Combining hydrodynamic, NPZ, and fish models into climate-physics-fish-fisher models: can the biology and people keep up with the computers?

Kenneth A Rose
Louisiana State University

Some Future Directions in Modeling

- Expansion of domains and finer resolution
- Spatially-detailed data requiring mining
- Mesoscale features within decadal simulations

Some Future Directions in Modeling

- Refinement of climate change beyond temperature
- Coupled natural and human systems
- Confrontational science
- Today:
  - End-to-end models
  - People and collaboration issues

Stalled Areas that Affect Modeling

- Community ecology
  - predation and competition
  - diversity
- Coding of models
- Public knowledge of science and trust in scientists
- Model forecasting of ecological conditions

Stalled Areas that Affect Modeling

- Ecosystem-based fisheries management
- Remote sensing
- Model coupling
- Density-dependence

End-to-End Models

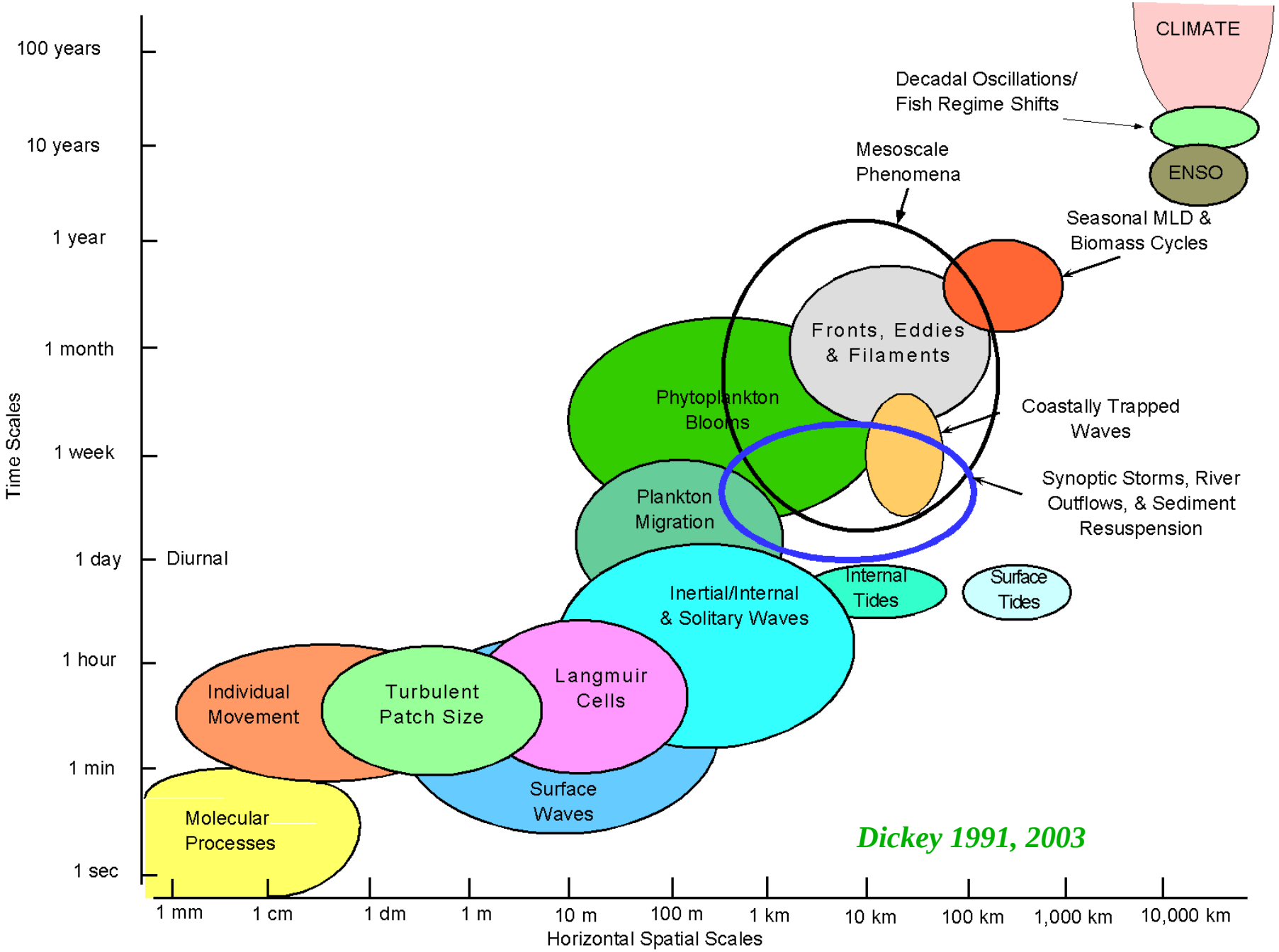
- Much emphasis on climate to fish linkages
  - Global change issues
  - Bottom-up, middle-out, top-down controls
- Increasing pressure for ecosystem-based considerations in management
- Continuation of the NEMURO effort
  - Multi-species, individual-based, physics to fish model
  - Proof of principle

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

Challenge

- How to combine models with different temporal and spatial scales
- No general theory
  - Modeling as art
- Including human dimensions
- Working across disciplines


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
Dickey 1991, 2003
100 years
10 years
1 year
1 month
1 week
1 day
Diurnal
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

Plaganyi (2007)

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Approaches to end-to-end ecosystem models

Elizabeth A. Fulton *

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

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End-to-End Model

Proof of Principle

- Sardine – anchovy population cycles
  - well-studied
  - teleconnections across basins

- Good case study
  - Forage fish tightly coupled to NPZ
  - Important ecologically and widely distributed
  - Cycles documented in many systems
  - Recent emphasis on spatial aspects of cycles

- Demonstrates we can solve some of the technical issues

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Scripps Institute - CALCOFI

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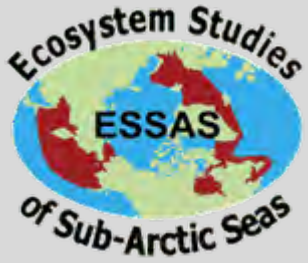
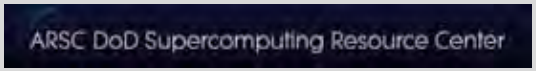
National Marine Fisheries Service

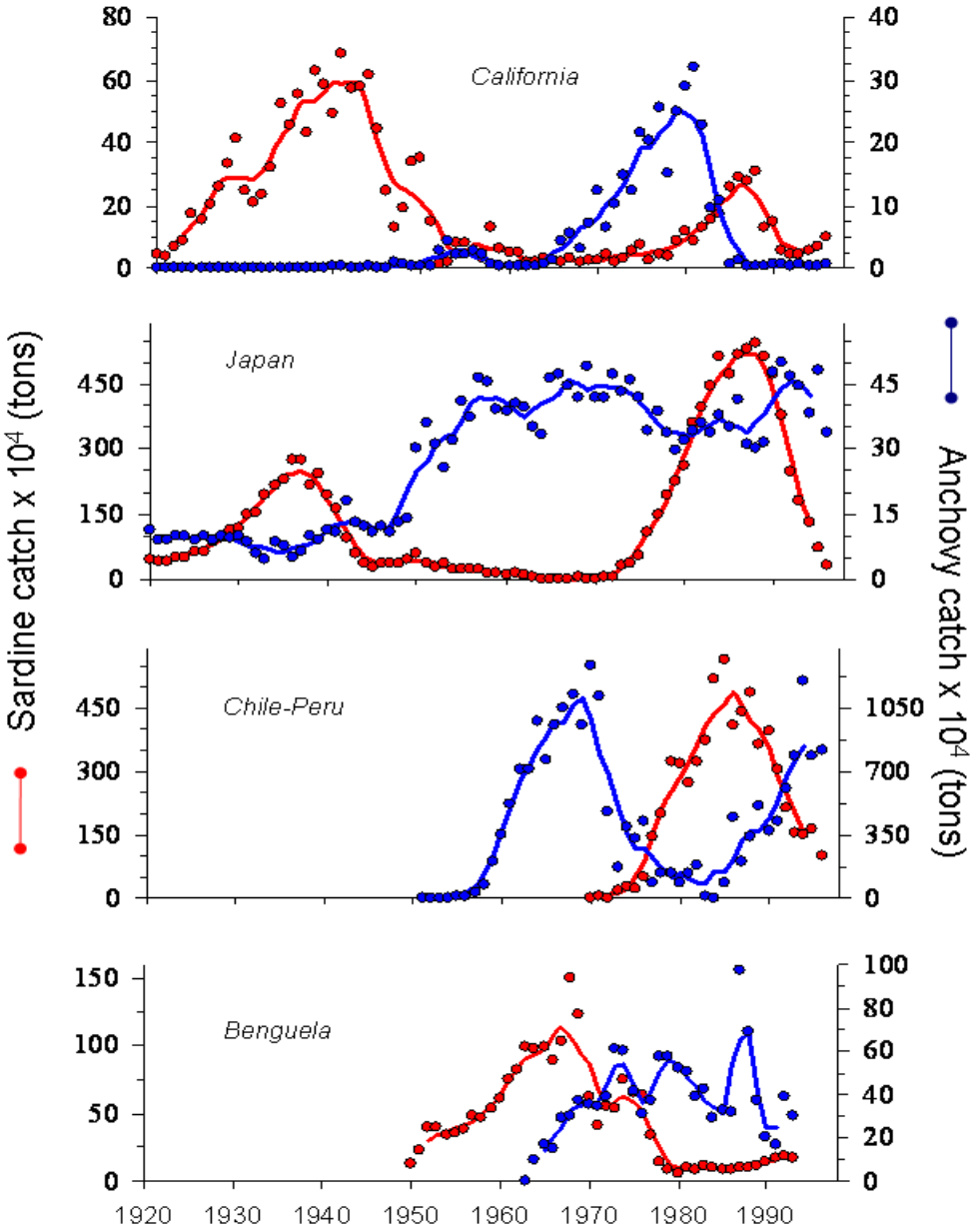
Francisco Werner
Rutgers University


MARINE and
COASTAL SCIENCES





NOAA HPCC
High Performance
Computing and
Communications

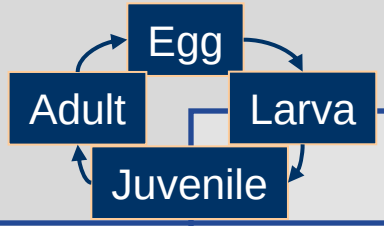


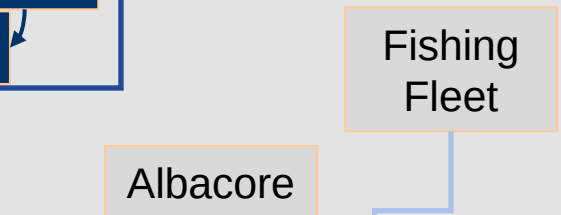
Provided by: Salvador E. Lluch-Cota
Source: Schwartzlose et al., 1999

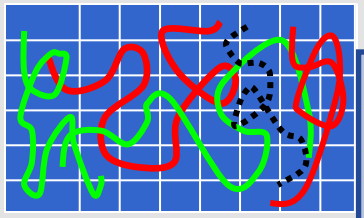
Population

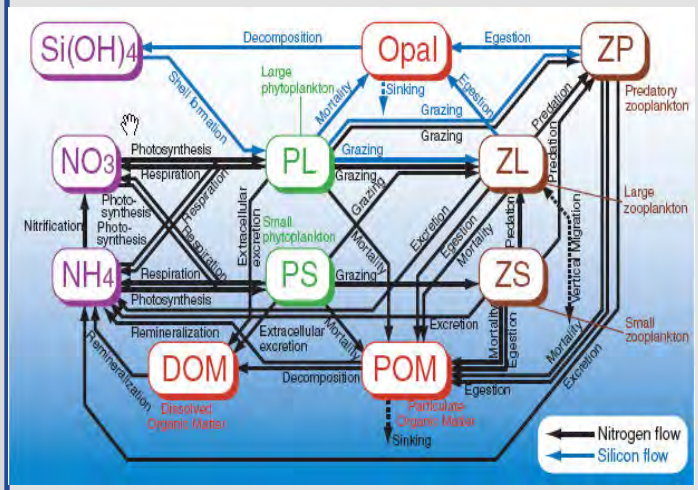
Multi-Species

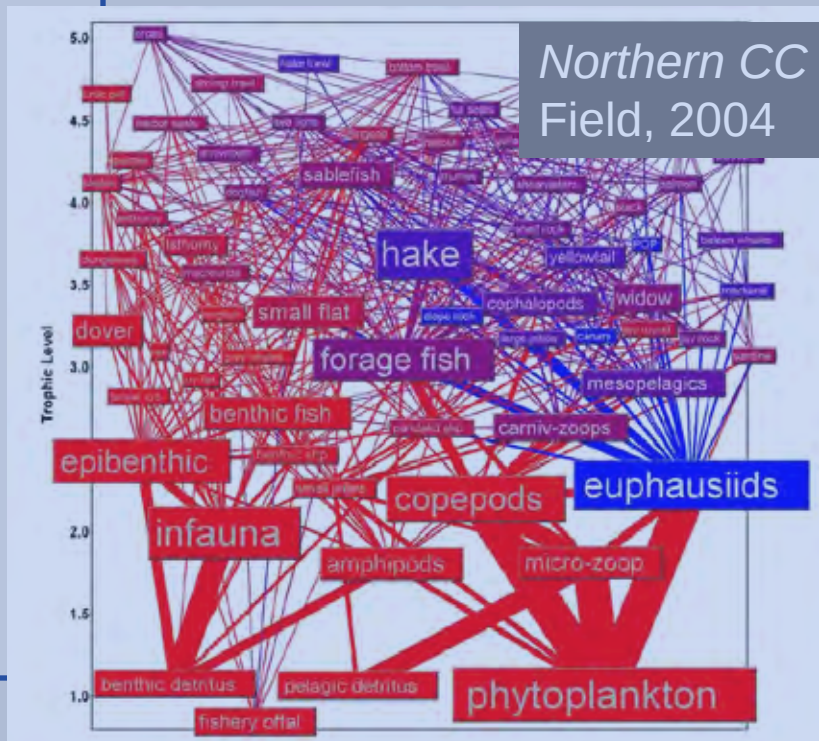
Food Web/Community











Why IBM for Fish

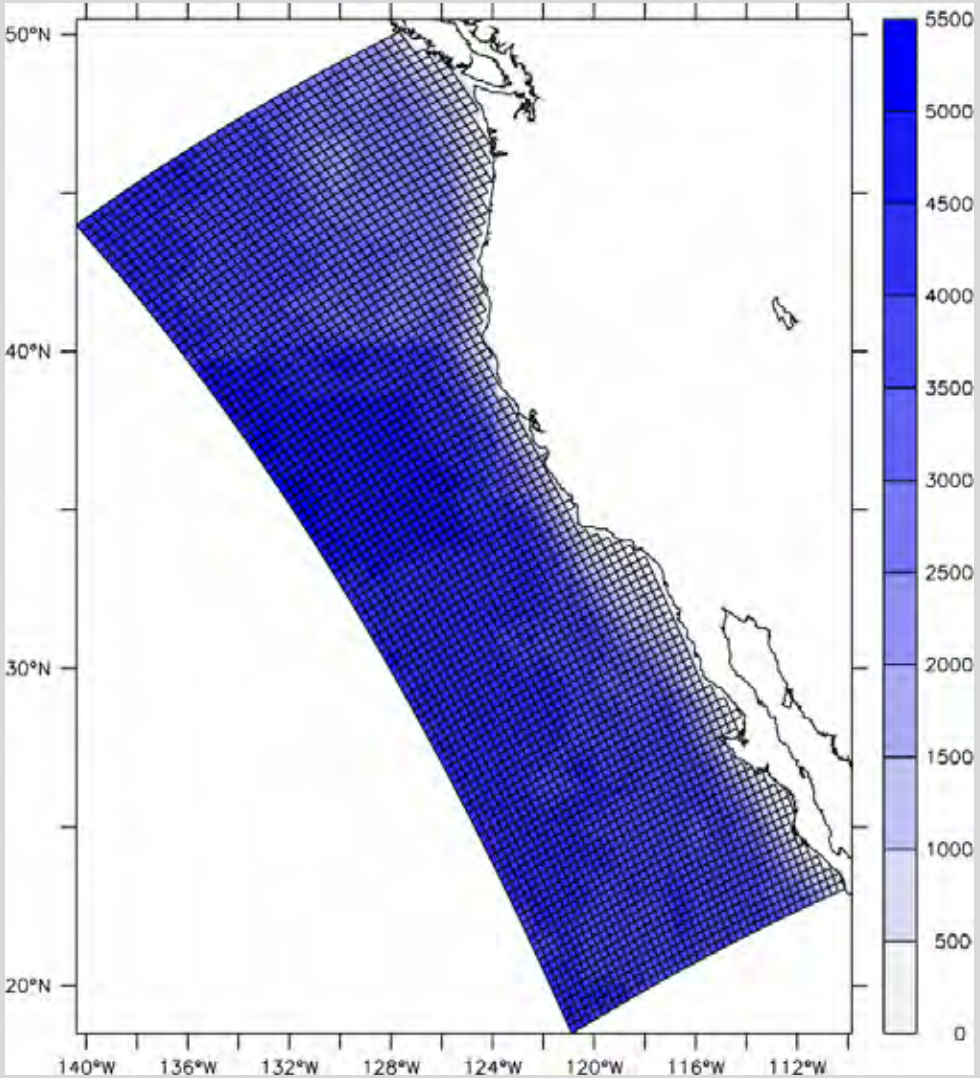
- Natural unit in nature
- Allows for local interactions and complex systems dynamics
- Complicated life histories
- Plasticity and size-based interactions
- Conceptually easier movement

NEMUroms.SAN

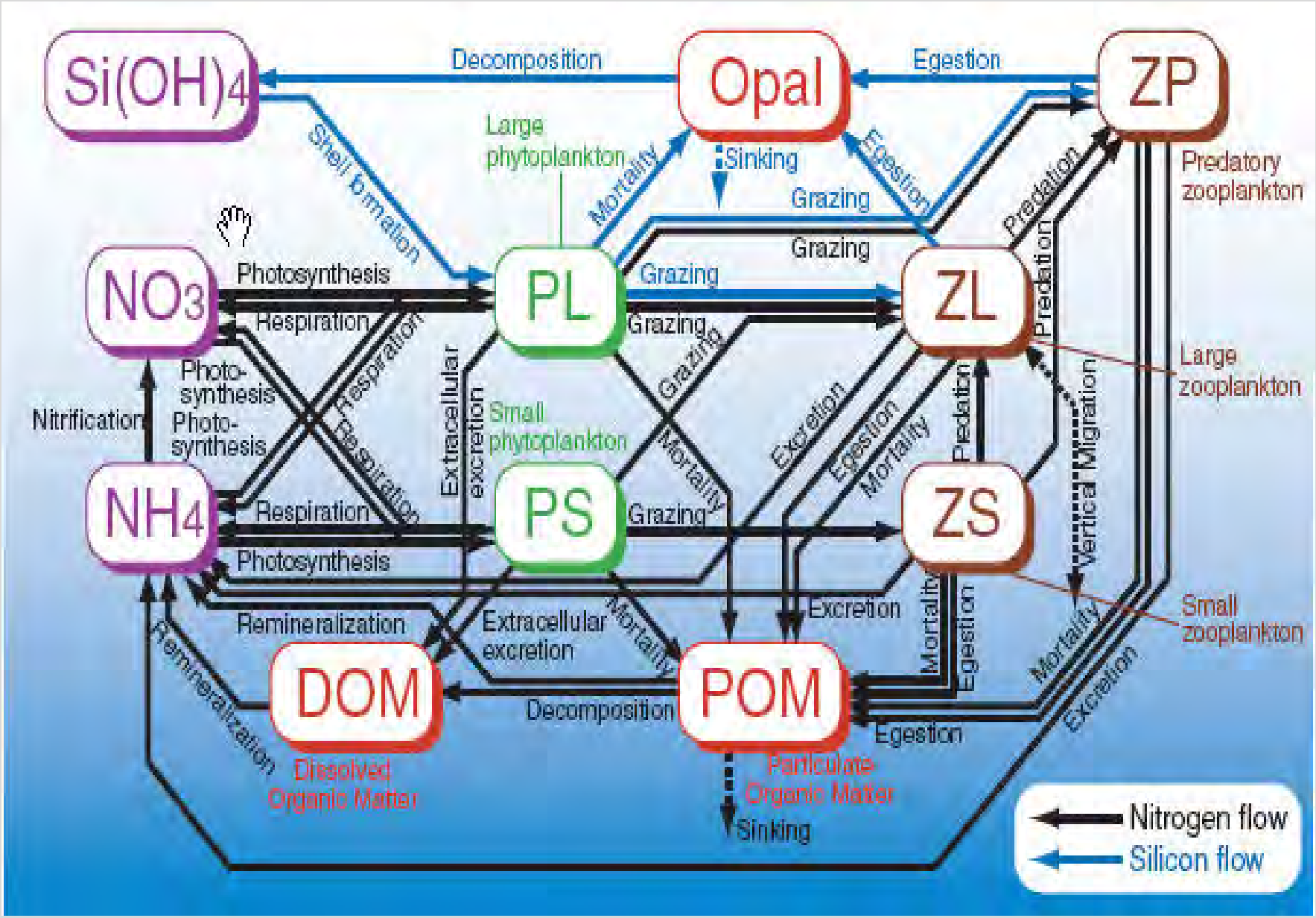
- Model 1: 3-D ROMS for physics
- Model 2: NEMURO for NPZ
- Model 3: Multiple-species IBM for fish
- Model 4: Agent-based fishing fleet

Model 1: ROMS

- Grid:
  - 44x114 horizontal grid
  - 30 km resolution
  - 30 vertical levels
- Run duration: 40 years (1960-2004)
- Hourly time step



Model 2: NEMURO



Model 3: Fish IBM

Species Types

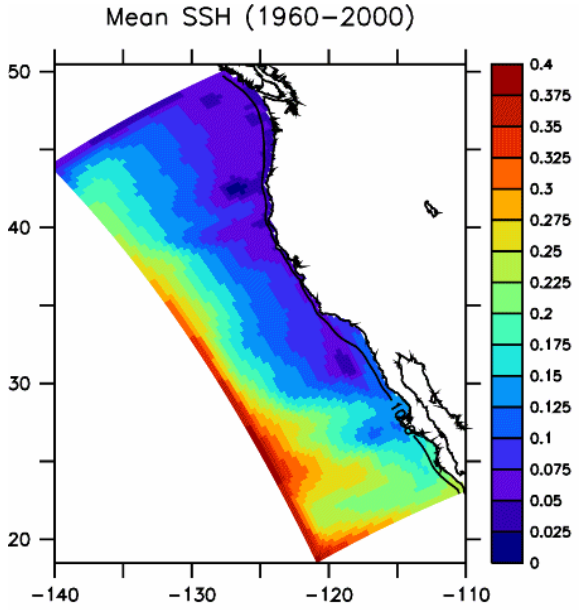
- Sardines and anchovy – fully modeled
  - Reproduction, growth, mortality, movement
  - Competitors (food, space) and predators
- Migratory predator
  - Enter and exit the grid
  - Movement and consumption of sardine and anchovy only
  - “albacore”

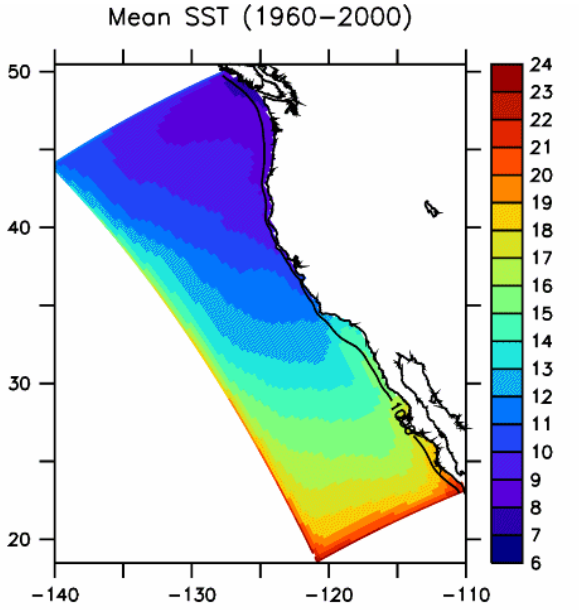
Model 4: Fishing Fleet

- 100 boats and 5 ports - sardine
- Day boats so complete a trip in 24 hours
- Daily evaluation
- Compute expected net revenue (ENR) based on:
  - Perceived CPUE (10-day average)
  - Price per pound
  - Cost per km
  - Return to nearest port

Numerical Details

- Major numerical and bookkeeping challenges
- Solving everything simultaneously
- We are working within ROMS source code, using the available particle tracking features
- Computing speed, mass balance, Eulerian with Lagrangian, and full life cycle
- 1960 to 2004


Mean SSH (1960–2000)
50
40
30
20
−140
−130
−120
−110
0.4
0.375
0.35
0.325
0.3
0.275
0.25
0.225
0.2
0.175
0.15
0.125
0.1
0.075
0.05
0.025
0


Mean SST (1960–2000)
50
40
30
20
−140
−130
−120
−110
24
23
22
21
20
19
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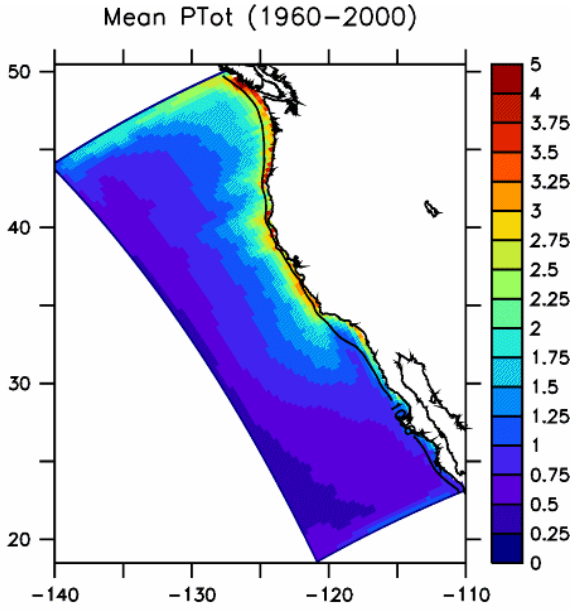
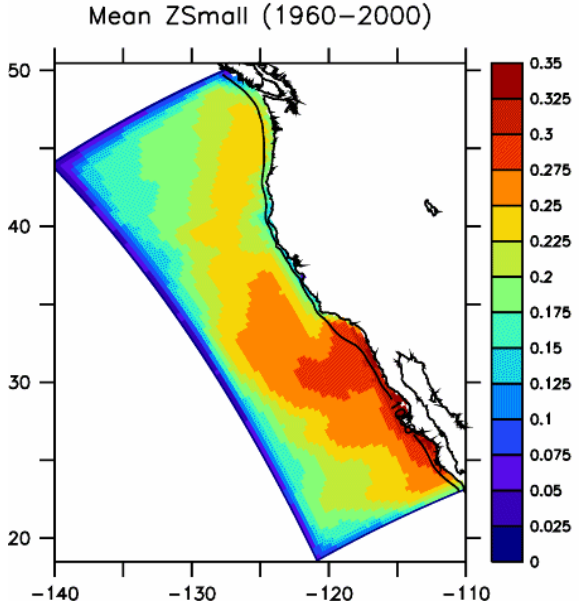
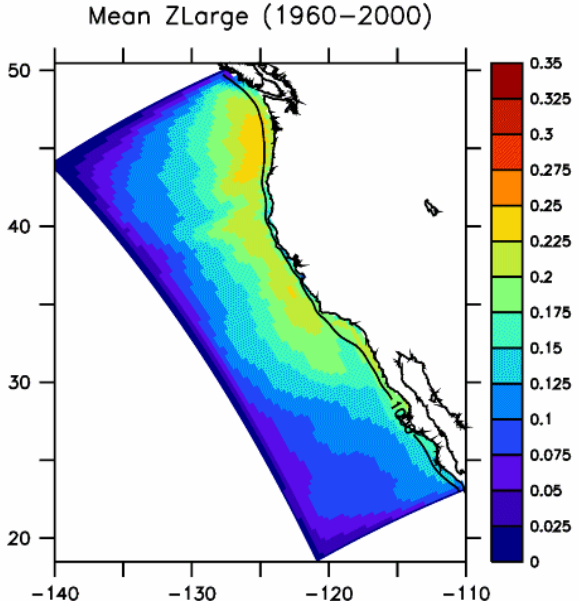
17
16
15
14
13
12
11
10
9
8
7
6


Mean PTot (1960–2000)
50
40
30
20
−140
−130
−120
−110
5
4
3.75
3.5
3.25
3
2.75
2.5
2.25
2
1.75
1.5
1.25
1
0.75
0.5
0.25
0


Mean ZSmall (1960–2000)
50
40
30
20
−140
−130
−120
−110
0.35
0.325
0.3
0.275
0.25
0.225
0.2
0.175
0.15
0.125
0.1
0.075
0.05
0.025
0


Mean ZLarge (1960–2000)
50
40
30
20
−140
−130
−120
−110
0.35
0.325
0.3
0.275
0.25
0.225
0.2
0.175
0.15
0.125
0.1
0.075
0.05
0.025
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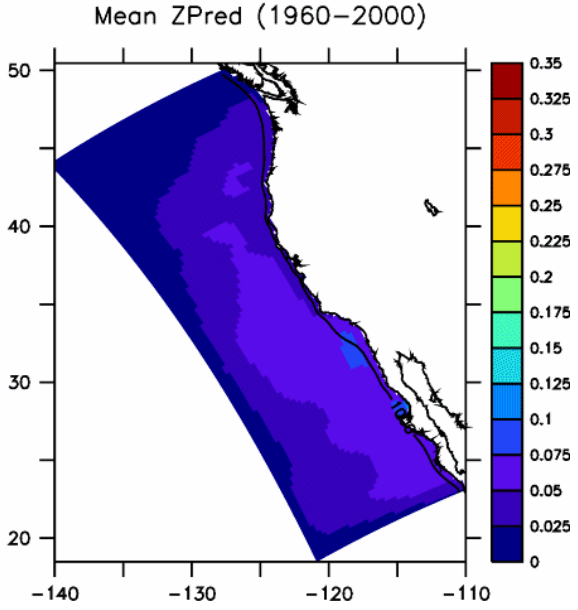
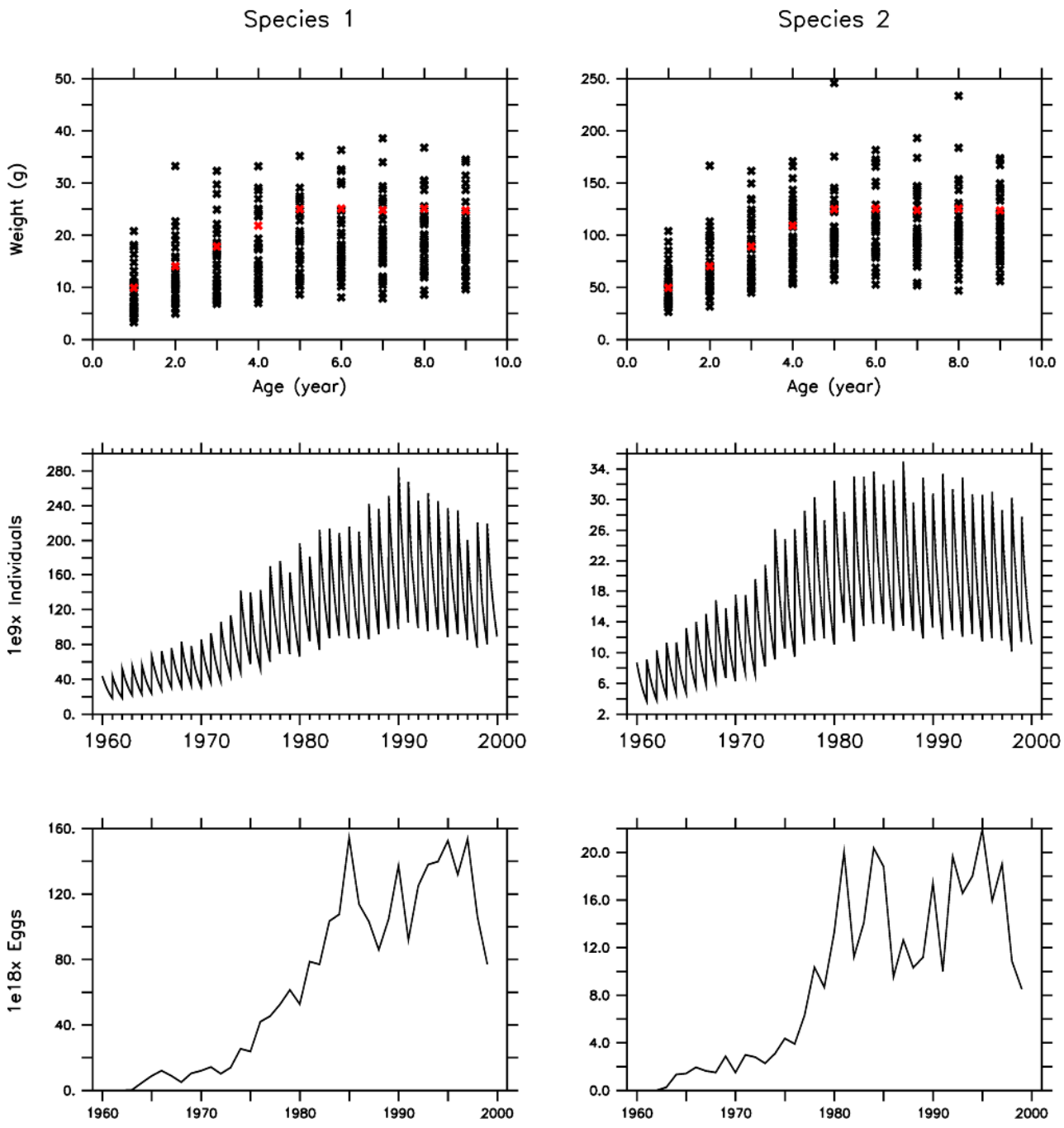
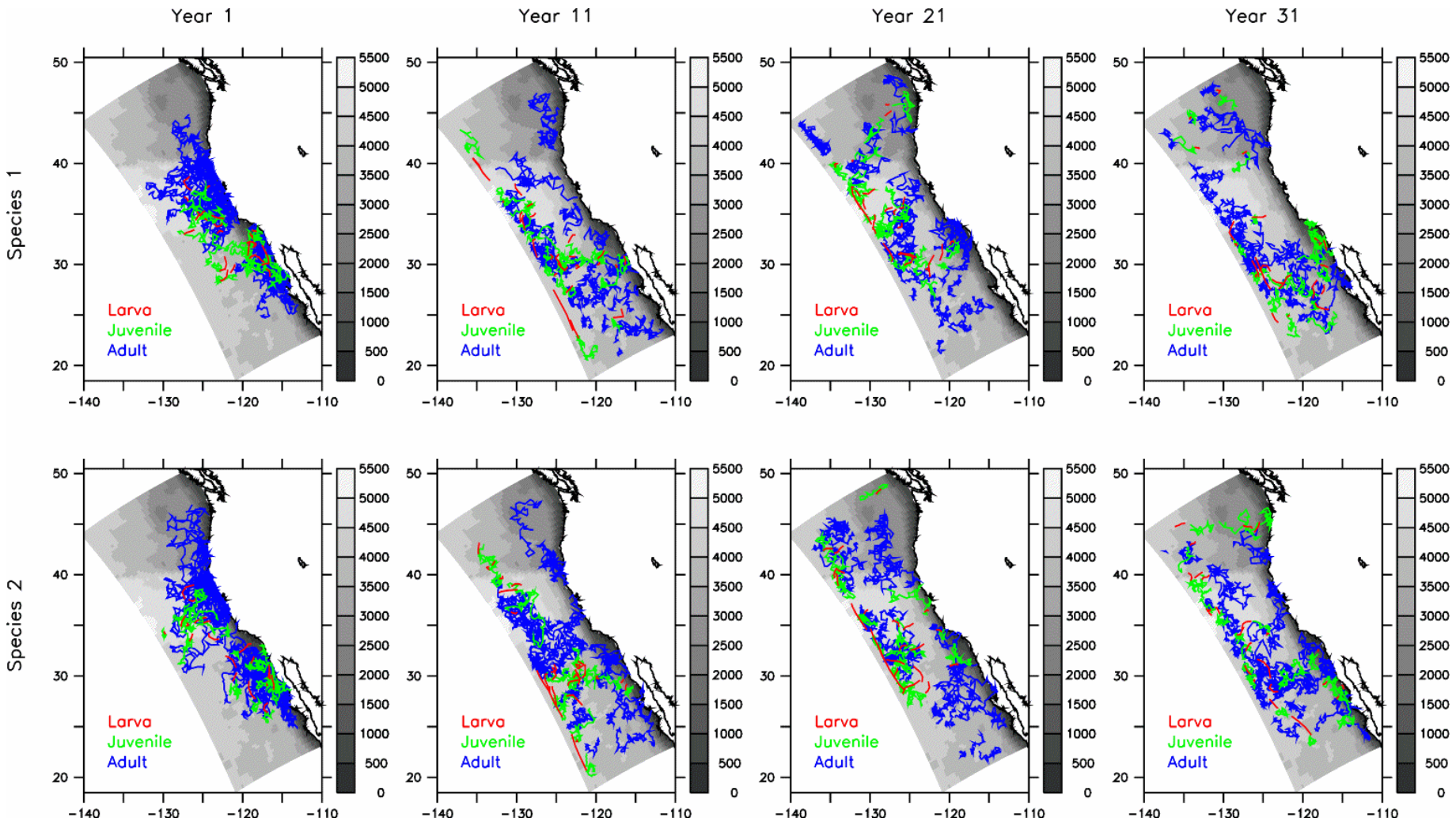

Mean ZPred (1960–2000)
50
40
30
20
−140
−130
−120
−110
0.35
0.325
0.3
0.275
0.25
0.225
0.2
0.175
0.15
0.125
0.1
0.075
0.05
0.025
0



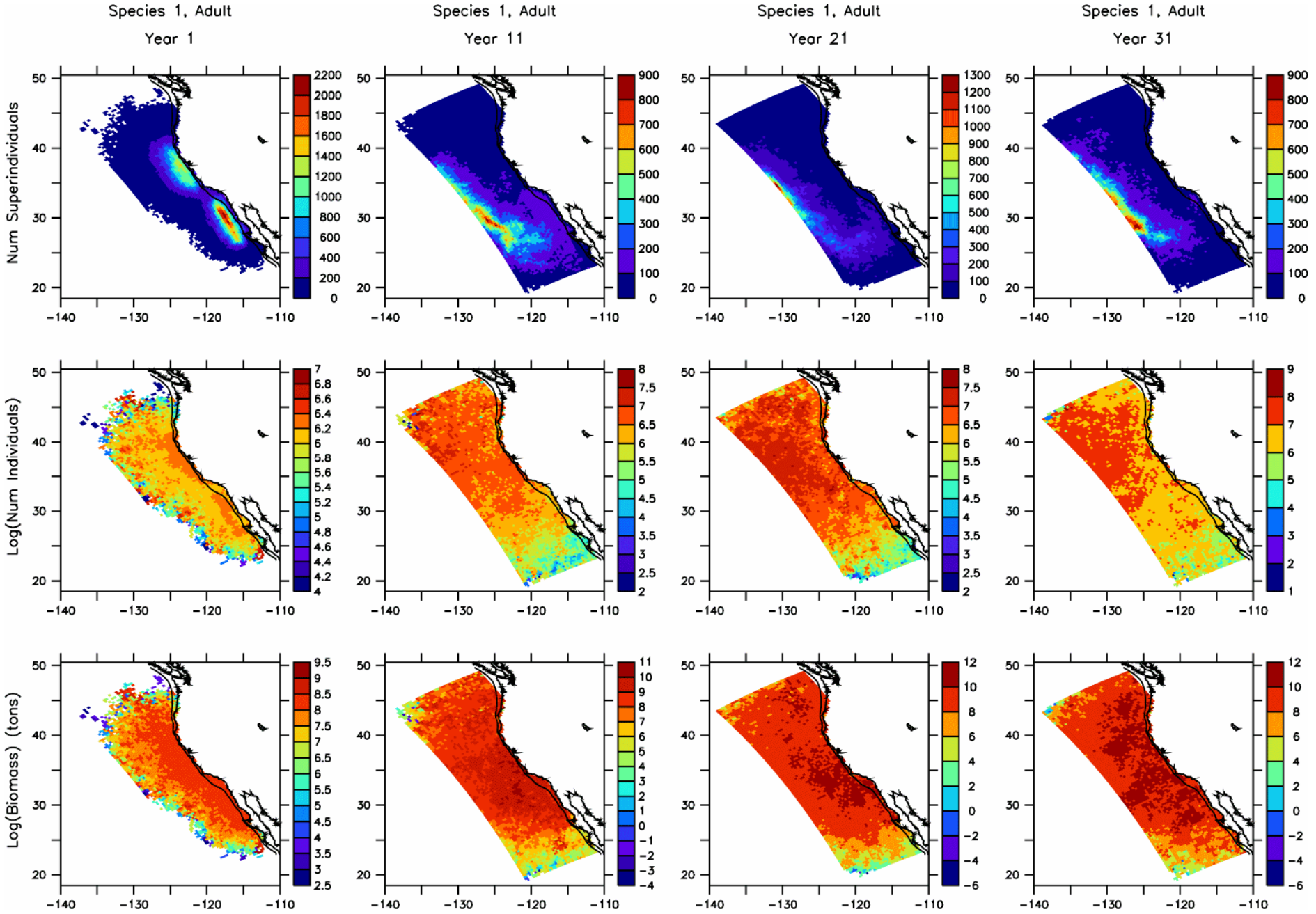
Mean weight on January 1

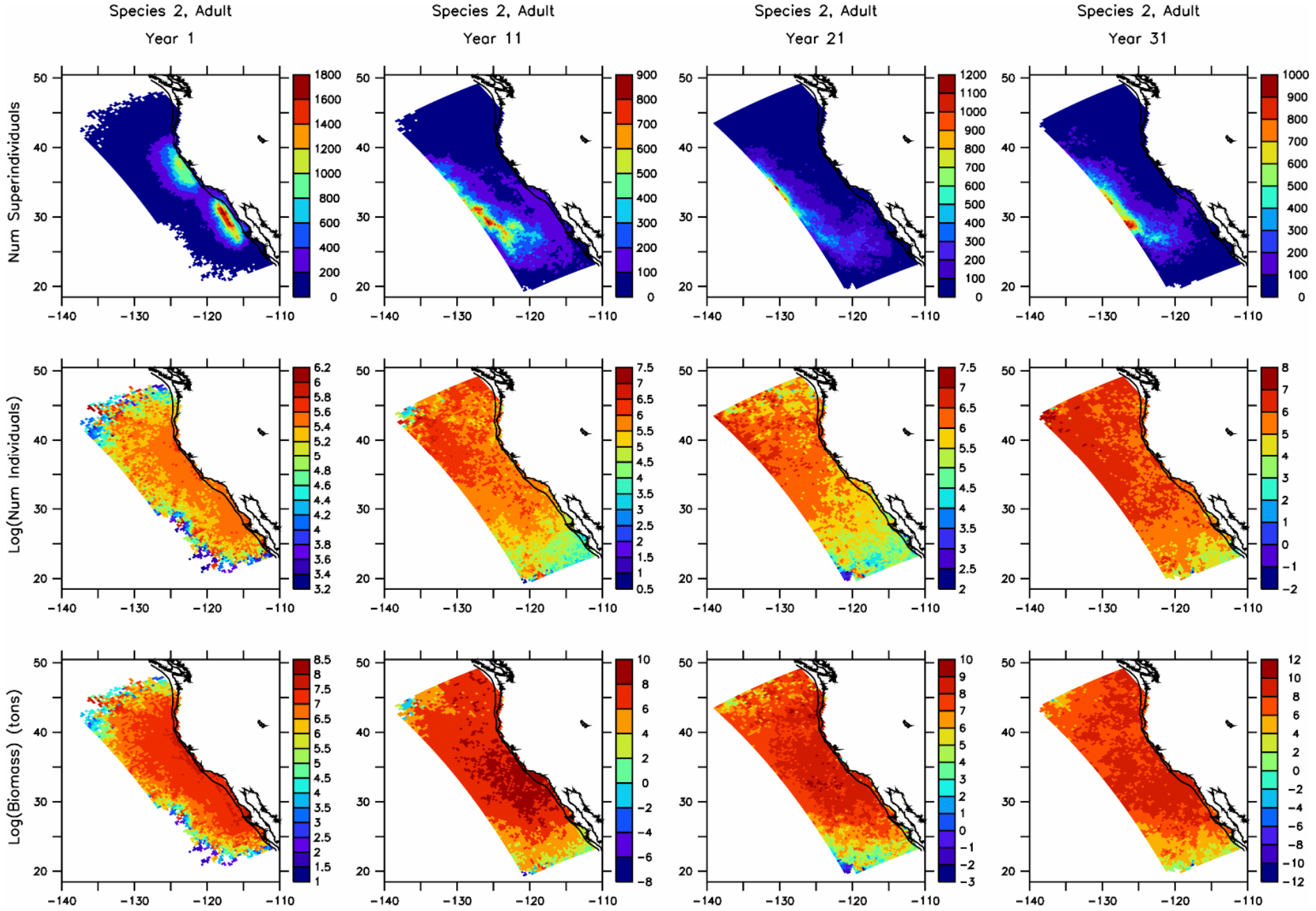
Subadults and Adults every 5 days

Total eggs produced

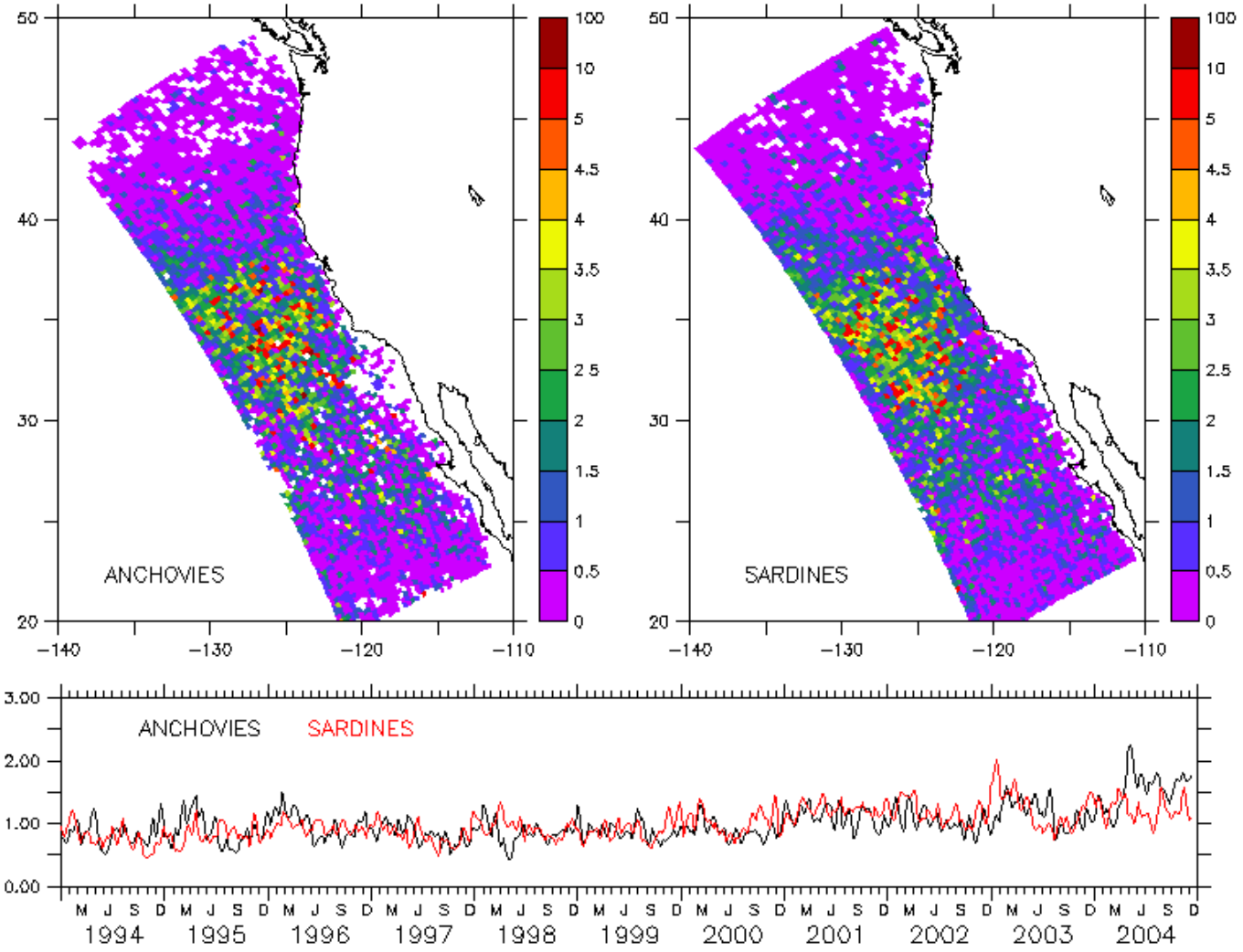


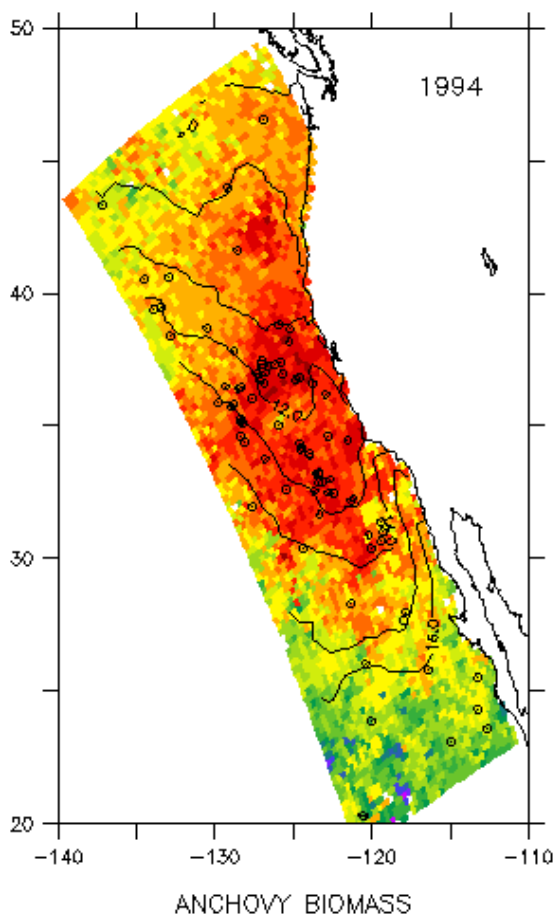
Locations every 5 days for one year
Grey shading shows bottom topography


Species 1, Adult
Year 1
Species 1, Adult
Year 11
Species 1, Adult
Year 21
Species 1, Adult
Year 31
Num Superindividuals
Log(Num Individuals)
Log(Biomass) (tons)

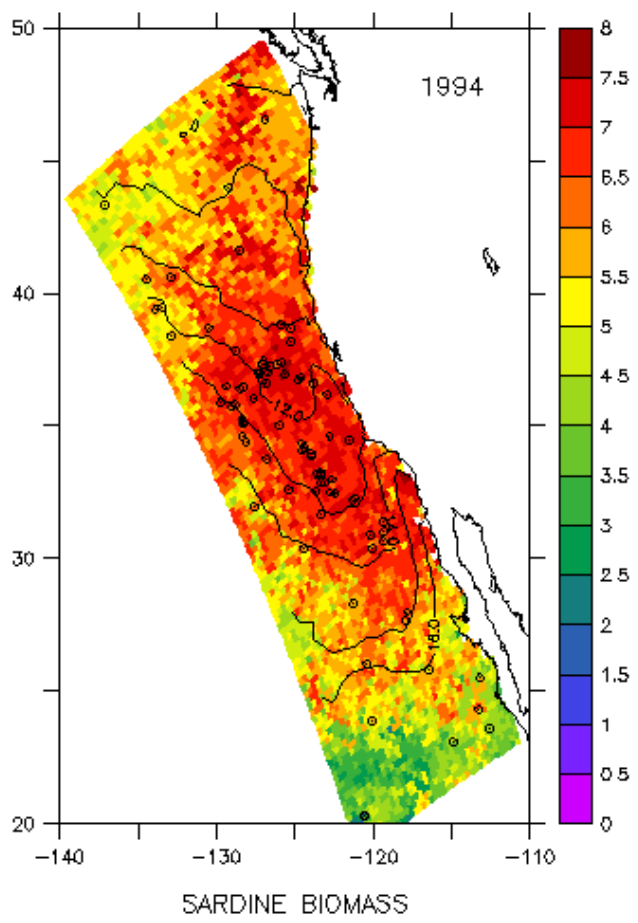

Species 2, Adult
Year 1
Species 2, Adult
Year 11
Species 2, Adult
Year 21
Species 2, Adult
Year 31
Num Superindividuals
Log(Num Individuals)
Log(Biomass) (tons)

SPATIAL AND TEMPORAL RELATIVE PREDATION MORTALITY (1994–2004)

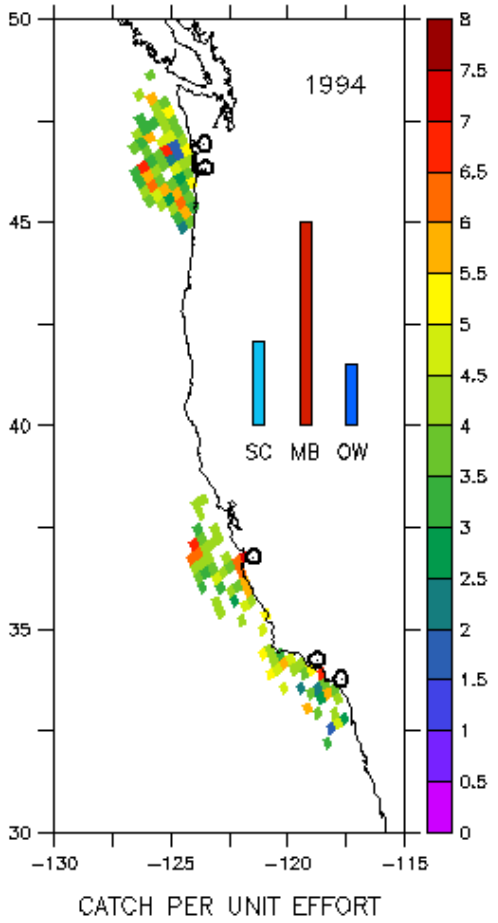




ANCHOVY BIOMASS



SARDINE BIOMASS

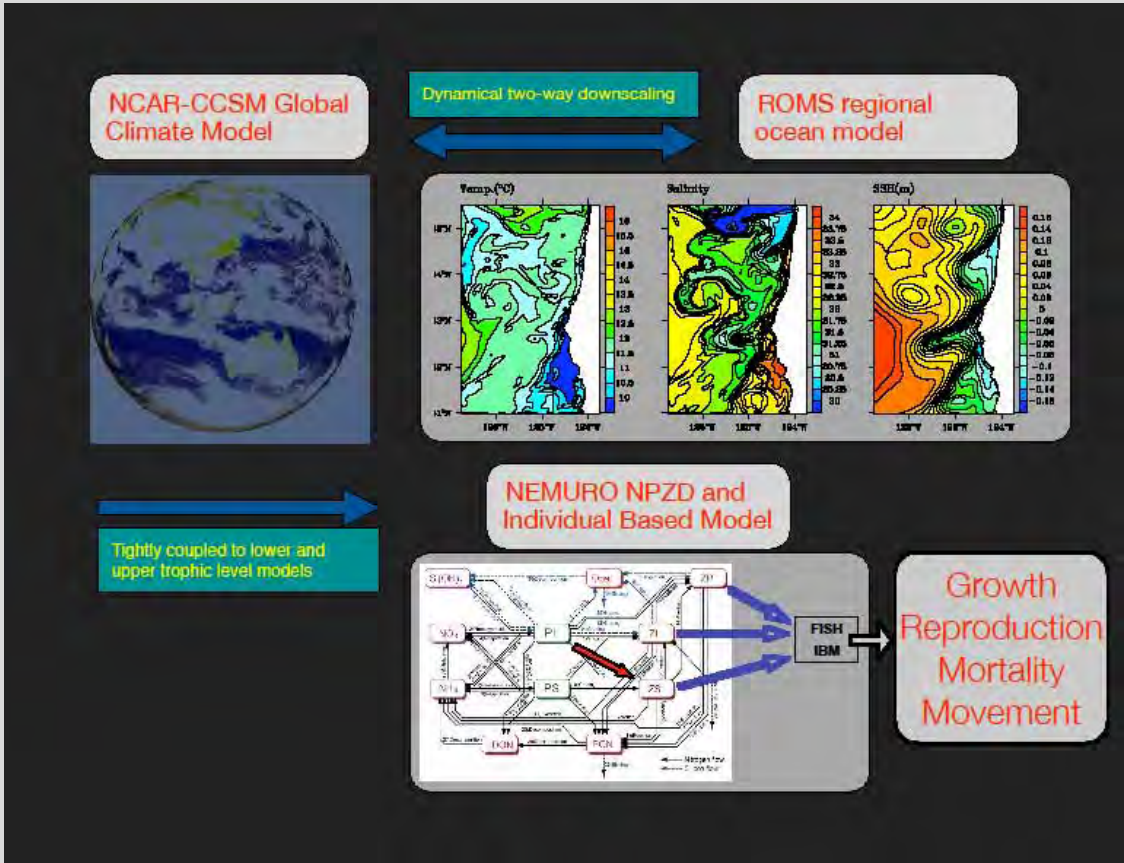


CATCH PER UNIT EFFORT

Biomass is Log(kg) and CPUE is log(kg) per location visited

Next Steps

- It can be done – proof of principle
- Next, is it useful?
- Parallel effort in Japan (Ito-san)
- Earth system model



Data Needs – Title of Symposium

- Long-term monitoring
  - Decadal scale
  - Multiple generations of fish populations
- Spatio-temporal distributions
  - Vertical dynamics (e.g., SST compared to satellite)
  - Lagrangian versus Eulerian
- Zooplankton as a population dynamics
- Behavioral movement

Interdisciplinary Aspects

- Not just for end-to-end models but most all modeling into the future
- Institutional
- People

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

Institutional

- "silo" legacy
  - Different departments, buildings, agencies

- Funding agencies
  - Risk
  - disciplines

$40 million gift from W.M. Keck Foundation to US National Academies (Science 2003)

"To bring about structural changes in funding organizations and academic institutions… to identify shortcomings … that hinder interdisciplinary science"

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

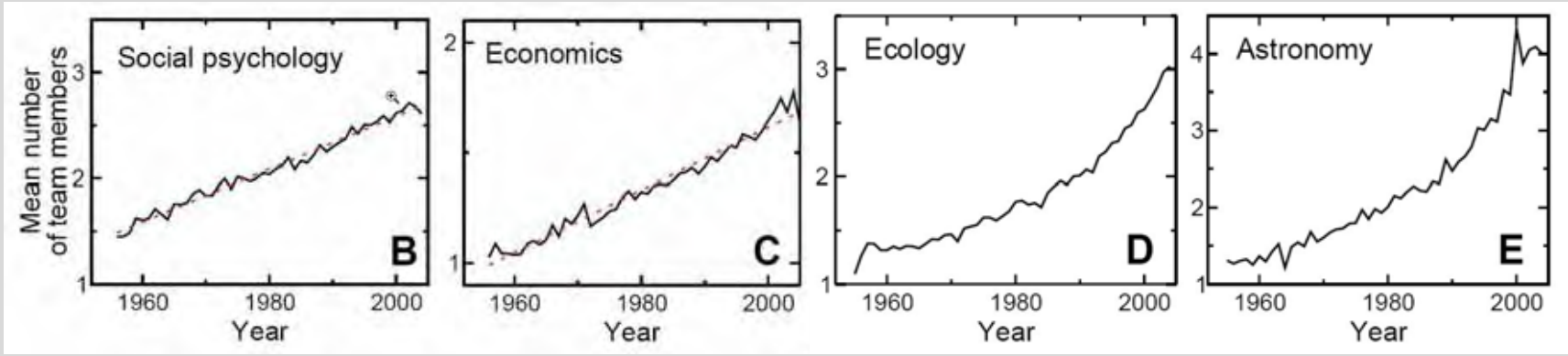
Galileo Newton Darwin Einstein

Crick and Watson

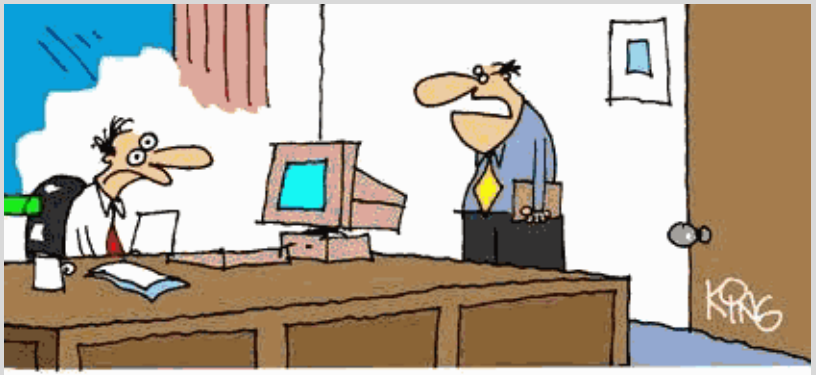
International Human Genome Sequencing Consortium

Barabasi 2005

Guimera et al. 2005



"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."

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

FACILITATING INTERDISCIPLINARY RESEARCH

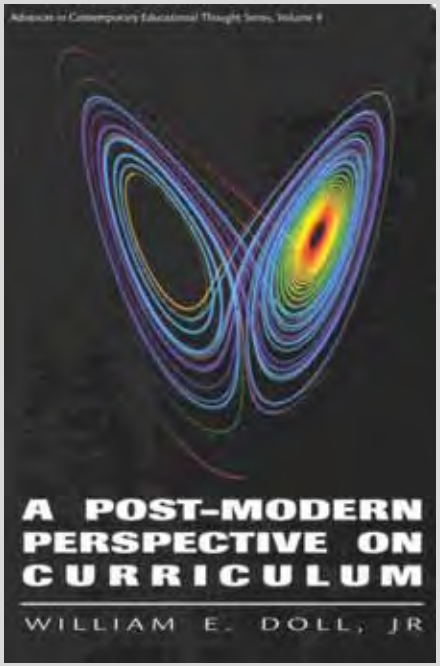
Committee on Facilitating Interdisciplinary Research
Committee on Science, Engineering, and Public Policy

GLOBEC

PICES

Complexity Theory

- Result is not simply sum of the parts
- Nonlinear responses
- Chaos – future irregularity
- We use it for ecological systems but also used for learning



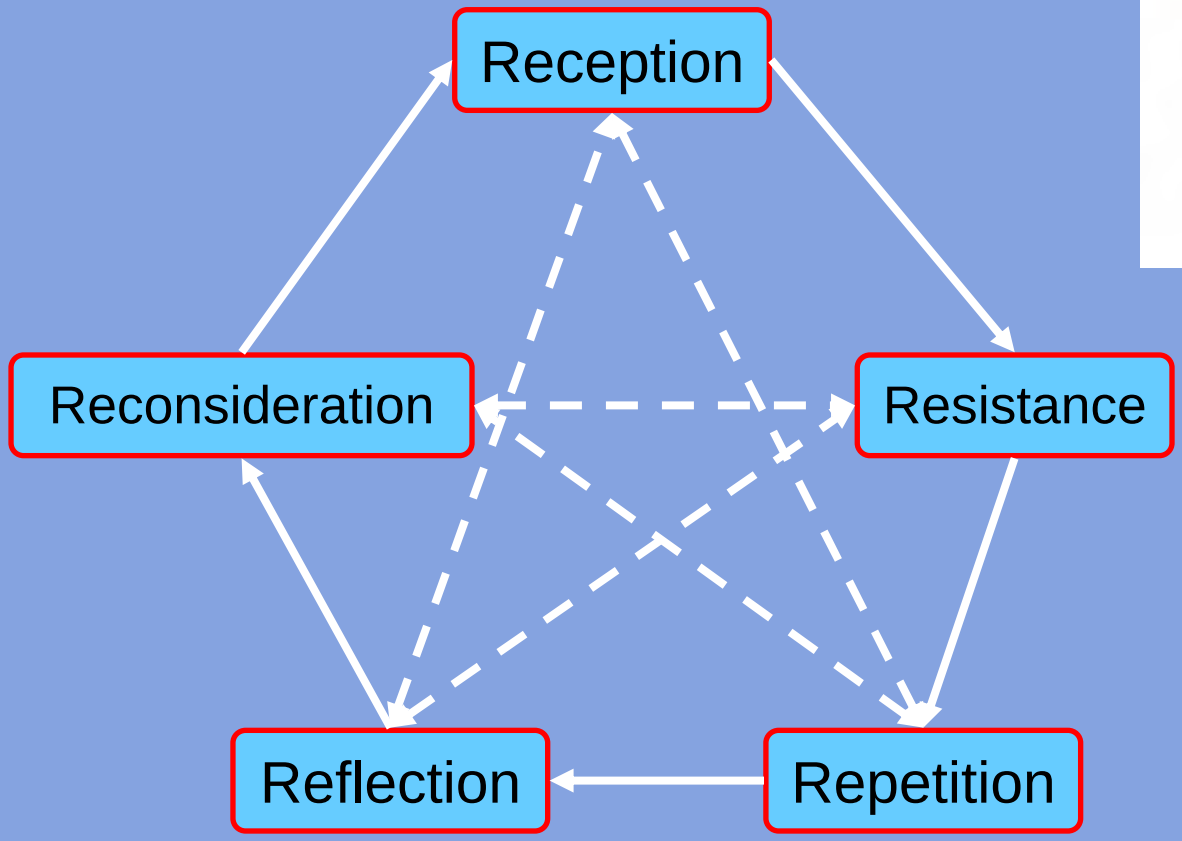
Scientists as Learners

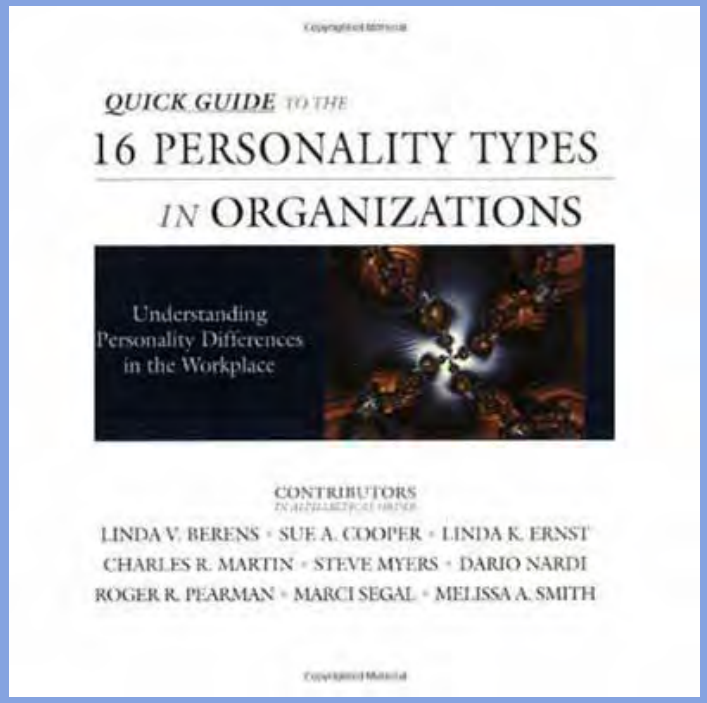
- Group learning can be challenging
  - New unfamiliar methods
  - Challenge to the status quo
- To varying degrees, scientist's positions and opinions are associated with institutional culture, traditions, and personal attachments
- New or unfamiliar knowledge can challenge self-identity, and learners strive for internal stability
- Personalities influence roles people take and group success

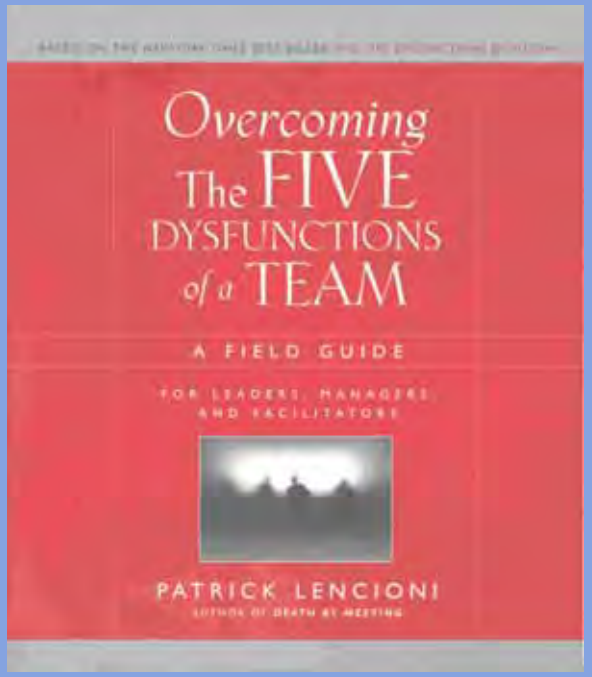
Group Dynamics

- Much already about group dynamics
- Evolution (Adair 1986)
  - Forming – Storming – Norming – Performing
- Group members
  - doer, carer, achiever, thinker, leader
  - monopoliser, silent member, saboteur, habitual joker, know-it-all
  - hubs, diversity, incumbents, newcomers – network analysis to citation indices

Learning Difficult Knowledge (an extreme case) (J. Rose, 2007)







Concluding Remarks

- Listed areas of future advances and areas that have seemingly, in my humble opinion, stalled

- One advancing area is end-to-end models
  - Many technical issues – solvable
  - Proof of principle with sardine and anchovy
  - Mentioned data needs

Concluding Remarks

- Collaboration
  - Important to end-to-end and all modeling
  - I think needs more consideration – too ad hoc
  - Roles people play within a group
  - Scientists as learners

- Hence the title: Can biology and people keep up with computers?

What we want to avoid
in future models

What we want more of
as we develop new models

Rose, K.A., in review. End-to-end models for marine ecosystems: Are we on the precipice of a significant advance or just putting lipstick on a pig? Scientia Marina

Call for Papers

Climate Change and Marine Ecosystem Models

Special Issue of *Ecological Modelling*

Contact one of the guest editors:

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Icarus Allen: jia@pml.ac.uk