Can (Should?) End-to-End Models be Assembled from Existing Models?

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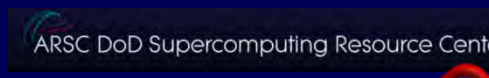
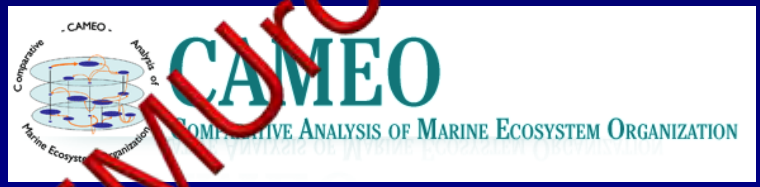
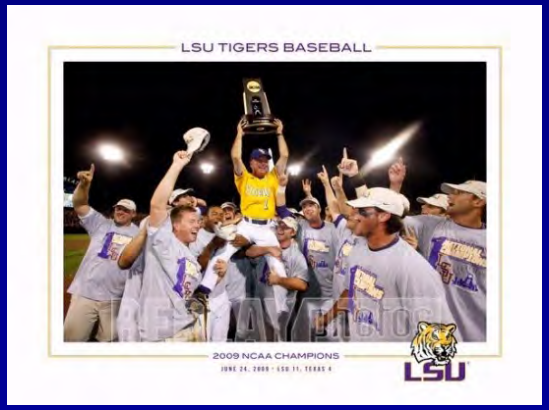






NOAA HPCC
High Performance Computing and Communications

Presently, anchovy-sardine end-to-end model is funded by a grant from NOAA's CAMEO Program

Introduction

- Accelerating interest in end-to-end models
- End-to-end means climate to physics to fish to fisheries to people
- Conceptually and politically attractive

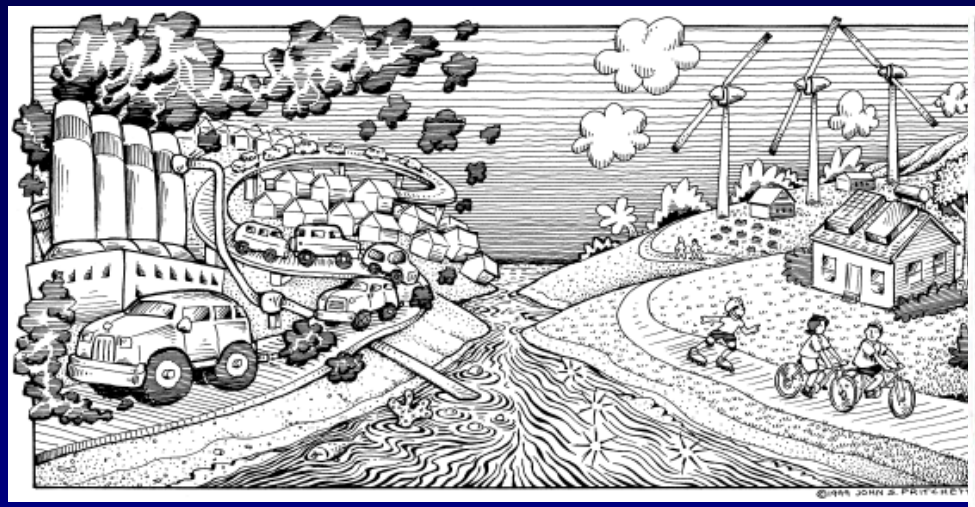
Introduction

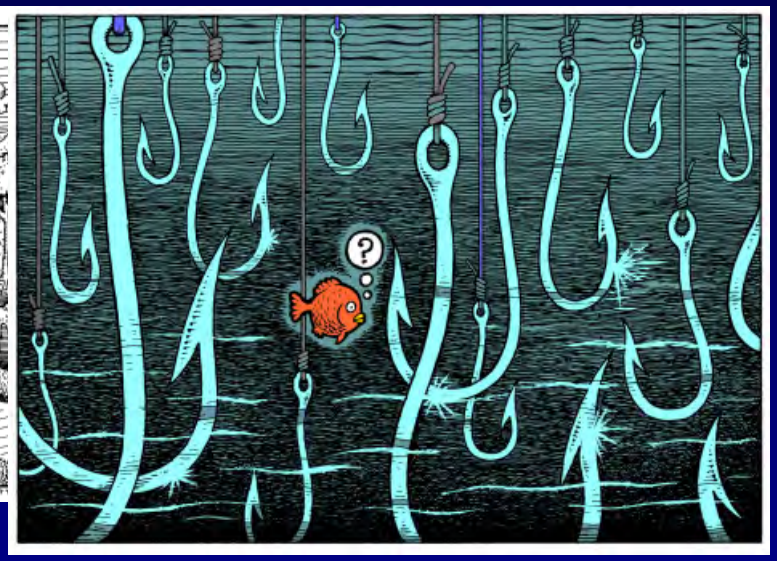
- To date, physics-NPZ (lower tropic levels) and fish models were developed separately
- Meet at zooplankton (fish food)
  - Closure term for NPZ
  - Assumed available for fish
- Advances in each seemed out-of-phase
- Today: thoughts about end-to-end modeling

Why now?

- Advances in data collection
  - Spatially-detailed data
  - Behavioral measurements
- Continued increases in computing power
- Advances in modeling
  - Physics: meso-scale features in decadal runs
  - Fish: individual-based, fine-scale observations

Why now?





Preparation documents sent to review panel members for the Gulf of Mexico Red Snapper stock assessment

One Solution

- Coupled models that can address bottom-up, top-down, and side-ways issues
- Climate change effects on fish
- Perceived fisheries management crisis due to simple single-species approach
- Ecosystem-based management (whatever that means)

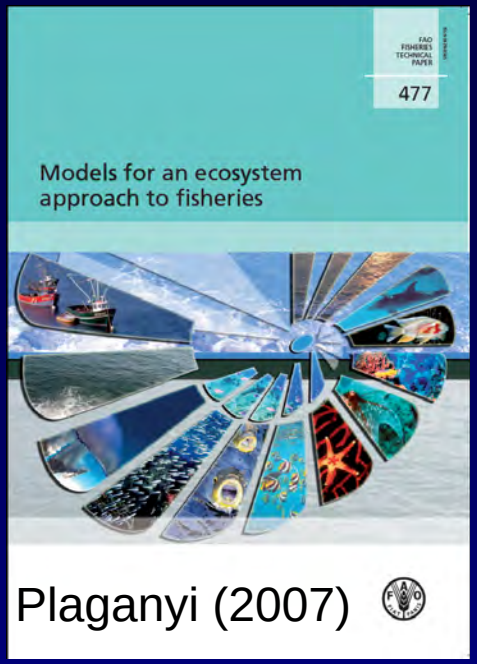


FIGURE 1

A flowchart summarizing the classification of the various models listed in Table 1. The flowchart has been modified and updated from that presented in Hollowed *et al.* (2000). Boxes with models covered in this report are highlighted

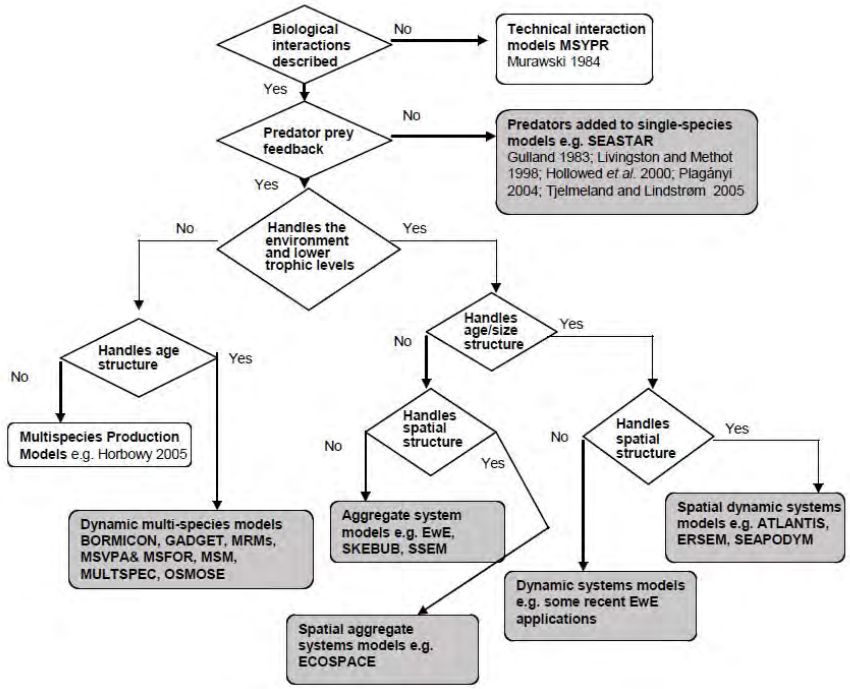
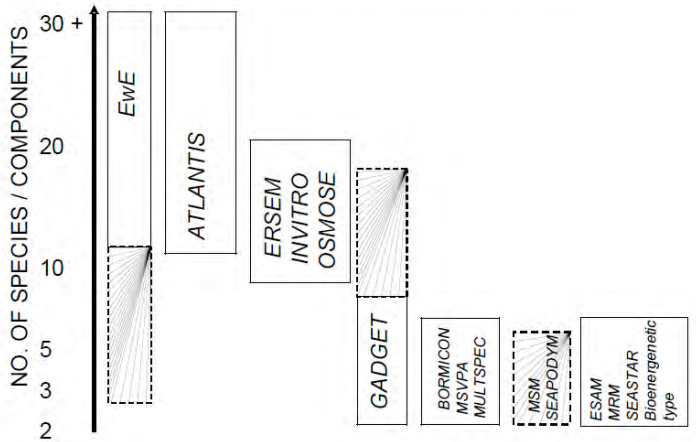


FIGURE 3

Schematic summarizing (approximately) the typical (current) number of modelled species or model compartments for selected models as listed in Table 1. The solid rectangles represent the range whereas the dashed lines indicate either rare/unusual applications or intended future extensions to the model.



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Approaches to end-to-end ecosystem models

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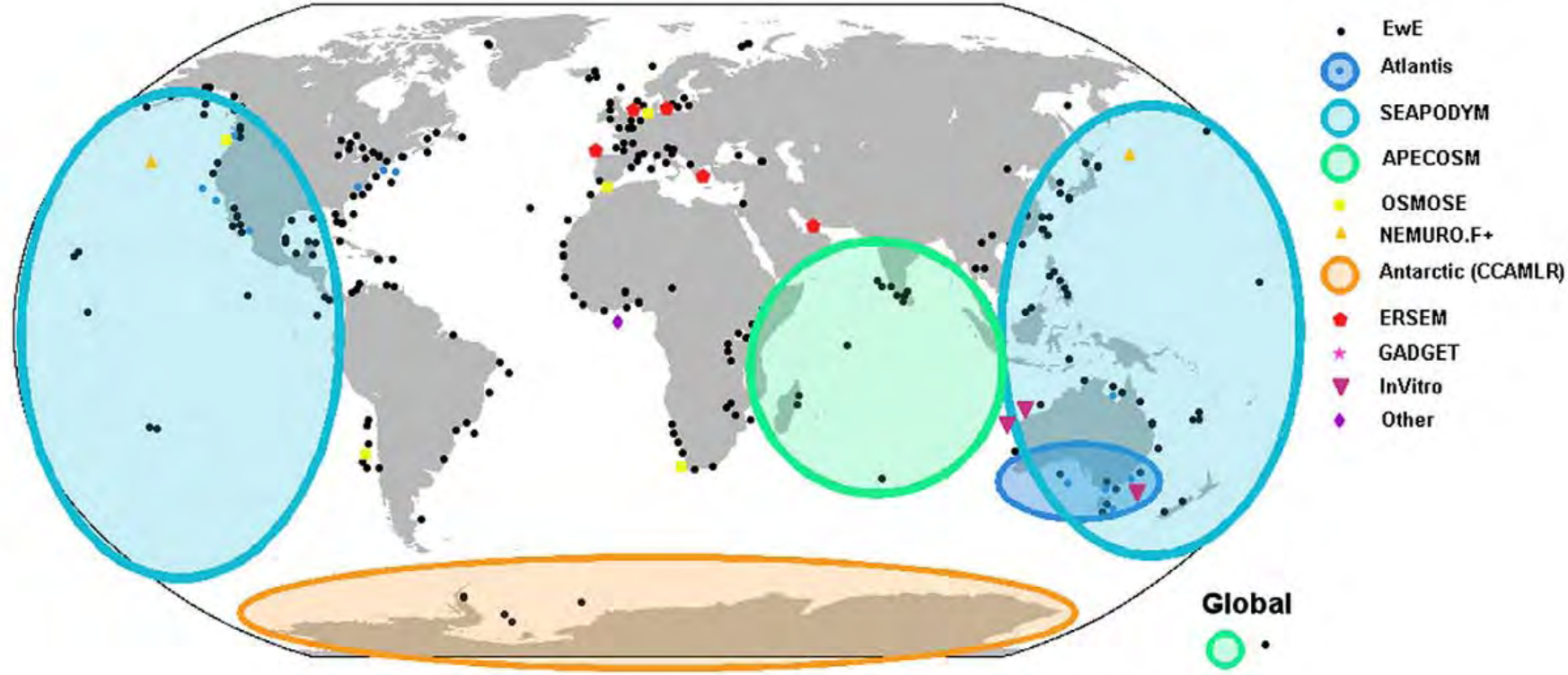

Fig. 3. Map of end-to-end models implemented to date (many more have been proposed or are in early development).

Status

- When viewed together, it seems we are tweaking existing models and submodels to push them towards end-to-end models
- There are advances in some of the models, but it is enough?
- I am guilty of this – see my talk

End-To-End Models for the Analysis of Marine Ecosystems: Challenges, Issues, and Next Steps

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"Bridging the gap between lower and higher trophic levels"
February 2009
Plymouth, England
AMEMR and MEECE

Issue 1: Zooplankton

- Shift from biochemical cycling to fish food
  - Fundamental change in modeling objectives
- Functional groupings
  - Diet shifts in fish
  - Prey selection by zooplankton
  - Physiological differences
- Dynamic stochiometry

Issue 1: Zooplankton

- Biomass versus stages?
  - Copepods as stages (e.g., Moll and Stegert 2007)
- Other approaches
  - Post-processing to obtain detailed prey fields (e.g., Daewel et al. 2008)
  - Some have changed to size classes (e.g., Maury et al. 2007)

Issue 2: New Organisms

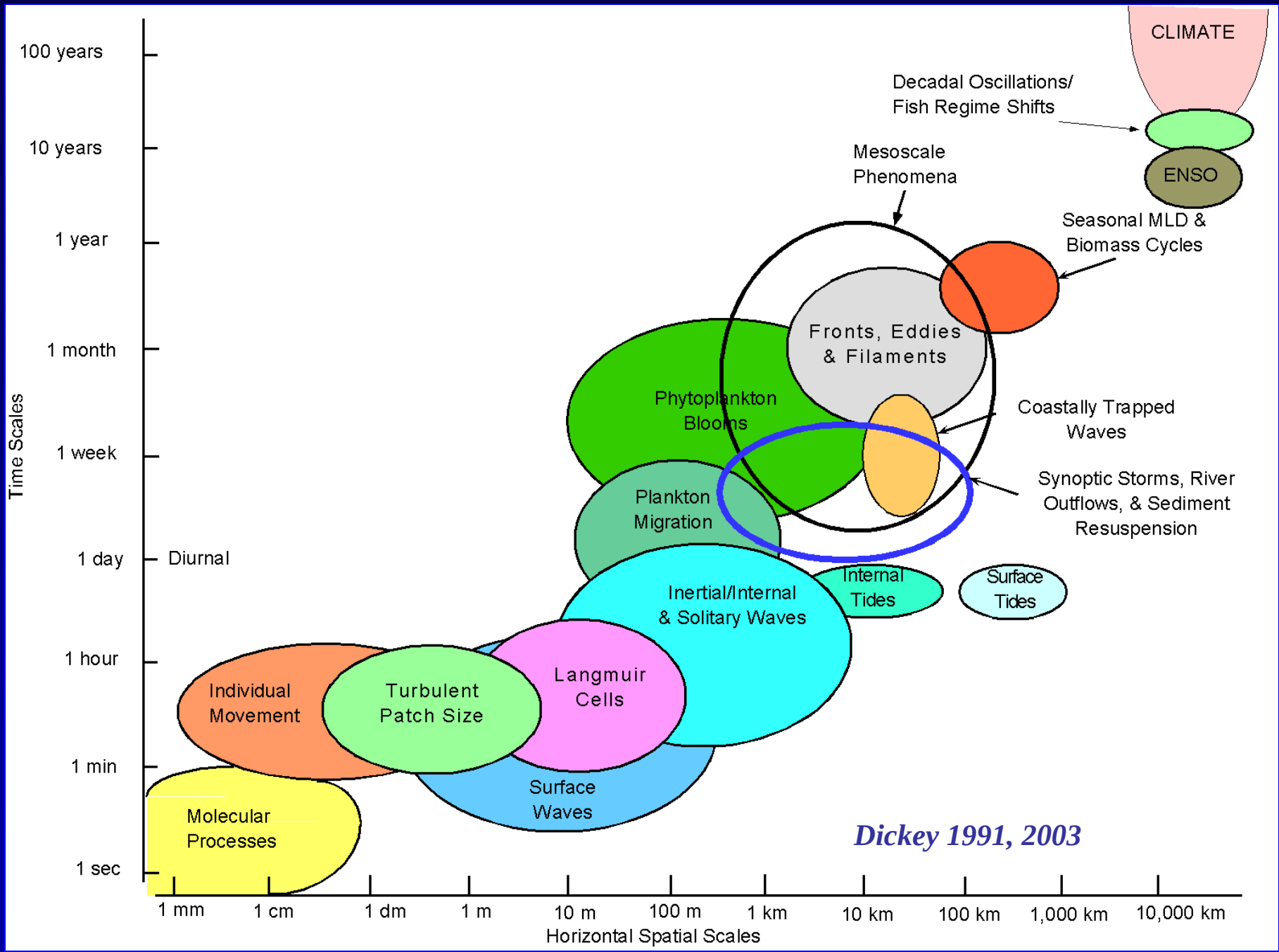
- Macroinvertebrates
  - Salps, jellyfish
- Demersal fish species
  - Shift from focus on early life stages of pelagic species
  - Now the bottom, benthos, and demersal habitat
- Shifted closure term problem to even higher trophic levels
  - Zooplankton to fish
  - Not acceptable to use B^2 for fish
  - Major mortality on fish is fish predation and harvest
- Now we want to add people

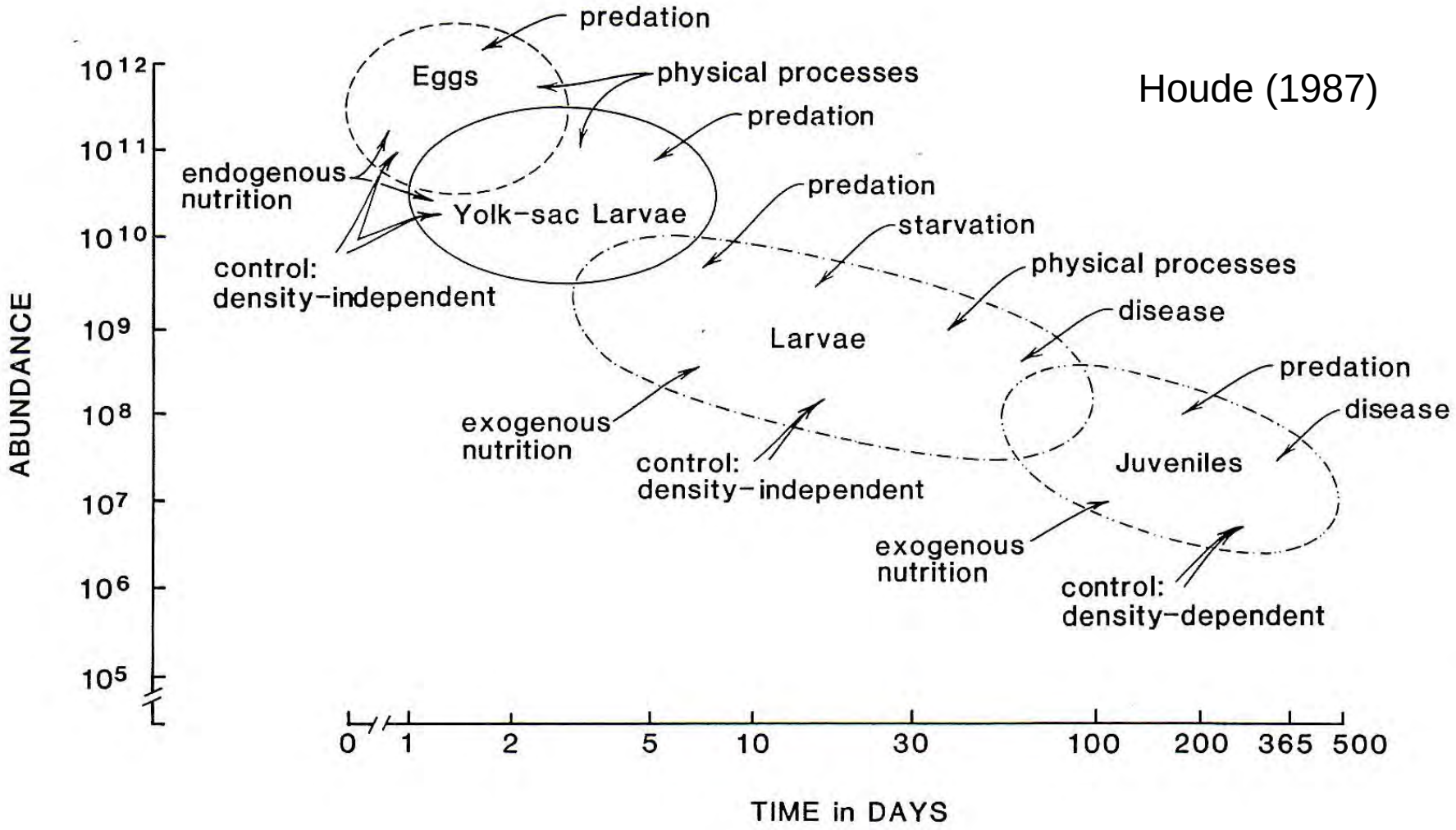
Issue 3: Scaling

- Determining the appropriate temporal, spatial, and biological scales for a model is always challenging

- Now, we made the problem more difficult
  - Time: Seconds to days to decades
  - Body size: 10^{-12} to 10^{6} grams
  - Space: Large domains near coasts, mesoscale
  - Interspecific interactions – community ecology has failed us
  - Include people

- Compromise usually makes everyone unhappy


CLIMATE
Decadal Oscillations/
Fish Regime Shifts
ENSO
Mesoscale
Phenomena
Seasonal MLD &
Biomass Cycles
Fronts, Eddies
& Filaments
Phytoplankton
Blooms
Coastally Trapped
Waves
Synoptic Storms, River
Outflows, & Sediment
Resuspension
Plankton
Migration
Internal
Tides
Surface
Tides
Inertial/Internal
& Solitary Waves
Langmuir
Cells
Individual
Movement
Turbulent
Patch Size
Surface
Waves
Molecular
Processes
Diurnal
100 years
10 years
1 year
1 month
1 week
1 day
1 hour
1 min
1 sec
Time Scales
1 mm
1 cm
1 dm
1 m
10 m
100 m
1 km
10 km
100 km
1,000 km
10,000 km
Horizontal Spatial Scales
Dickey 1991, 2003


Houde (1987)
ABUNDANCE
10^{12}
10^{11}
10^{10}
10^{9}
10^{8}
10^{7}
10^{6}
10^{5}
Eggs
predation
physical processes
predation
endogenous nutrition
Yolk-sac Larvae
control: density-independent
predation
starvation
physical processes
disease
Larvae
exogenous nutrition
control: density-independent
predation
disease
Juveniles
exogenous nutrition
control: density-dependent
0
1
2
5
10
30
100
200
365
500
TIME in DAYS

Issue 4: Acclimation and Adaptation

- Acclimation is phenotypic plasticity
- Genotypic changes leads to adaptation
- Rapid turnover organisms, but even fish
- Climate change time scales

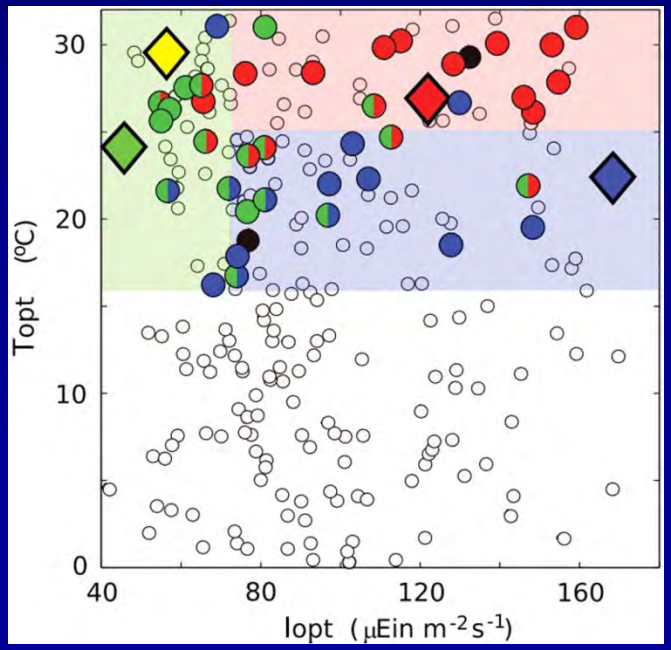


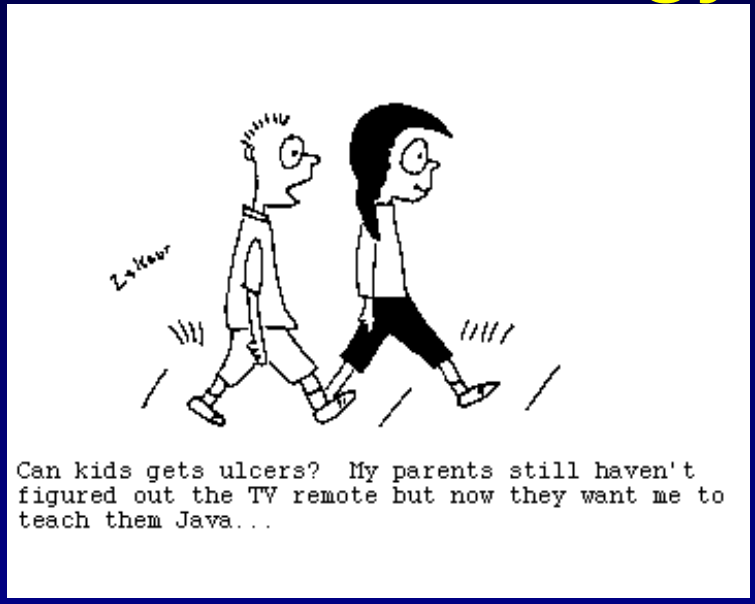
Figure 3. Optimum temperature and light intensity for growth. Large circles indicate the analogs that exceeded a total biomass of 10^6 mol P in the 10th year. Colors indicate classification into model ecotypes. From Follows et al. 2007.

Issue 5: Movement

- Juvenile and adult fish move where they want
- Critical we get this correct or else will experience wrong conditions
  - Short-term
  - Migrations
- Long-history of particle tracking
- Fitness, kinesis, ANN-GA, random walk
- No general guidelines or advice on which approaches work under what conditions

Issue 6: Software and Technology

- Fortran and C will be used for a while (Barnes and Hopkins 2003)
- No off the shelf model coming anytime soon



- Hinders advances because difficult to understand and share lessons learned (Ropella et al. 2002)
- We have an opportunity now for community-oriented effort before strong camps are formed

Issue 7: Solution Techniques

- Two-way
  - allows for feedbacks, which is critical for realistic dynamics (Travis et al. 2009) and density-dependence
  - But computationally expensive
  - If coarser scales for fish, then must put the mortality on a finer scale for zooplankton (disaggregation)
- One-way
  - Runs faster
  - Aggregation as long as next model up is coarser
  - But no feedbacks
  - Will it remain one-way under new conditions?
  - One can force the feedbacks but limits questioned asked – no longer emergent property

Issue 7: Solution Techniques

- Can lead to array problems, especially cohort or individual-based approach

- Super-individuals (Scheffer et al. 1995) but can introduce numerical artifacts (Parry and Edwards 2008) and mass balance issues

Issue 8: Model Confidence and Forecasting

- Diverse calculations that require calibration and validation – *fuggeddaboutdit!!*
- Hydrodynamics and NPZ
  - Short-term feasible but now want long-term with “rare” events
- Fish
  - Complex life histories and sampling issues
  - Long-standing issue, only to be amplified
  - Never ask the source of the natural mortality rate
  - We use catch data we not believe to determine future catch based on unverified population estimates
  - Physics people need to relax more

Issue 8: Model Confidence and Forecasting

- Urge restraint for true forecasting mode (a la' Clark et al. 2001)
- Resist temptation or pulling towards forecasting until more evaluation
- Premature usage could hinder development

Issue 8: Model Confidence and Forecasting

- Recent NOAA workshop on linking IPCC-class models with fish (Stock et al. in review) suggested using modified recruitment and single-species models for now until end-to-end models mature

- Useful on a case-by-case basis for informing management

- *"Predictions are difficult, especially about the future."*

  Yogi Berra, Baseball player

Issue 9: True Interdisciplinary Efforts

- Move from multidisciplinary to interdisciplinary
  - Not nitrate specialist with a nitrite specialist
  - Rather, physics, zooplankton, benthos, fish, economics, ecology, climate
- Adjustment of plans based on others
  - Not just periodic meetings
- Communication and trust

I know little about nature and hardly anything about men.
-- Einstein

Issue 9: True Interdisciplinary Efforts

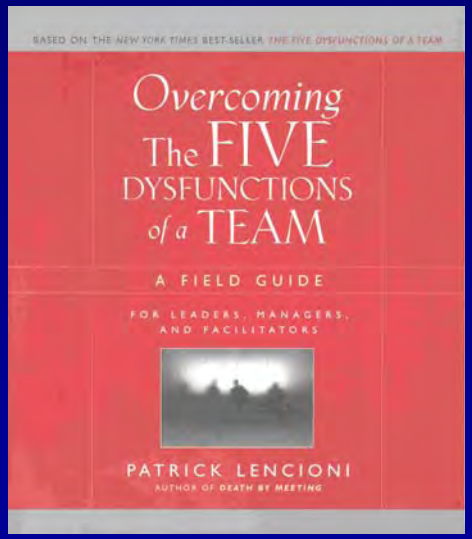
- “silo” legacy
  - Different departments, buildings, agencies

- Funding agencies
  - Risk
  - disciplines

"We can lick gravity, but the paperwork's a bit tougher."
- Werner von Braun, Director of NASA’s Marshall Space Flight Center

"Mr. Osborne, may I be excused? My brain is full."

"You should check your e-mails more often. I fired you over three weeks ago."



Conclusions

- Ingredients are now available
- It can (should) be done!
  - Decisions are now being made without it
- Challenges:
  - Technical (computing, algorithms, data)
  - Institutional
  - People

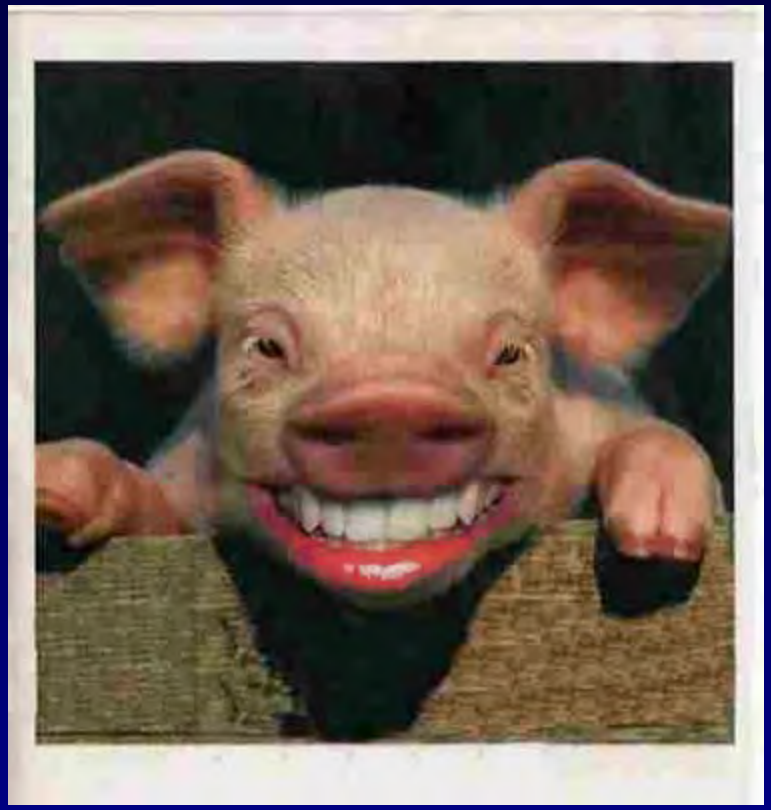
Conclusions

- Major progress in modeling and data
- Some progress in institutional and people aspects
- Do not mean joint projects but true collaboration
- Much more optimistic than 10 years ago

Conclusions

- Fisheries is finally looking downward

- Physics and NPZ are looking upward
  - ecosystem does not stop at zooplankton
  - We (fisheries) need you
- Proof of principle and then say what data are needed
- Modeling lead the way so get data in 5-10 years
- Proceed carefully and ensure we are using the best available modeling rather than convenience



We must be careful that we are not just putting lipstick on a pig