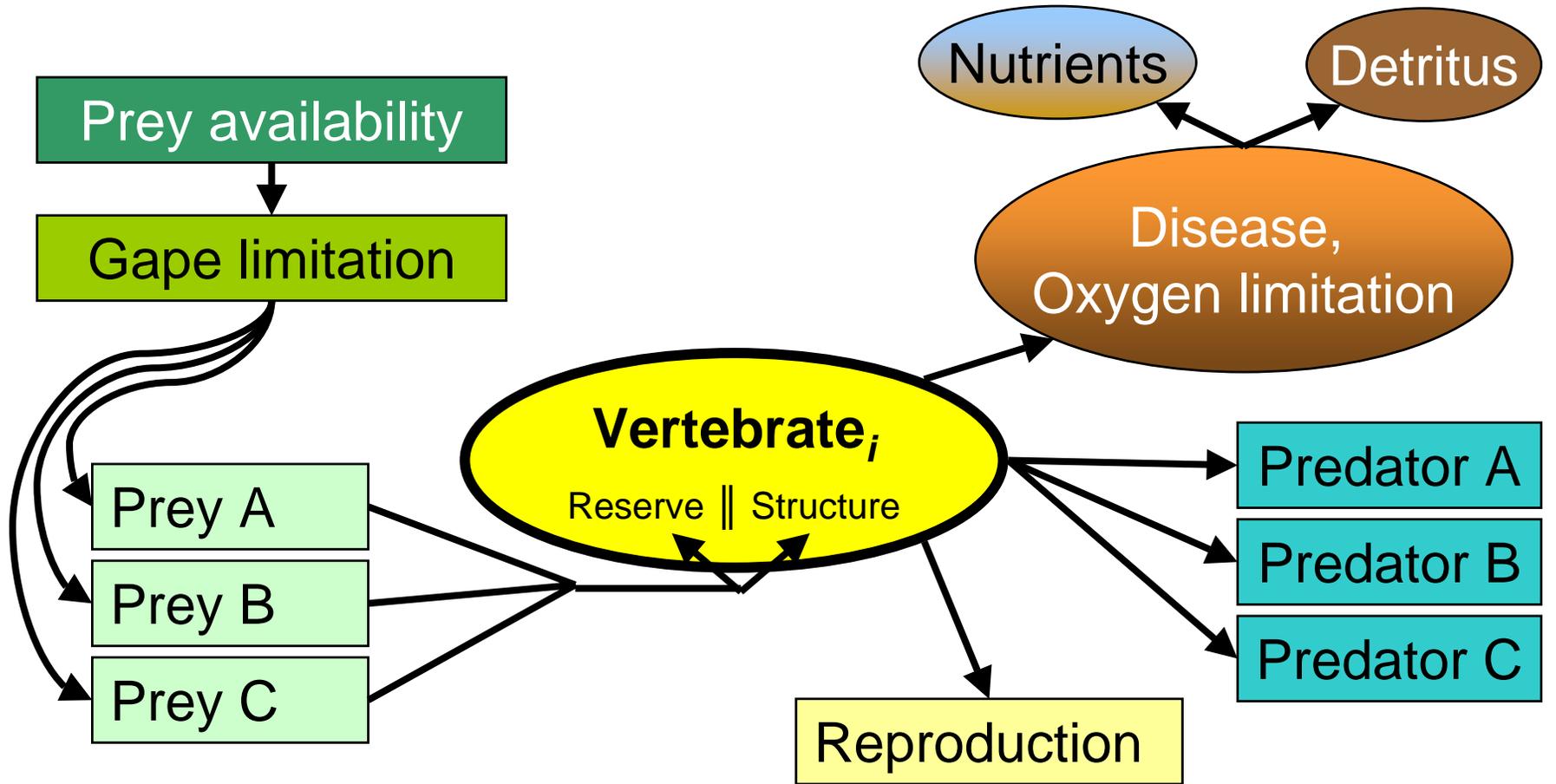
$$\frac{dP}{dt} = \mu \cdot P \cdot \delta_{light} \cdot \delta_{nut} \cdot \delta_{space} - M_{lysis} - M_{linear} - \sum_{grazers} M_{grazing}$$

# Invertebrate consumers



$$\frac{dB}{dt} = \sum_{prey} B \cdot A_{prey} \cdot \epsilon_{assim} \cdot \delta_{oxygen} \cdot \delta_{space} - M_{linear} - M_{other} - \sum_{preds} M_{pred}$$

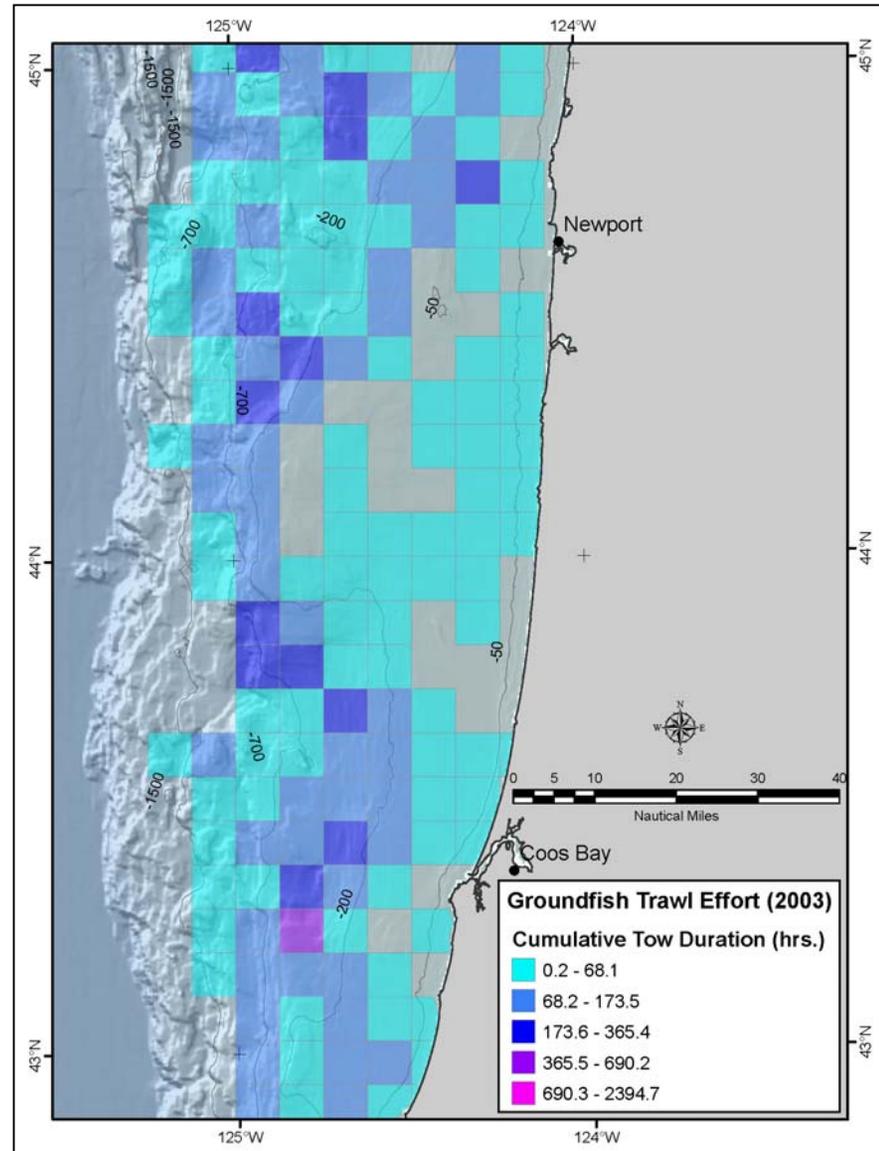
# Vertebrate consumers (age-structured)



$$\frac{dB_V}{dt} = \sum_{prey} B_{i_V} \cdot A_{i_{prey}} \cdot \epsilon_{assim} \cdot \delta_{oxygen} \cdot \delta_{space} - M_{i_{linear}} - M_{i_{other}} - \sum_{preds} M_{i_{pred}}$$

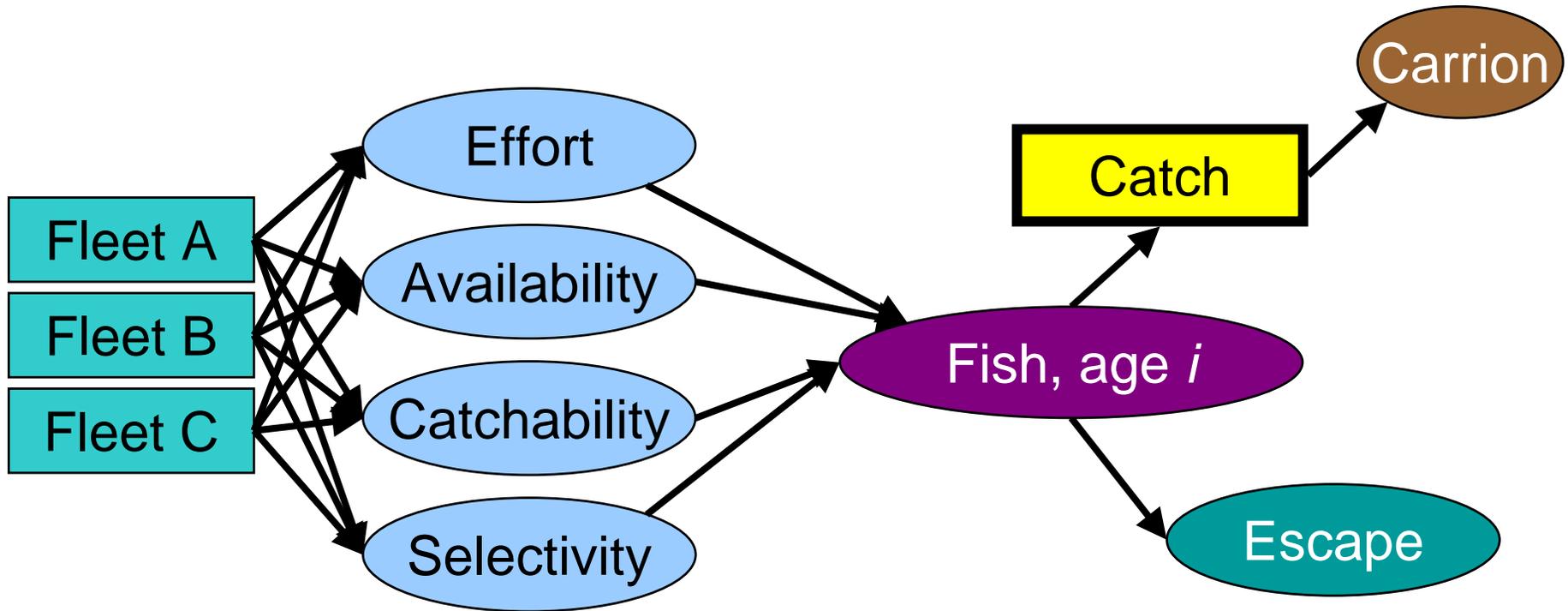
# Fisheries submodel

- estimates spatial allocation of impact by gear type
- based partly on port locations, effort maps
- the model can deal with issues relating to:
  - MPAs
  - gear selectivity
  - discarding practices
  - effort management
  - bycatch, distributed to account for habitat patchiness



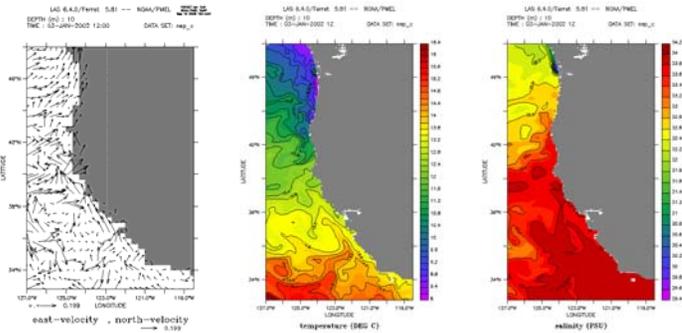
**Groundfish trawling effort off of central Oregon Coast, 2003**

# Fisheries: age-specific catch

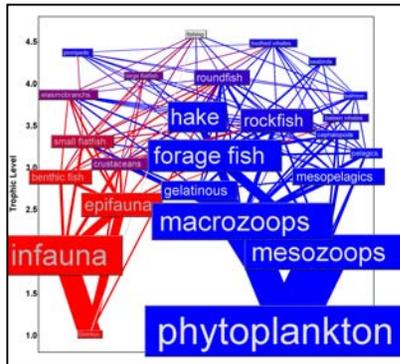


$$F_i = B_i \cdot effort_i \cdot \delta_{i_{catchability}} \cdot \delta_{i_{avail\_xy}} \cdot \delta_{i_{avail\_z}} \cdot \delta_{i_{selectivity}} \cdot (1 - \delta_{i_{escape}})$$

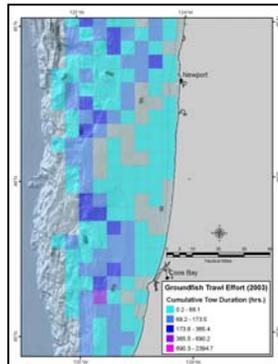
# Status of model development



**Oceanography:** currently the system is forced using a 2001-2002 loop; we are expanding this to 1997-2003 (includes a major El Niño)



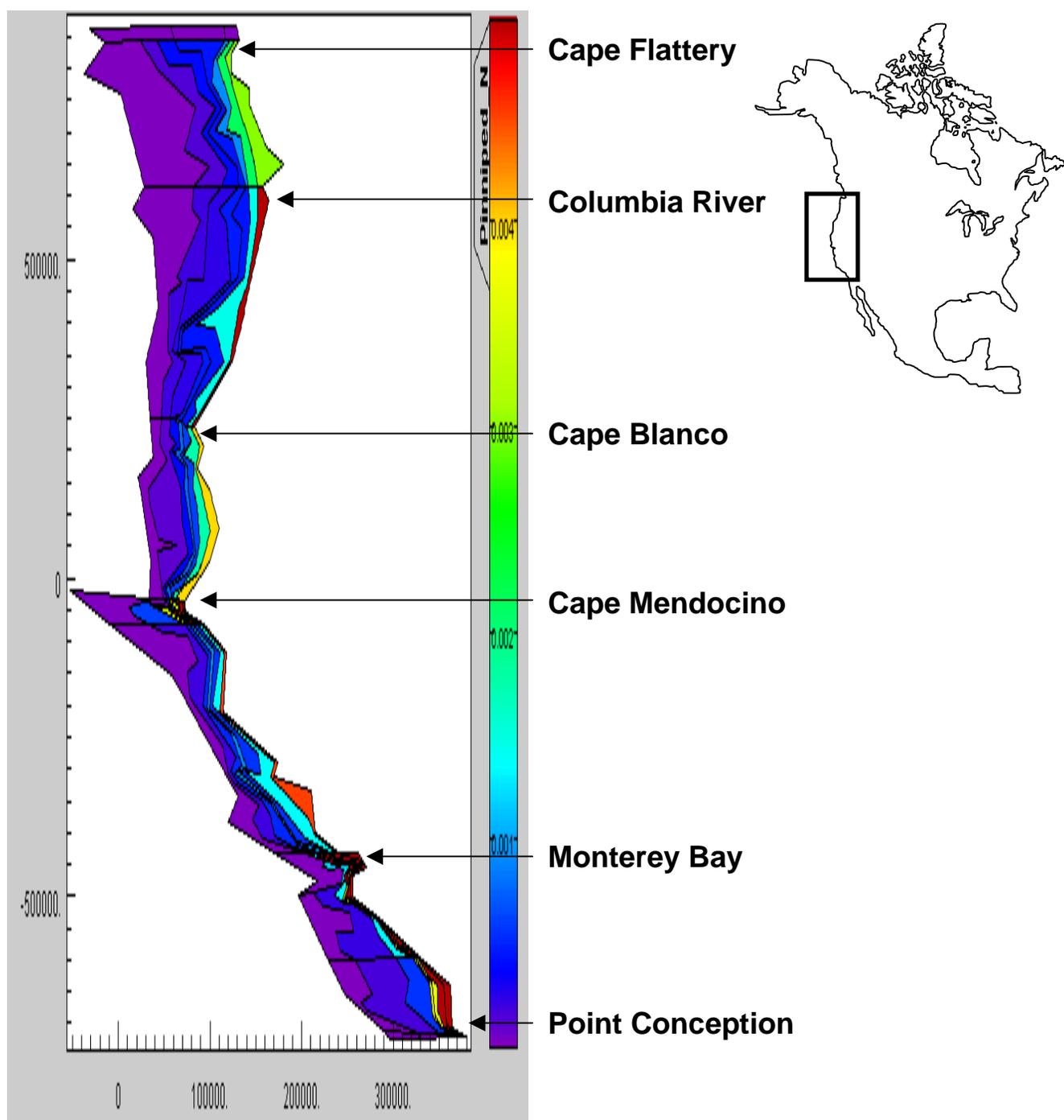
**Food web:** all functional groups' initial states entered, including seasonal biology (migration, reproduction), habitat preferences, and spatial distribution. Primary production is a function of nutrients, light.



**Fishing fleets:** not implemented yet

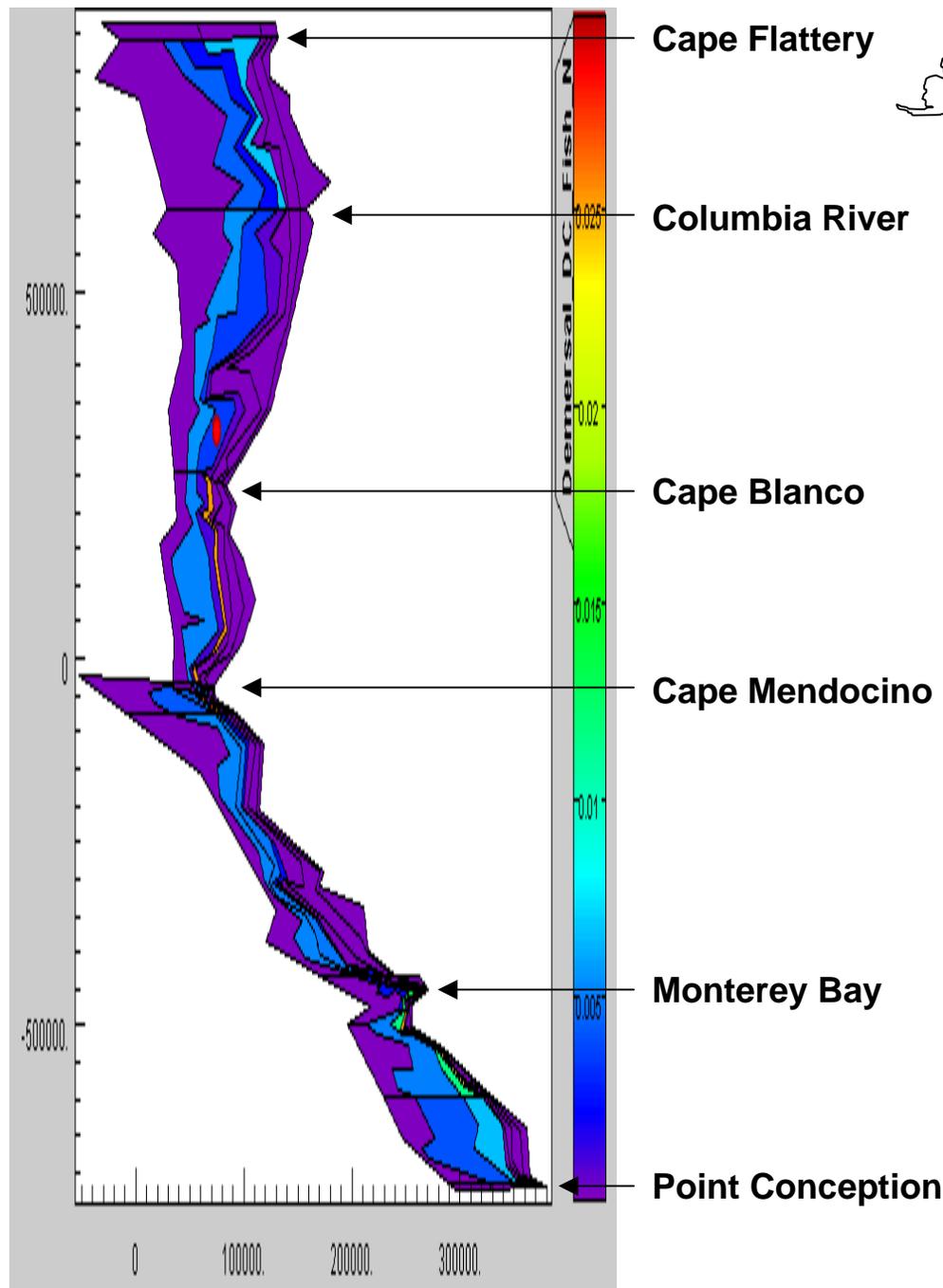
# Pinnipeds (mg N m<sup>-3</sup>)

Initial state—  
January 2001

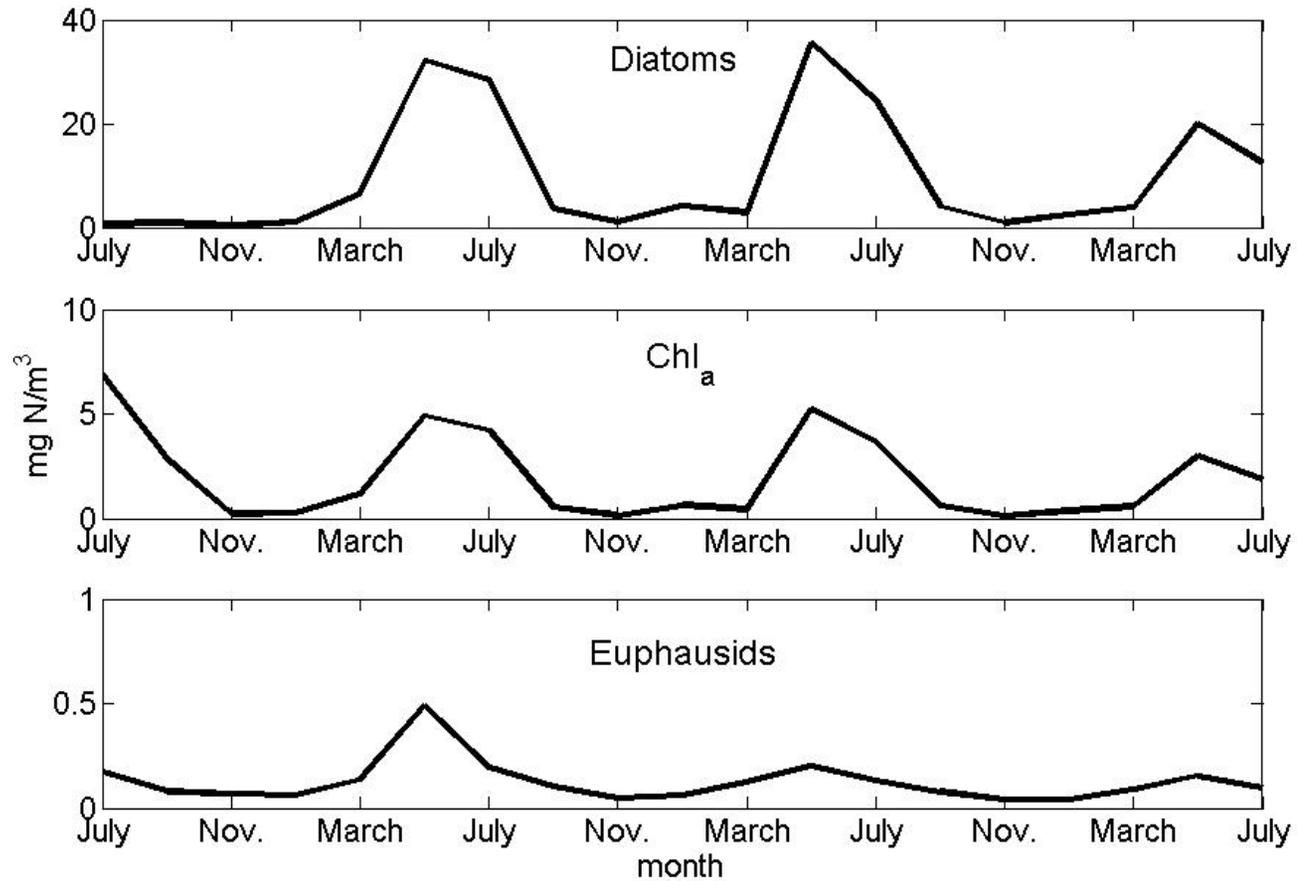


**Small offshore  
rockfish,  
*Sebastes* and  
*Sebastolomus*  
(mg N m<sup>-3</sup>)**

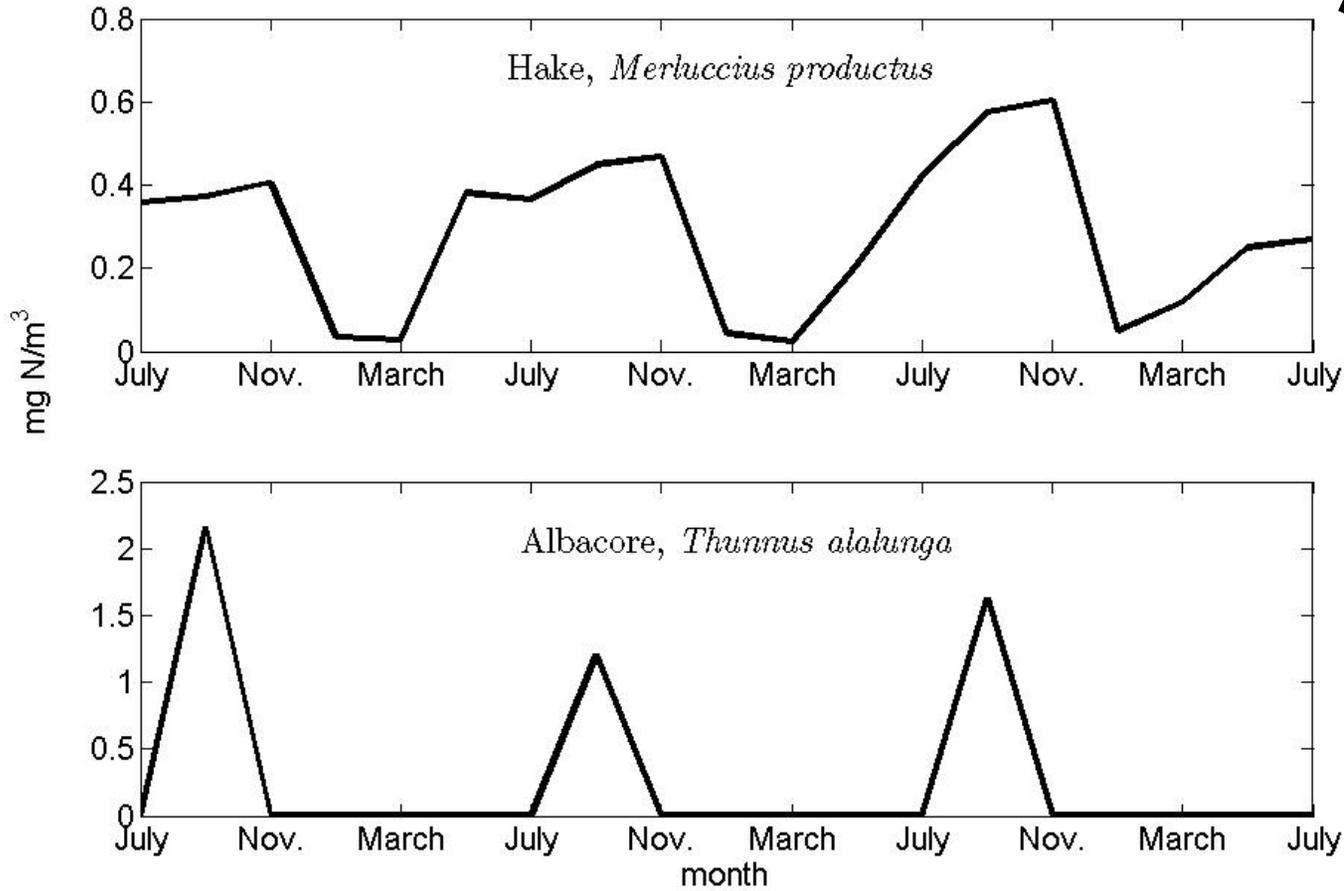
**Initial state—  
January 2001,  
150-200 m deep**



# Seasonal dynamics



# Migrations



## Clearly, we're still in the development phase

### Next steps:

- Ensure biological and oceanographic models are stable
- Integrate fishery submodel
- Expand spatial coverage (BC, Southern California)

### Scenario development:

- Alter fishing effort under different climate regimes to identify sensitive parameters (data gaps or indicators?)
- Estimate effects of space-time closures
- Evaluate ecosystem-level impacts on overfished functional groups
- Evaluate hypotheses about historic, current, future carrying capacity

Long-term question: can we bridge gap between this model and single-species stock assessments?

