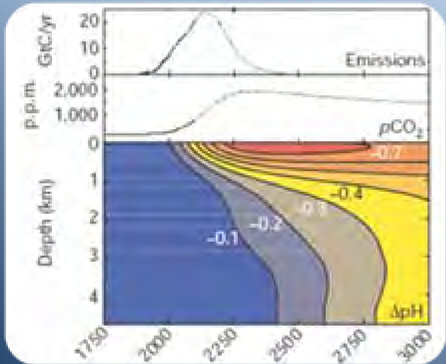

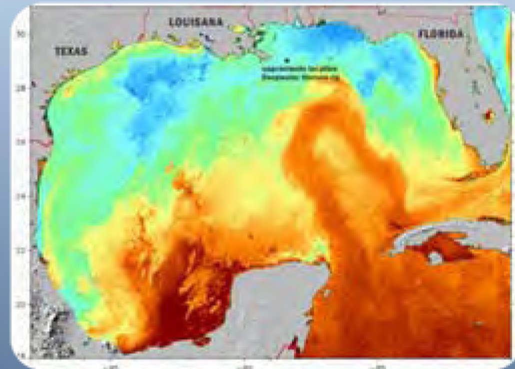

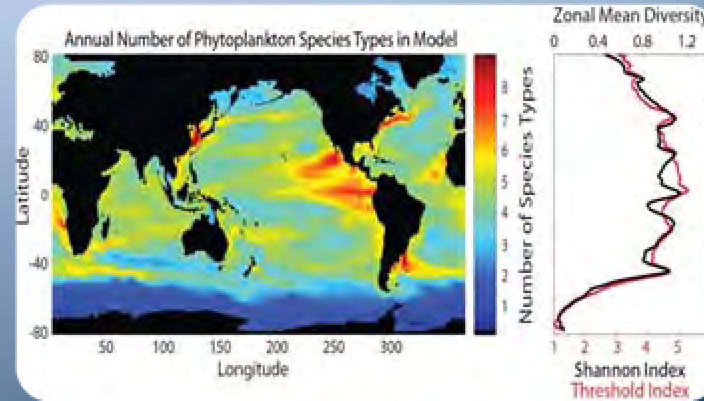

Understanding Ecosystem Processes: The Key to Predicting Climate Effects

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May 26, 2011

Overview

- Considerable recent work on inferring climate impacts from retrospective variability in environmental conditions combined with modeling. Mechanistic relationships imbedded into climate change models with exciting and sobering outcomes

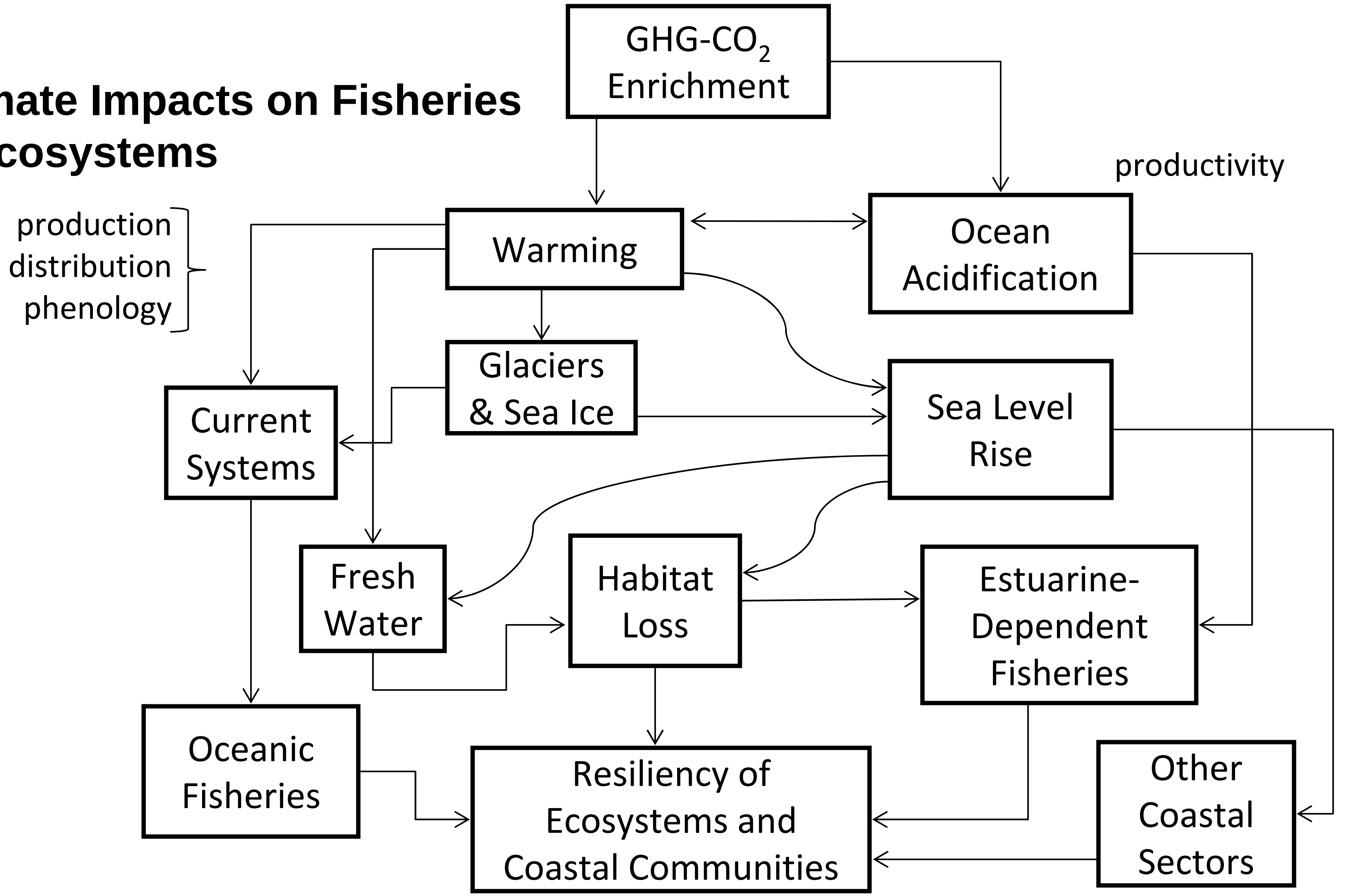
- Global patterns and ecological gradients of productivity, species richness, species distributions, and variability form the patterns of adaptation of biodiversity to the Earth's climate & offer important insights into just how complicated it will be to project warming/GHG induces impacts

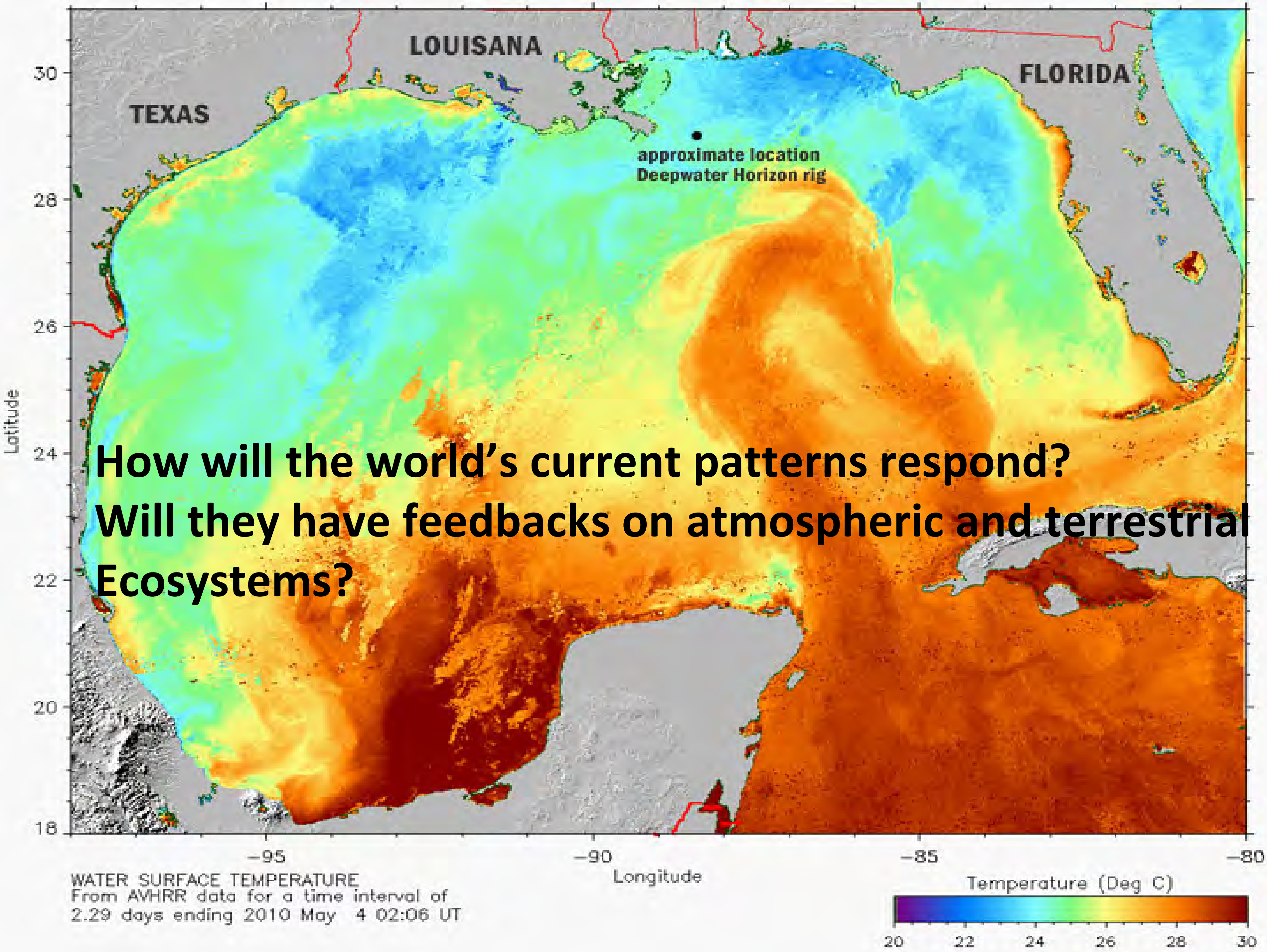
- Complex co-evolved dynamics that defy simple depiction with single drivers

- some example issues:
  - distribution changes of fishes in relation to warming scenarios
  - ocean acidification impacts on biota
  - sea level rise projections

- Comparative studies of ecosystem change in relation to variations in ocean climate offer a powerful way to infer process

Climate Impacts on Fisheries & Ecosystems




LOUISANA
TEXAS
FLORIDA
approximate location
Deepwater Horizon rig
How will the world's current patterns respond?
Will they have feedbacks on atmospheric and terrestrial
Ecosystems?
Latitude
30
28
26
24
22
20
18
−95
−90
−85
−80
Longitude
WATER SURFACE TEMPERATURE
From AVHRR data for a time interval of
2.29 days ending 2010 May 4 02:06 UT
Temperature (Deg C)
20
22
24
26
28
30

Climate Change and Extinction Risks

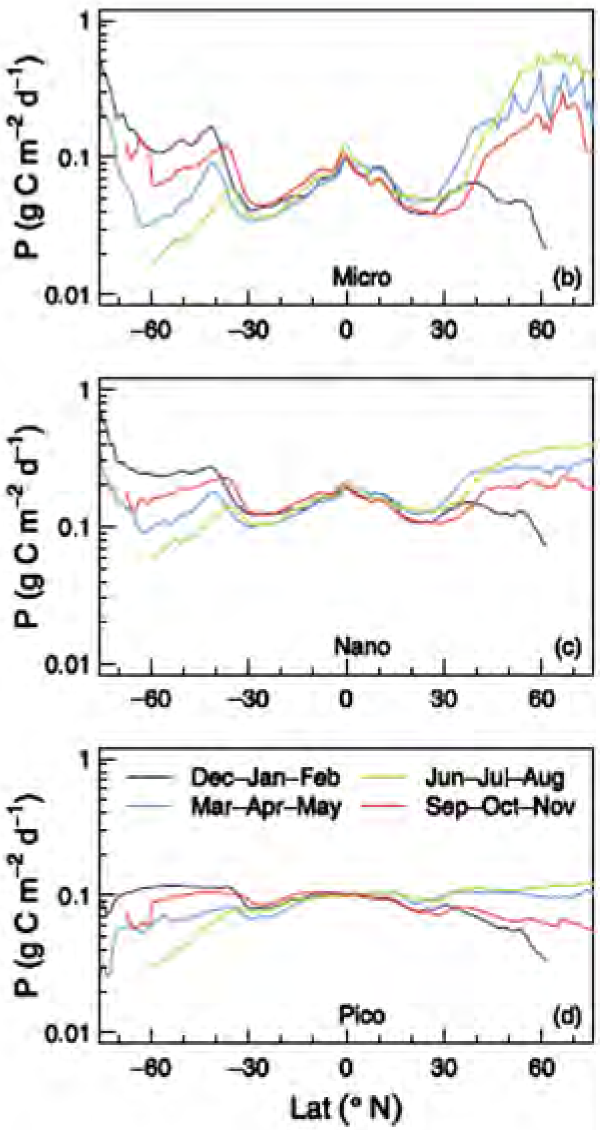
"Approximately 20 to 30% of plant and animal species assessed so far are *likely* to be at increased risk of extinction if increases in global average temperature exceed 1.5 to 2.5°C (*medium confidence*)."

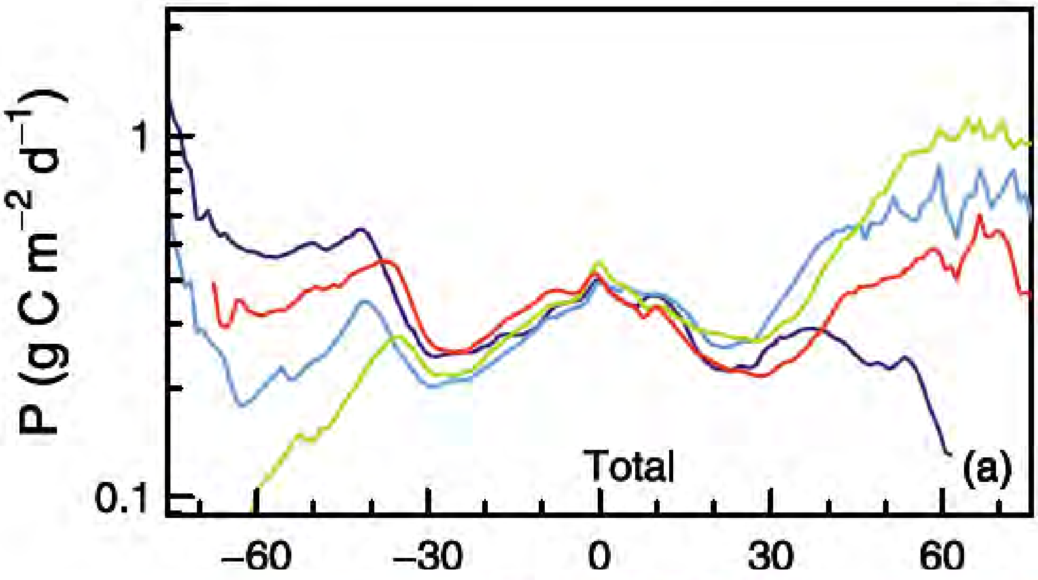
- IPCC Climate Change 2007:Synthesis Report

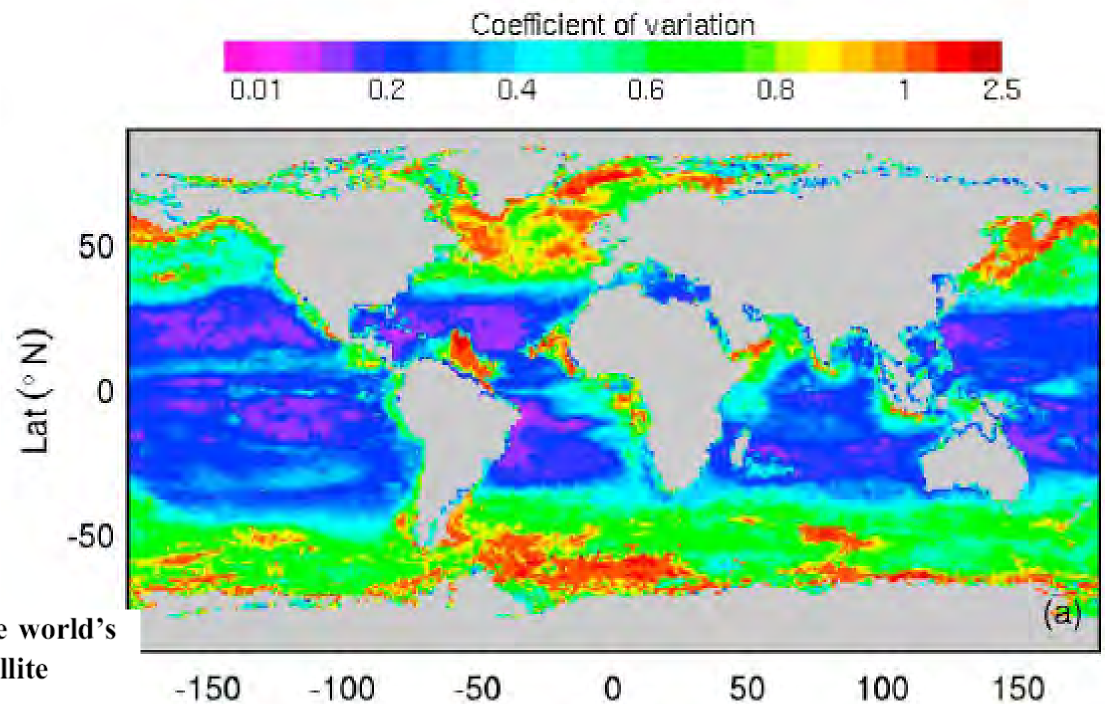
Environmental Gradients & species relationships – evolutionary aspects

- where and how productive are ecosystems?
- how variable are seasonal patterns of productivity?
- how mobile are species to exploit productivity patterns vs. non-preferred conditions? (migration more prominent closer to the poles?)

- what are the geographic patterns of productivity & richness?
- how will these patterns change and over what time scales?
- how will human societies adapt to these changes?



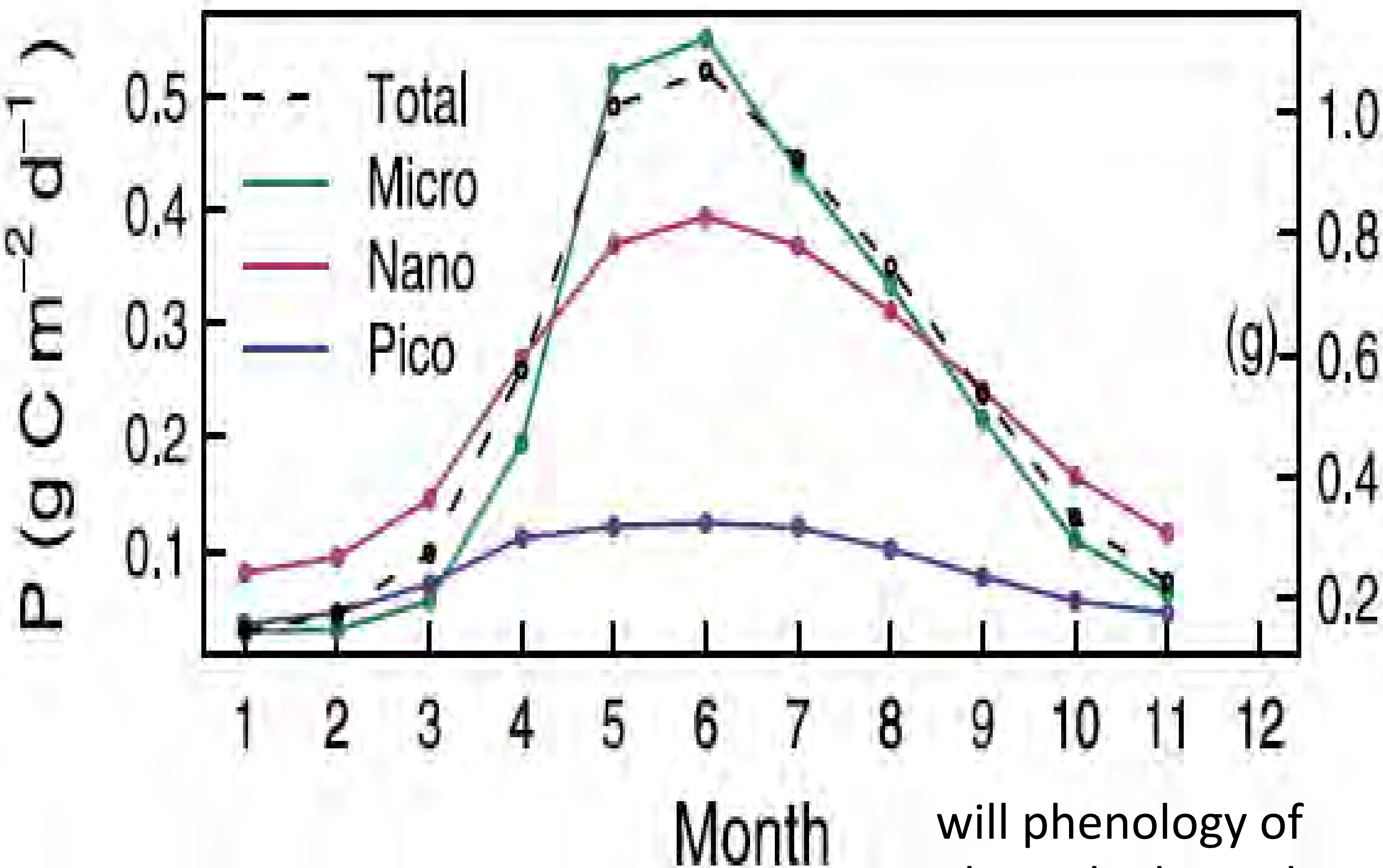




Phytoplankton class-specific primary production in the world's oceans: Seasonal and interannual variability from satellite observations

Julia Uitz,[1] Hervé Claustre,[2] Bernard Gentili,[2] and Dariusz Stramski[1]

CV monthly micro-phytoplankton productivity

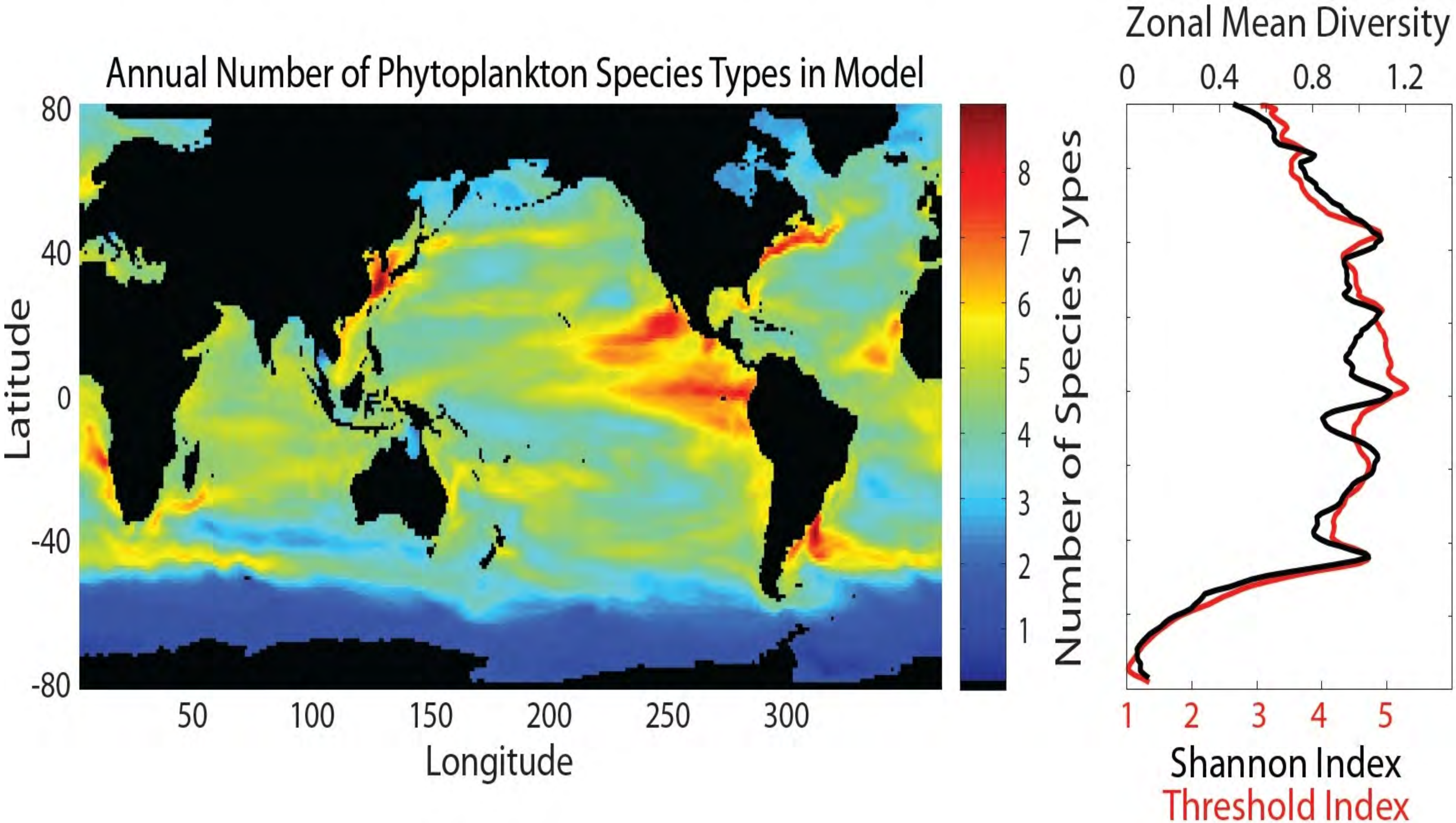


will phenology of phytoplankton change?

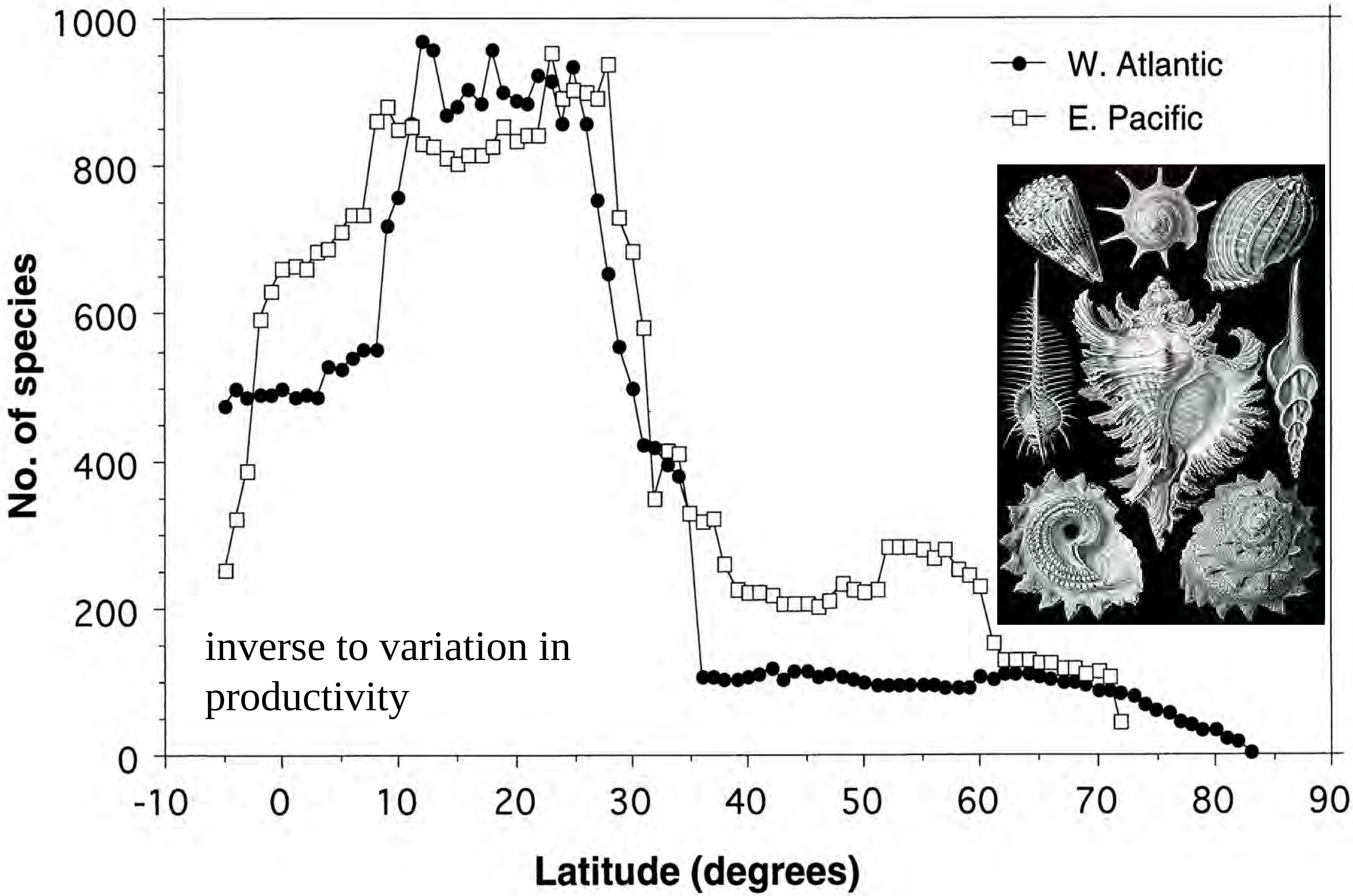
Phytoplankton class-specific primary production in the world's oceans: Seasonal and interannual variability from satellite observations

Julia Uitz,[1] Hervé Claustre,[2] Bernard Gentili,[2] and Dariusz Stramski[1]

Very Few Marine Taxa are Surveyed Synoptically
(in situ and remote sensing)



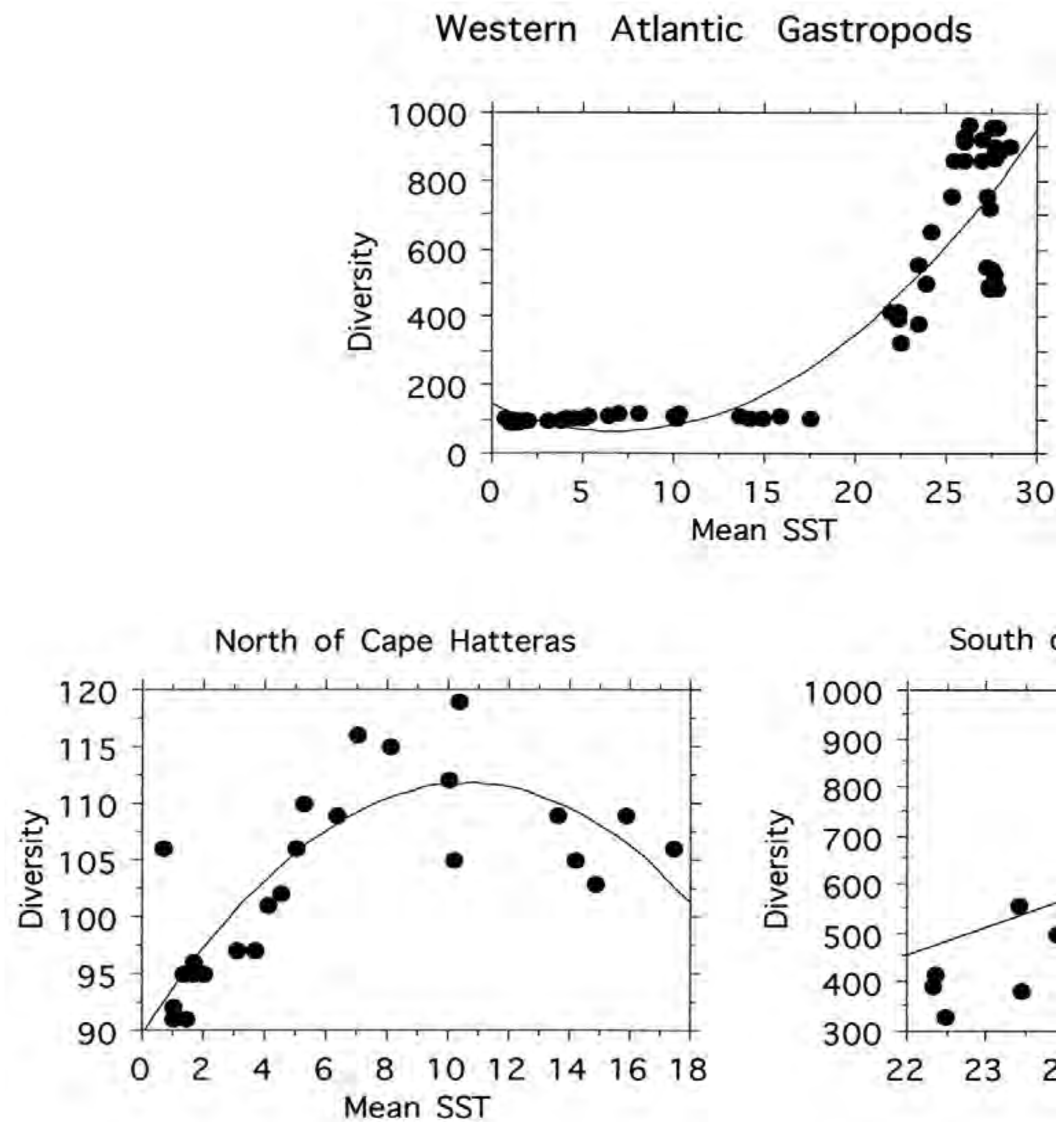
Latitudinal diversity gradient of eastern Pacific (□) and western Atlantic (•) marine prosobranch gastropods, binned per degree of latitude.



Marine latitudinal diversity gradients: Tests of causal hypotheses Roy et al. 1998

PNAS

Relationships between mean annual SST and diversity for western Atlantic marine gastropods.



N.B., Seasonal variability inversely correlated with Mean SST

Roy K et al. PNAS 1998;95:3699-3702

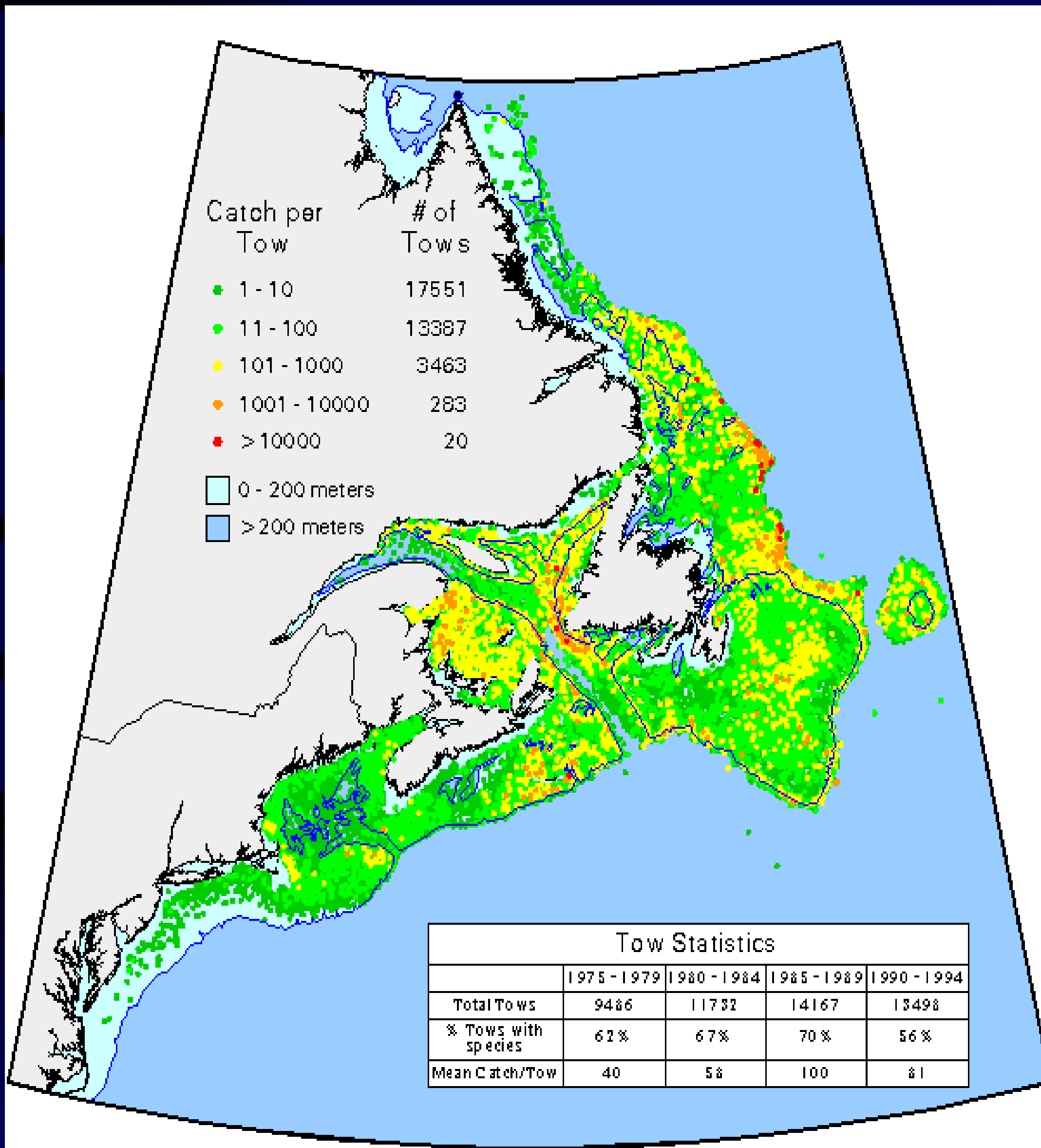
How will Patterns of Species Distribution Change in Relation to Warming?

Complicated by many confounding factors:
- abundance changes (e.g., “basin” hypothesis of McCall)
- fishing effects (cod in the western Atlantic)
- predation effects (do predatory fishes “prefer” their dominant prey over their optimal temperatures?)

On land, species of plants can substitute altitude for latitude

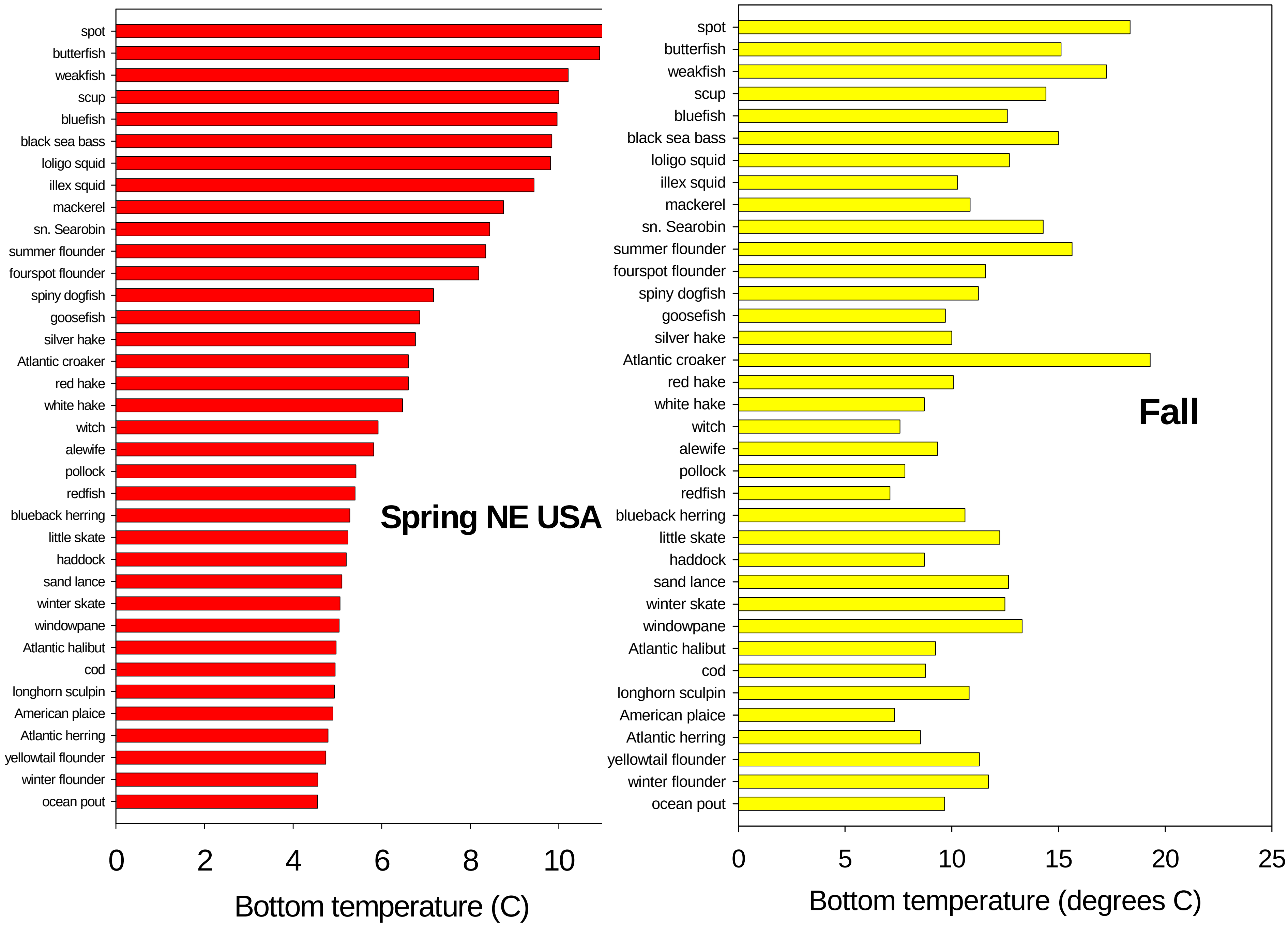
In the ocean species can in some cases substitute depth for latitude & potential for demersal species to become more pelagic

Atlantic Cod in the NW Atlantic – 12 management Units

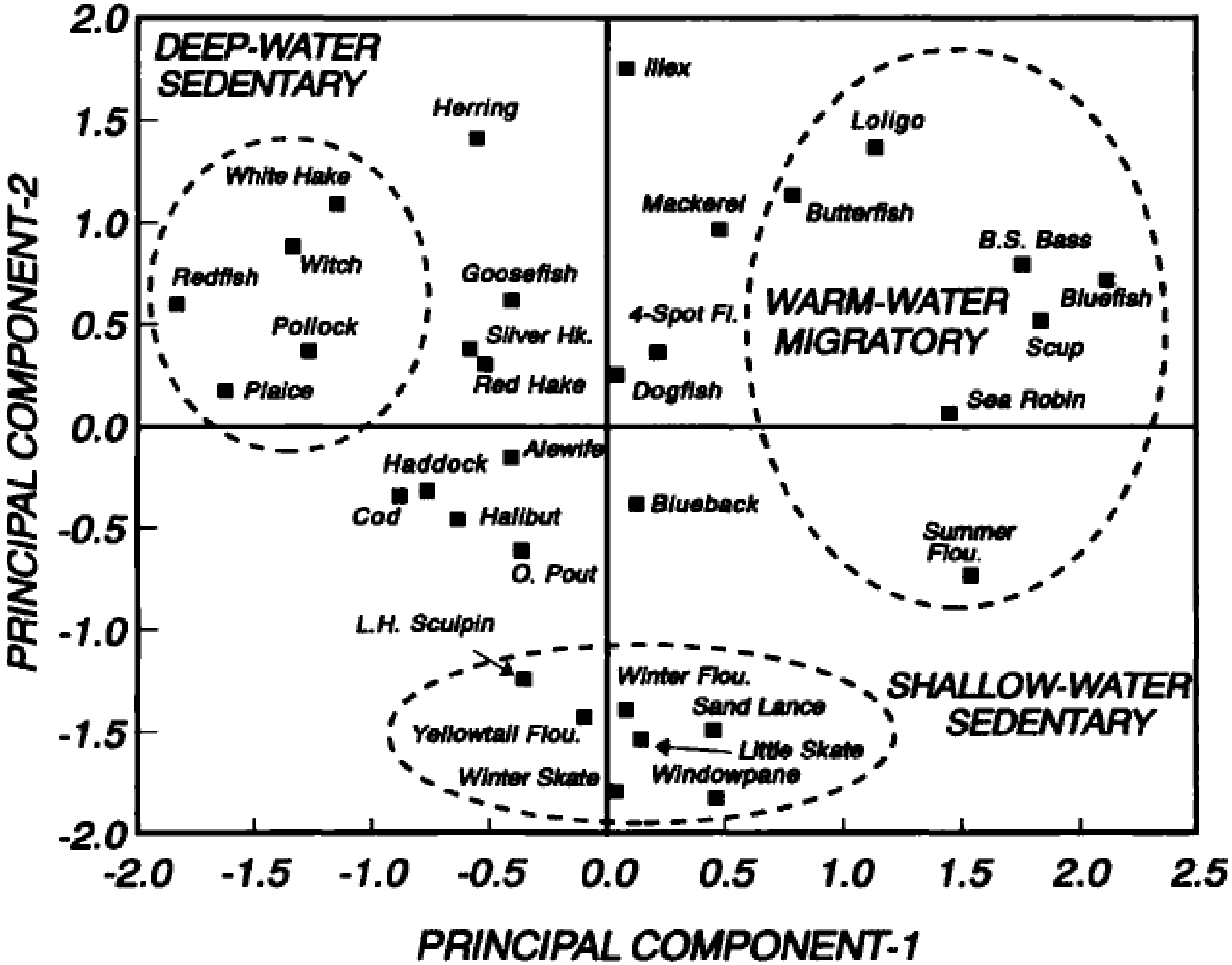


Tow Statistics

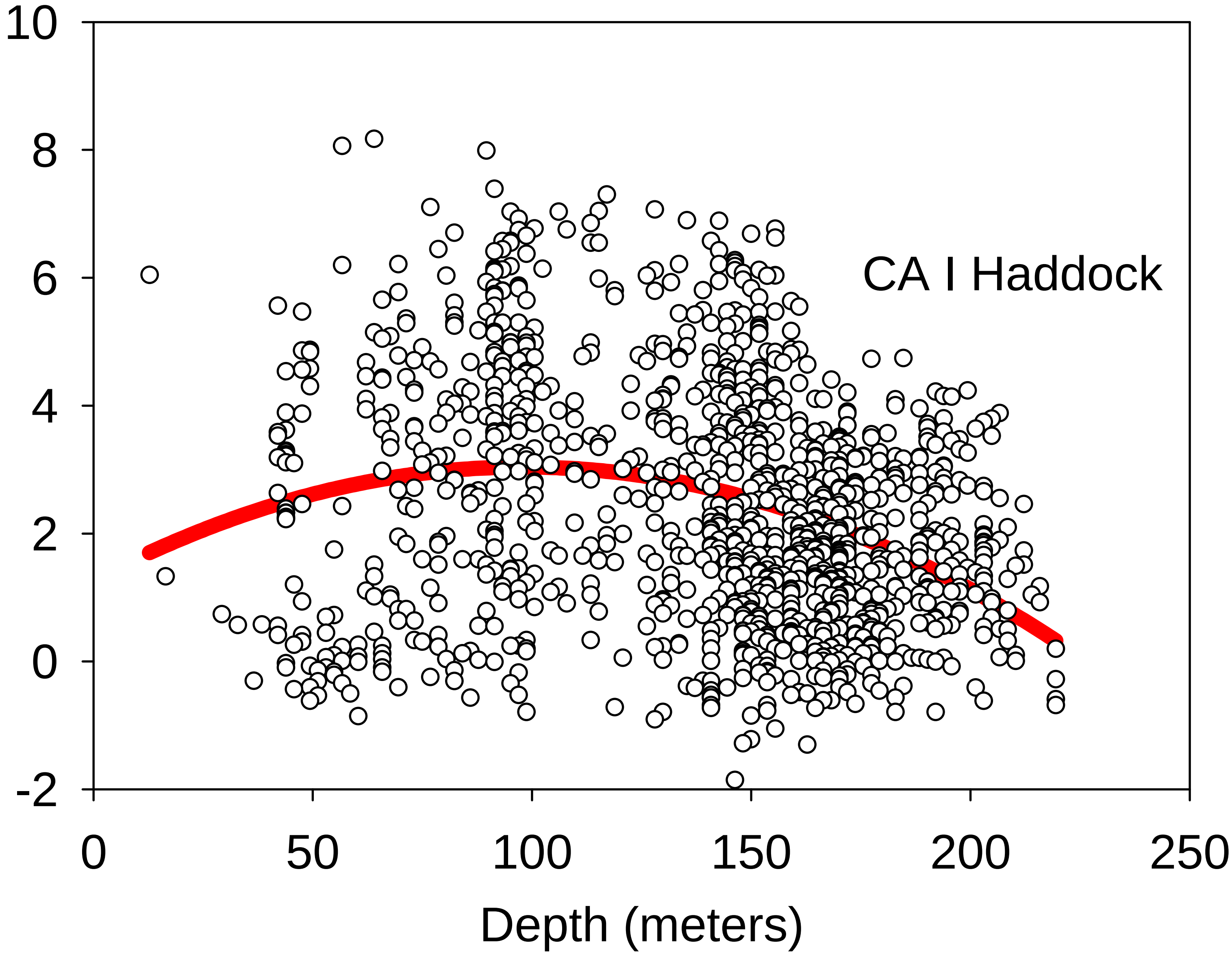
	1975 - 1979	1980 - 1984	1985 - 1989	1990 - 1994
Total Tows	9486	11732	14167	13498
% Tows with species	62%	67%	70%	56%
Mean Catch/Tow	40	58	100	81


spot
butterfish
weakfish
scup
bluefish
black sea bass
loligo squid
illex squid
mackerel
sn. Searobin
summer flounder
fourspot flounder
spiny dogfish
goosefish
silver hake
Atlantic croaker
red hake
white hake
witch
alewife
pollock
redfish
blueback herring
little skate
haddock
sand lance
winter skate
windowpane
Atlantic halibut
cod
longhorn sculpin
American plaice
Atlantic herring
yellowtail flounder
winter flounder
ocean pout
Spring NE USA
0
2
4
6
8
10
Bottom temperature (C)
Fall
0
5
10
15
20
25
Bottom temperature (degrees C)

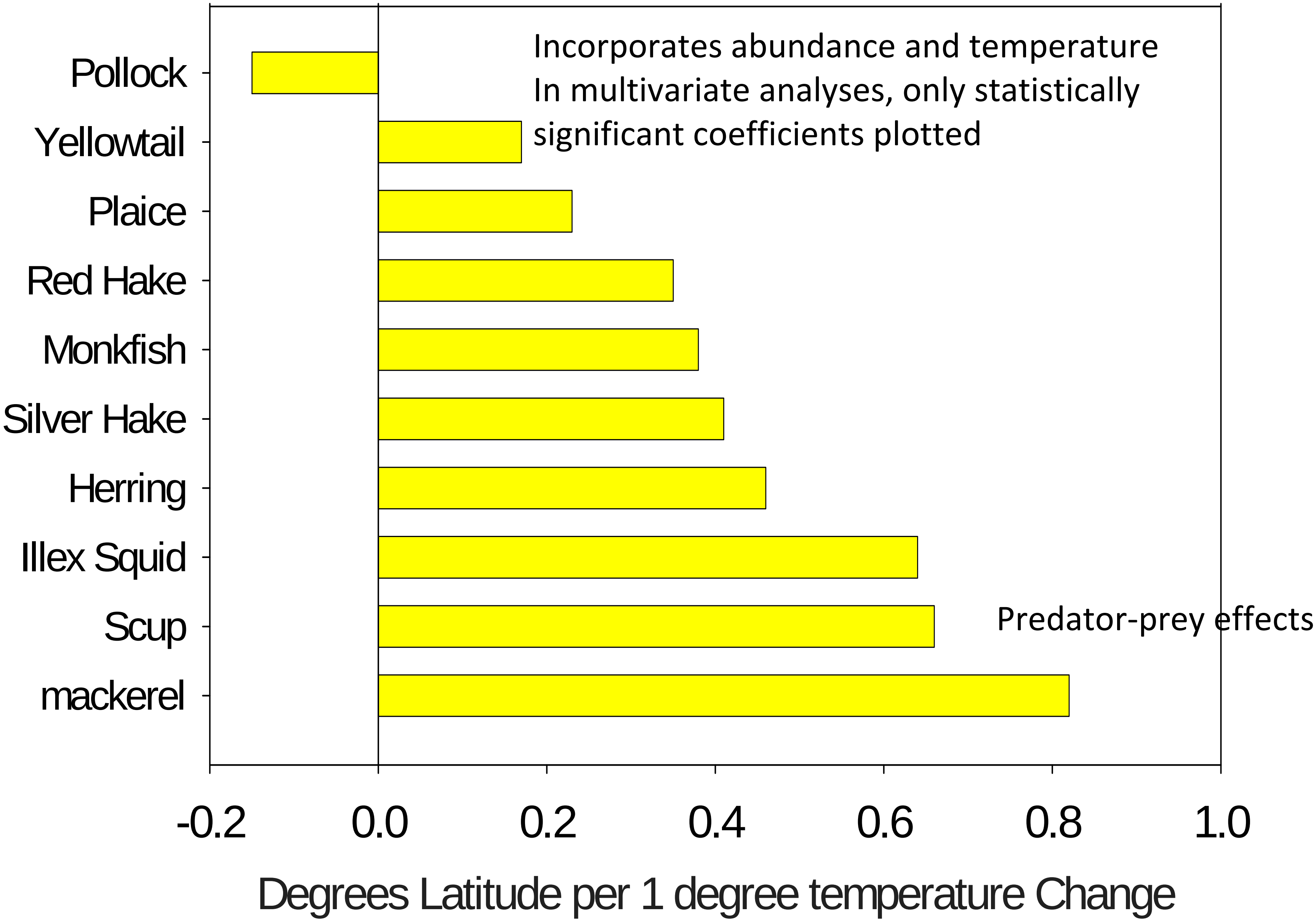
Life history types more or less sensitive to warming scenarios



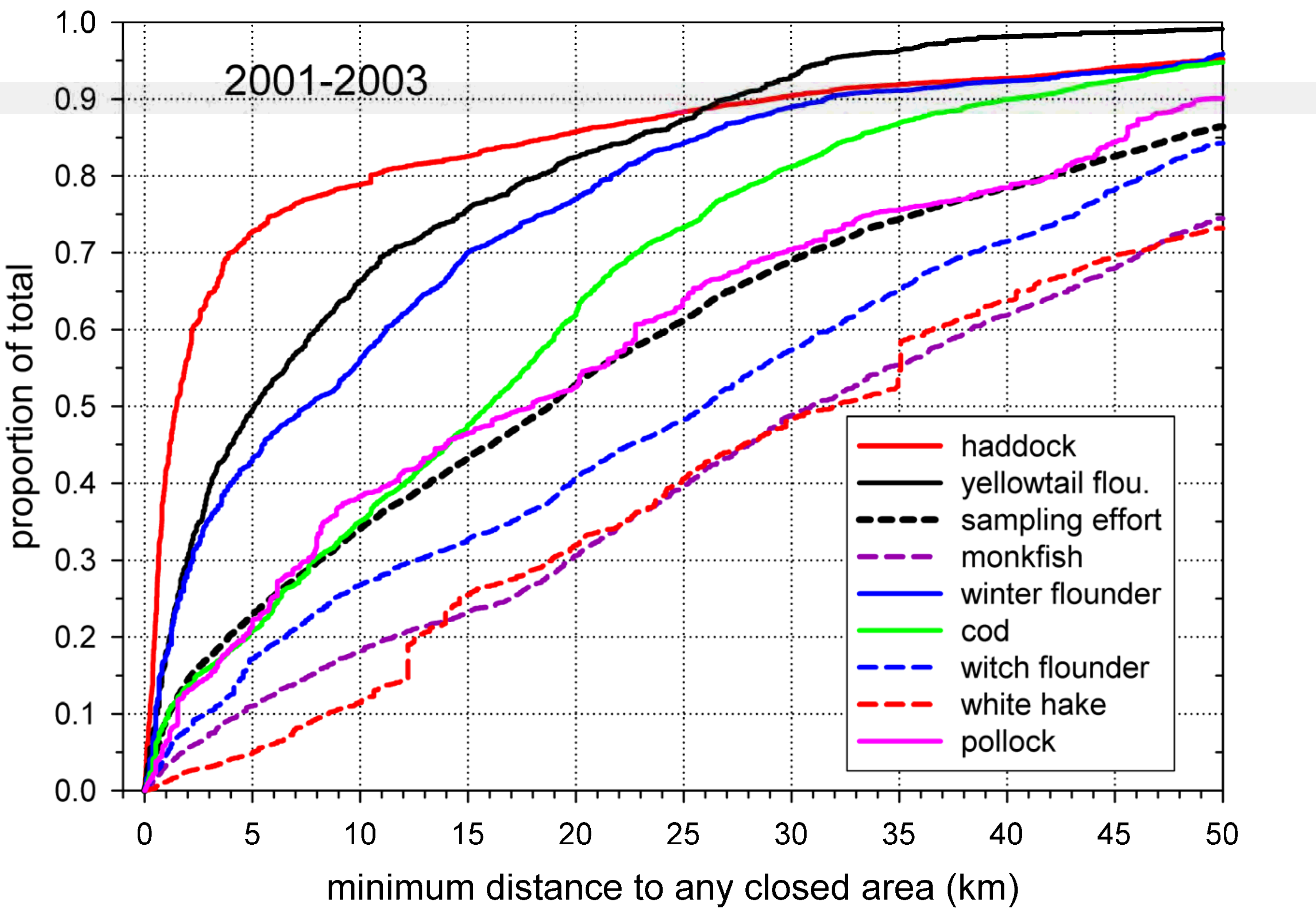
Considerable variation around the mean for some species and life stages In environmental preferences (ln CPUE by depth)



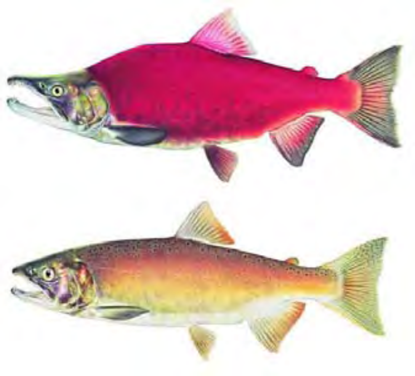
Western North Atlantic off USA & Canada



How do we measure "preferences"? Factor out available space

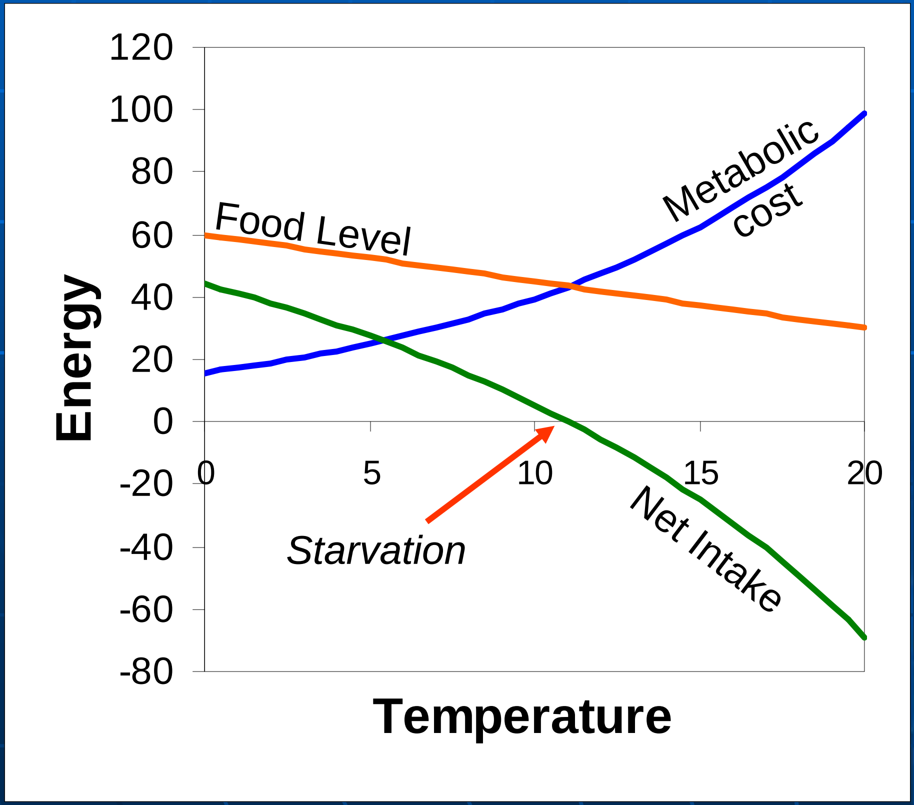


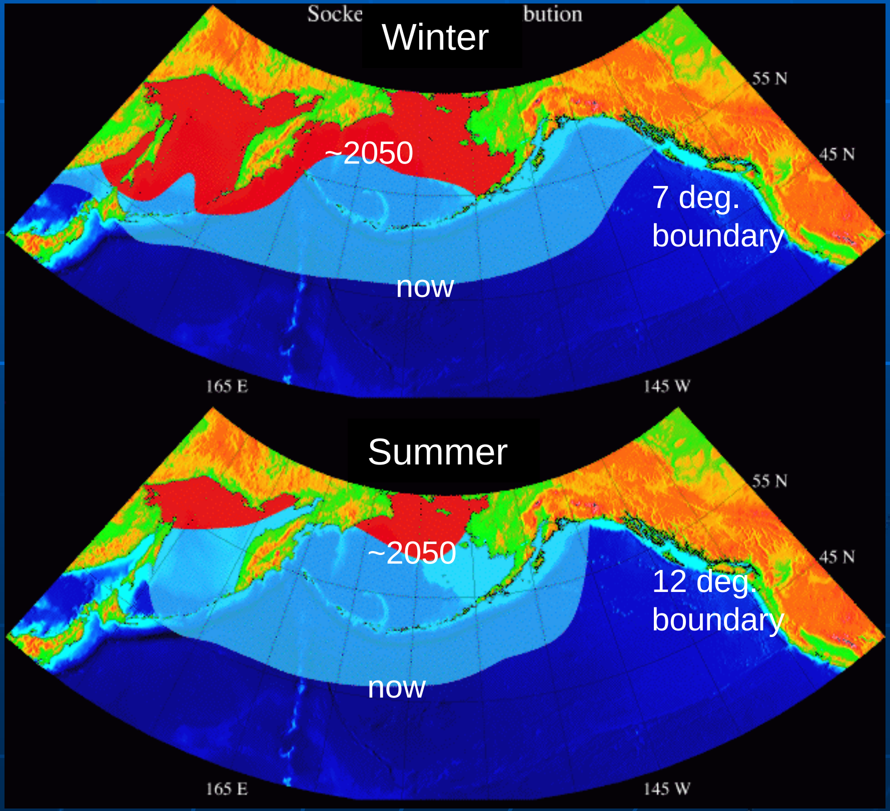
Confounded by ecophysiology: Potential Changes in Sockeye Salmon Distribution



Sockeye Salmon spend ~2-3 y in the NE Pacific and Bering Sea

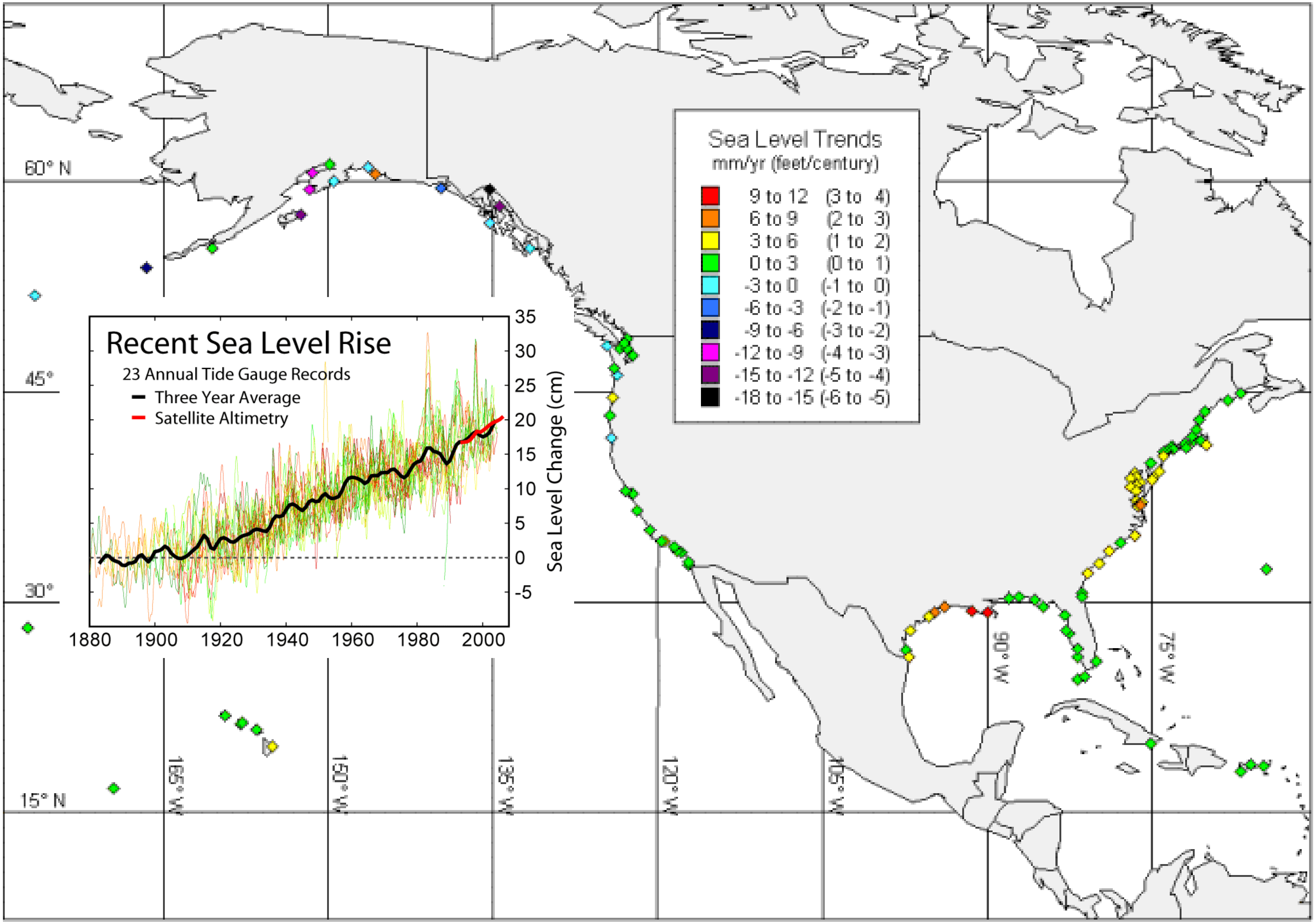
- Migrate northward in summer, southward in winter
- Food availability greatest in summer, but decreases with warmer temperature
- Metabolic costs increase exponentially with temperature.
- Net intake drops to <0 (beginning starvation) at warmer temperatures





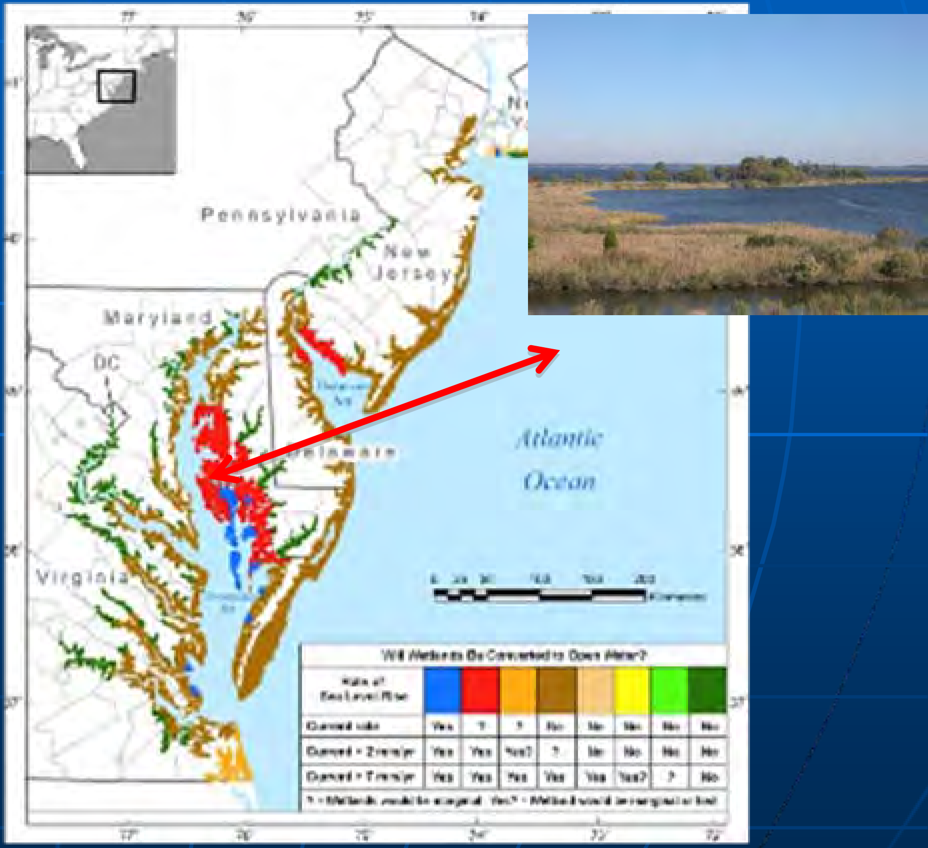
Welch et al. 1998

Trends in Sea Level Rise & Potential Resource Impacts



Chesapeake Bay: Essential Fish Habitat - Wetland impacts of SLR

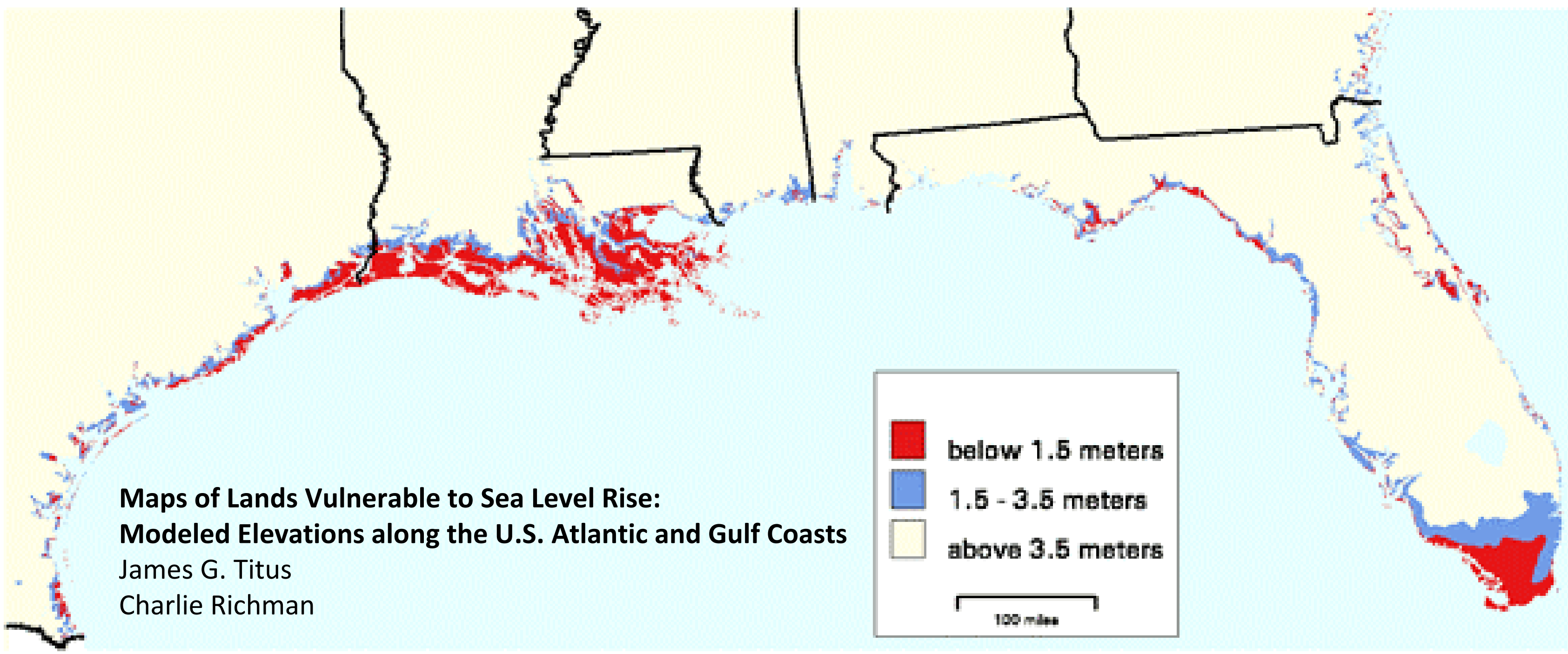
- Much of the most vulnerable low lying land around the Chesapeake Bay is currently wetland
- Even current rate of sea level rise in the Bay is often outpacing the ability of wetlands to maintain themselves
- Projected rates of sea level rise would inundate 80-90% of existing wetlands
- Under this scenario, the region would lose:
  - More than 167,000 acres of undeveloped dry land
  - 58% of beaches along ocean coasts
  - 69% of estuarine beaches along the bay
  - 161,000 acres of brackish marsh
  - More than half of the region’s important tidal swamp



Wetland survival in response to three sea level rise scenarios (Reed et al., 2007)

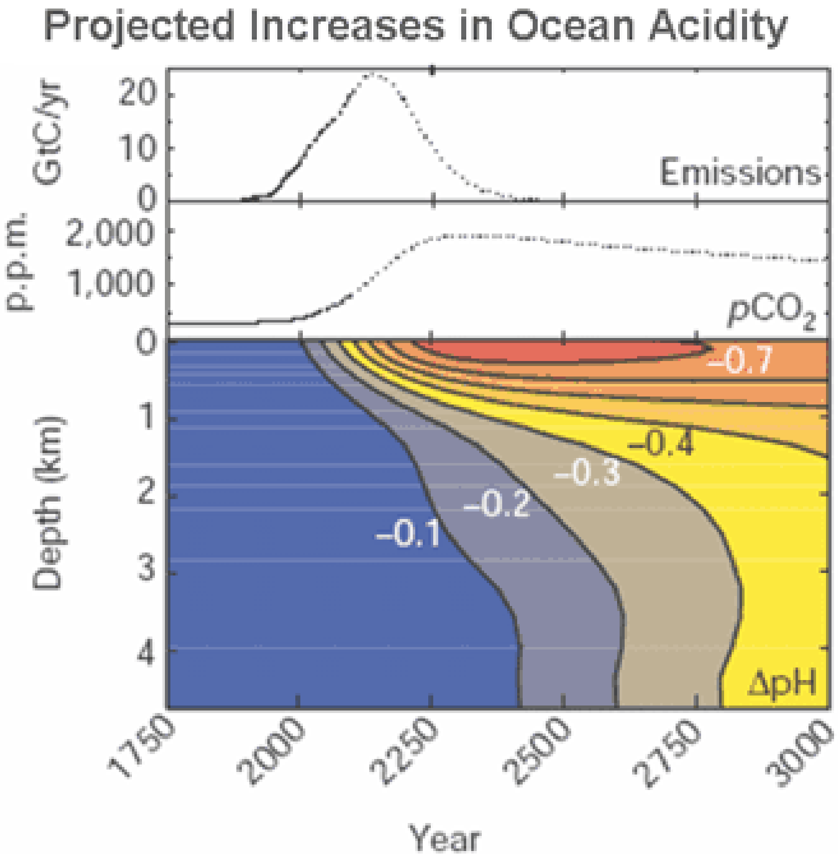
Barataria Bay

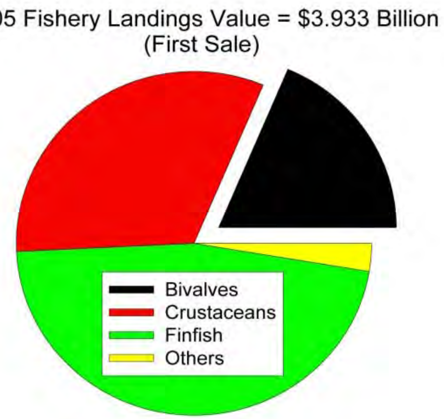
Beware just filling up the bath tub!



Maps of Lands Vulnerable to Sea Level Rise:
Modeled Elevations along the U.S. Atlantic and Gulf Coasts
James G. Titus
Charlie Richman

Ocean Acidification: Scenarios and impacts on biota

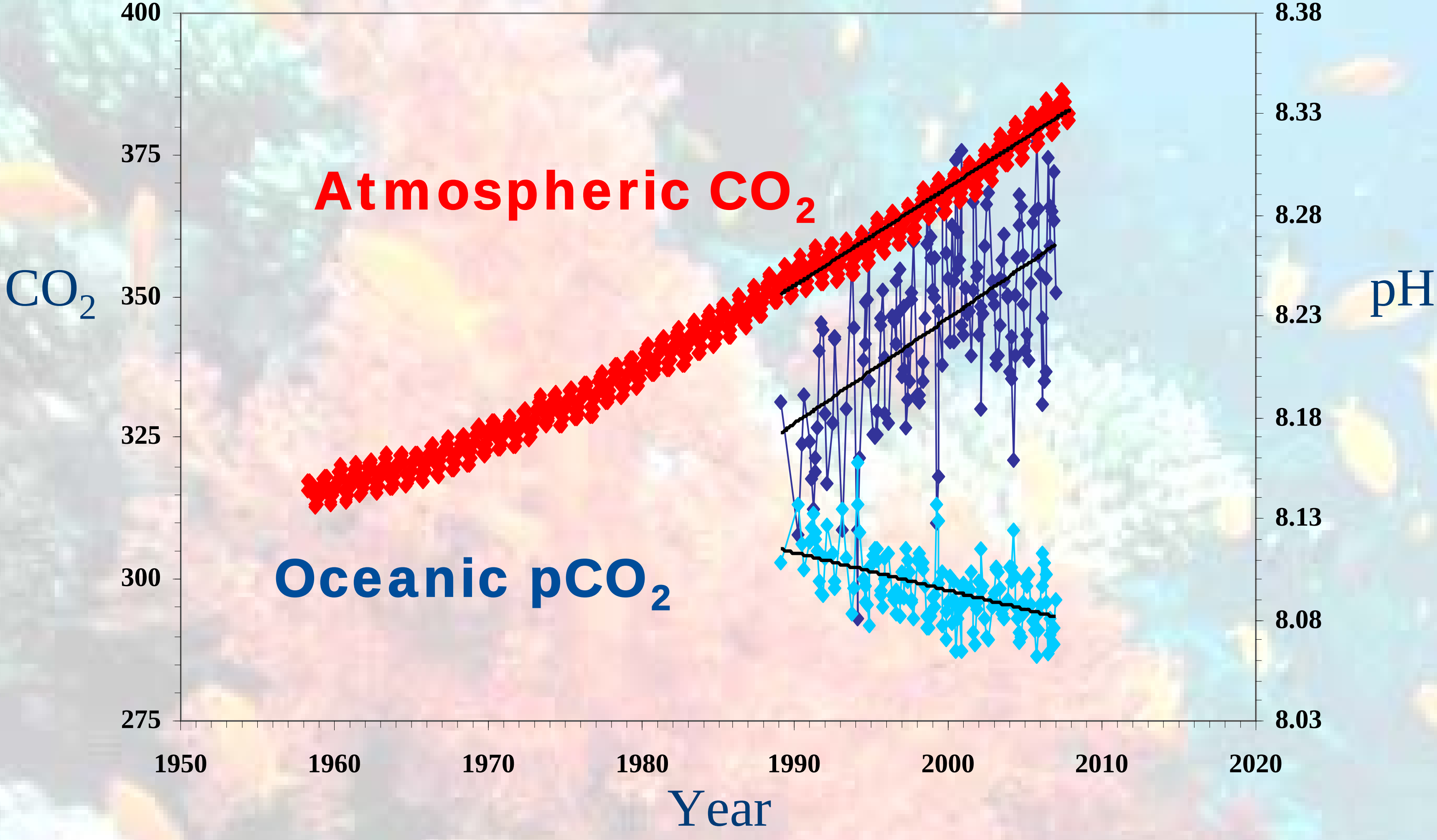




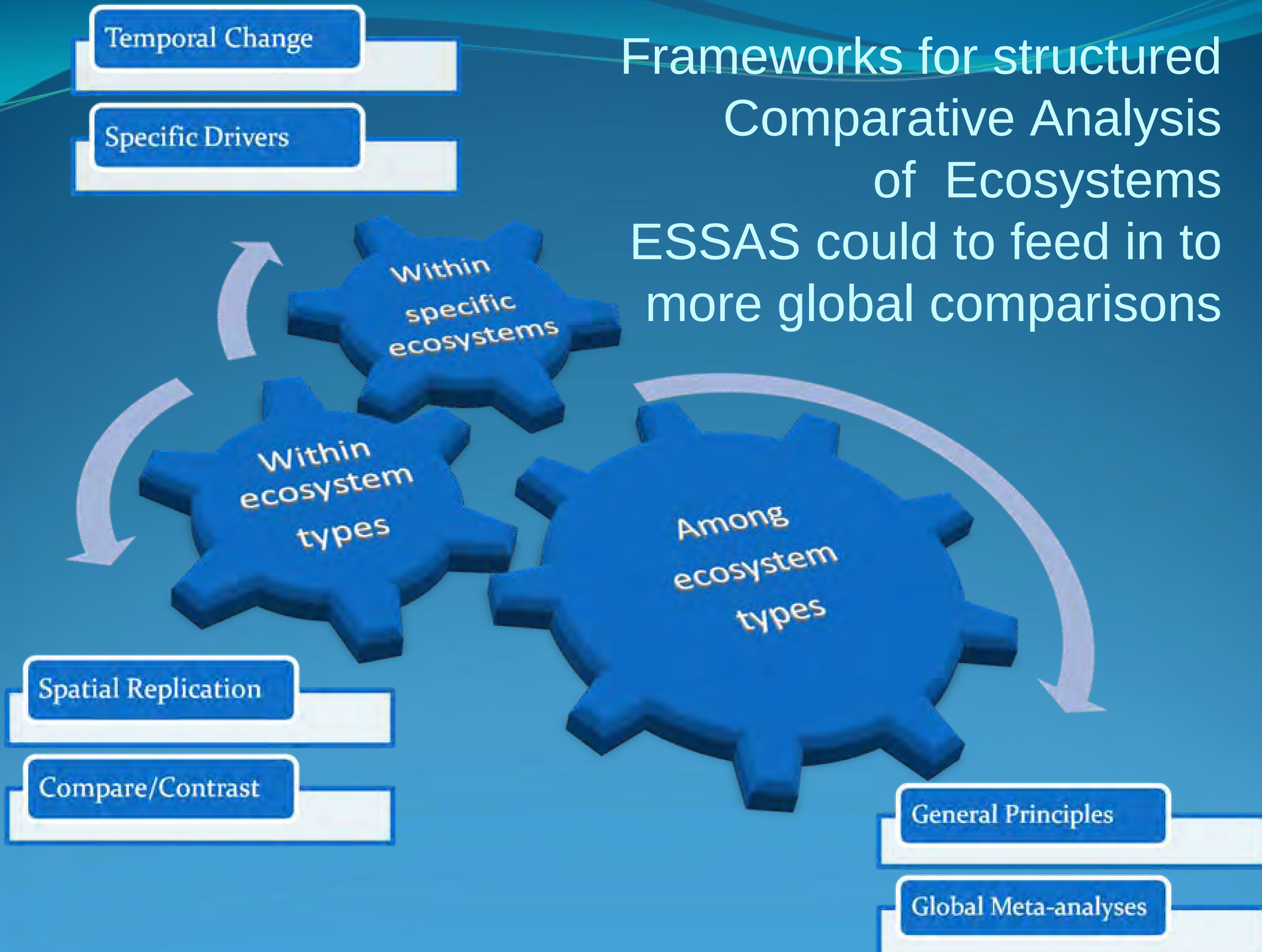
Value:
Bivalves: $732M ex-vessel commercial value
Crustaceans: $1,265M ex-vessel commercial value
Combined : $1,997M ex-vessel commercial value
(51% of commercial catch by $)

- Potential impacts on shelled plankton, coral reefs (shallow and deep), bivalves and crustaceans, and food chains
- Managed resources under Coral Reef Conservation Act, MSRA, ESA

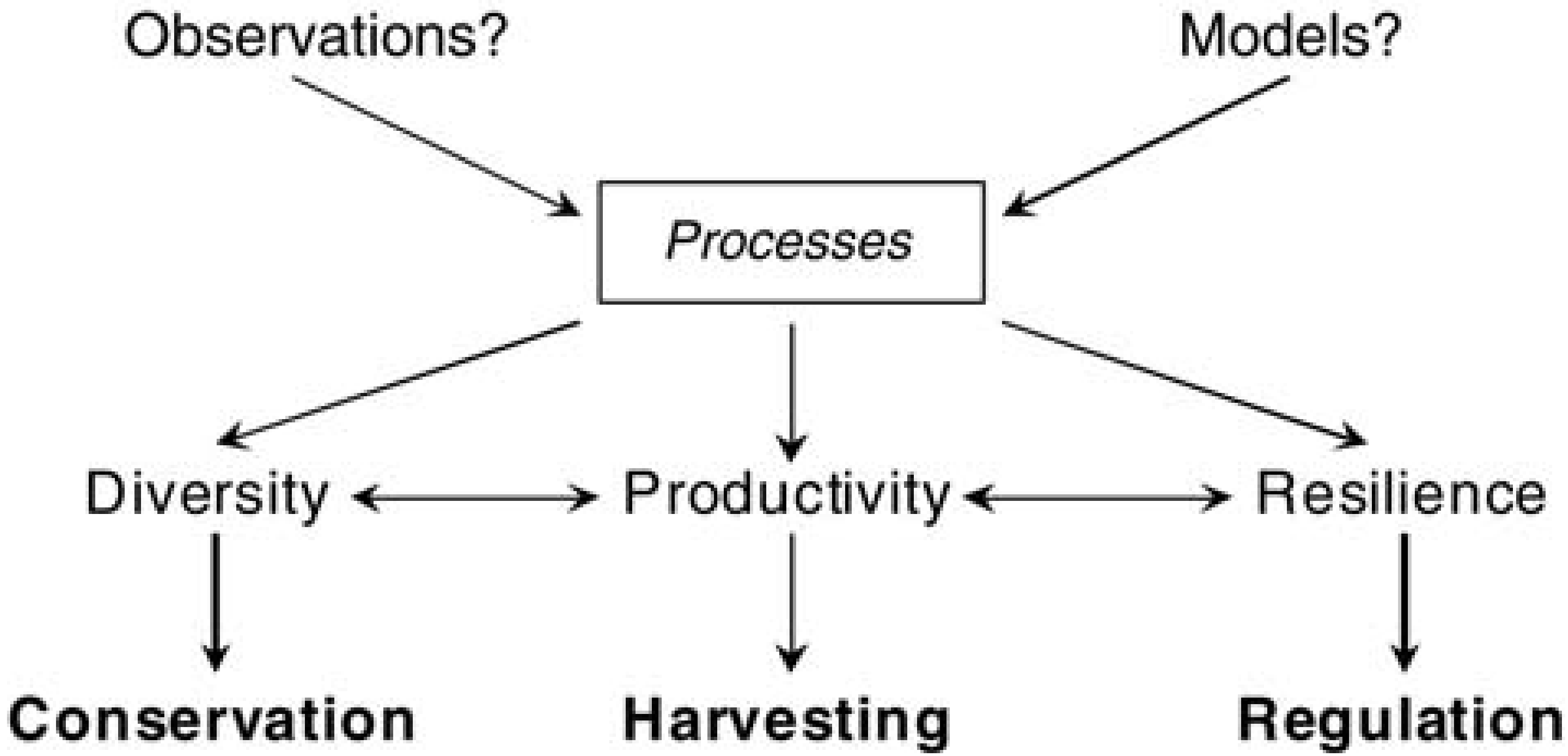
Ocean Acidification observations at Hawaii
How do we conduct laboratory studies?



Frameworks for structured Comparative Analysis of Ecosystems
ESSAS could to feed in to more global comparisons

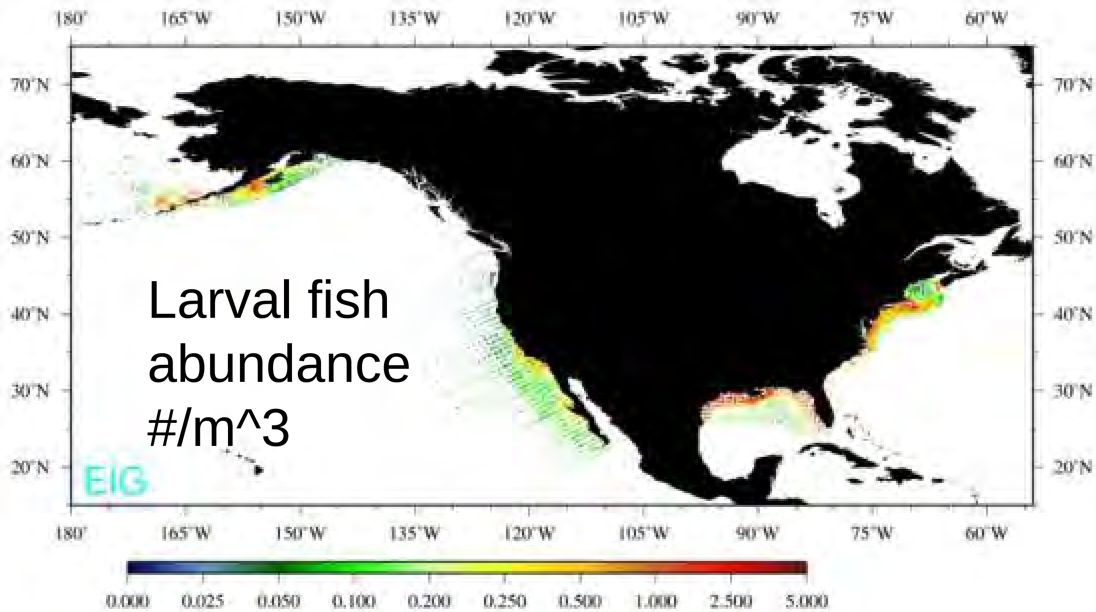


What should we compare?

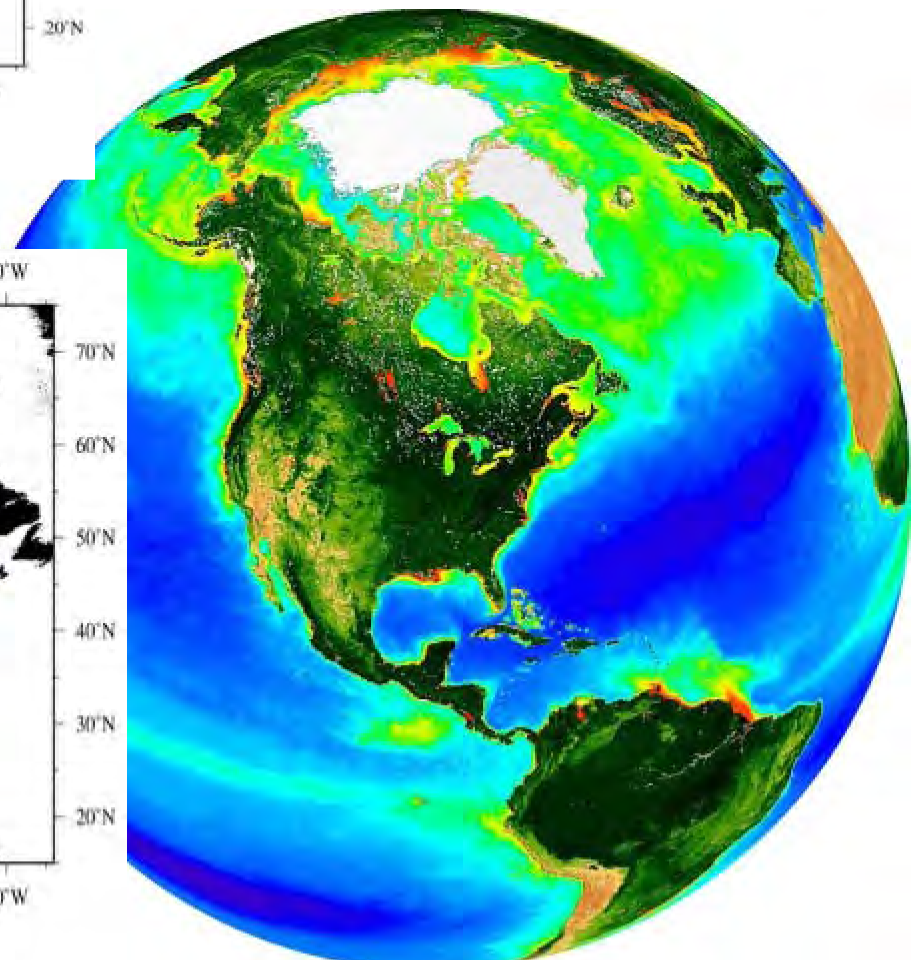


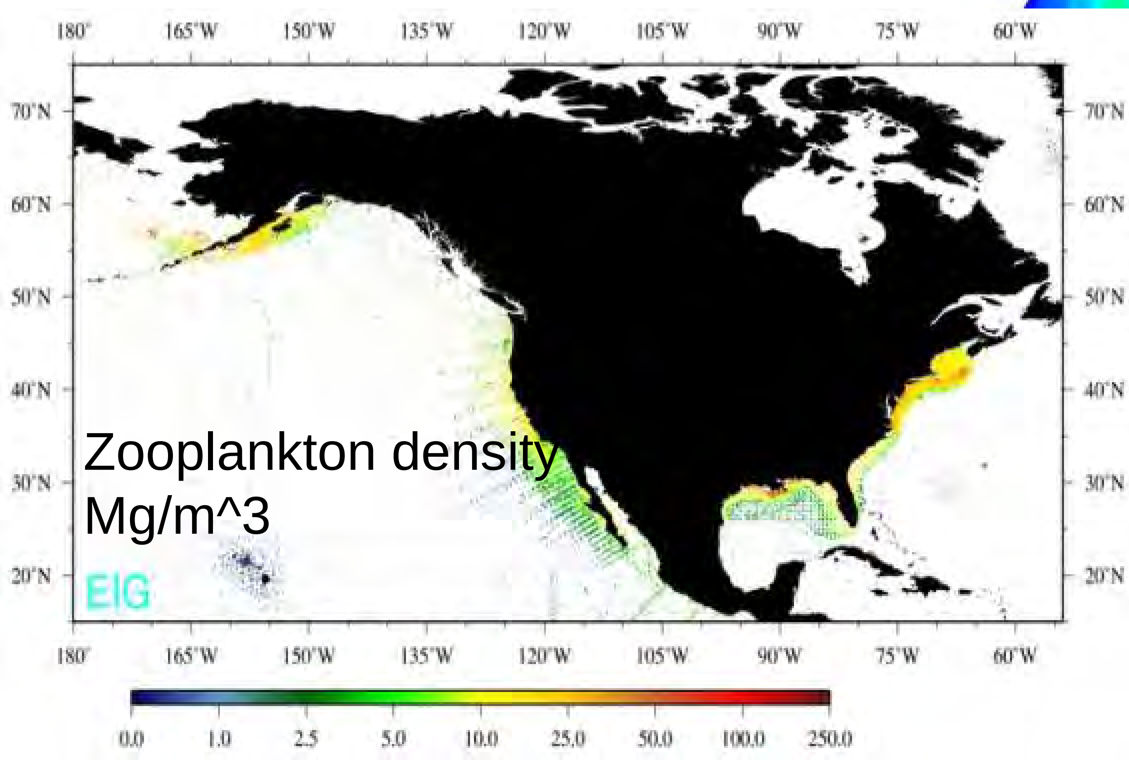
Murawski, Steele, Taylor, Fogarty, Sissenwine, Ford, & Suchman. 2010.
Why compare marine ecosystems? ICES Journal of Marine Science

We have considerable data scattered across agencies & countries

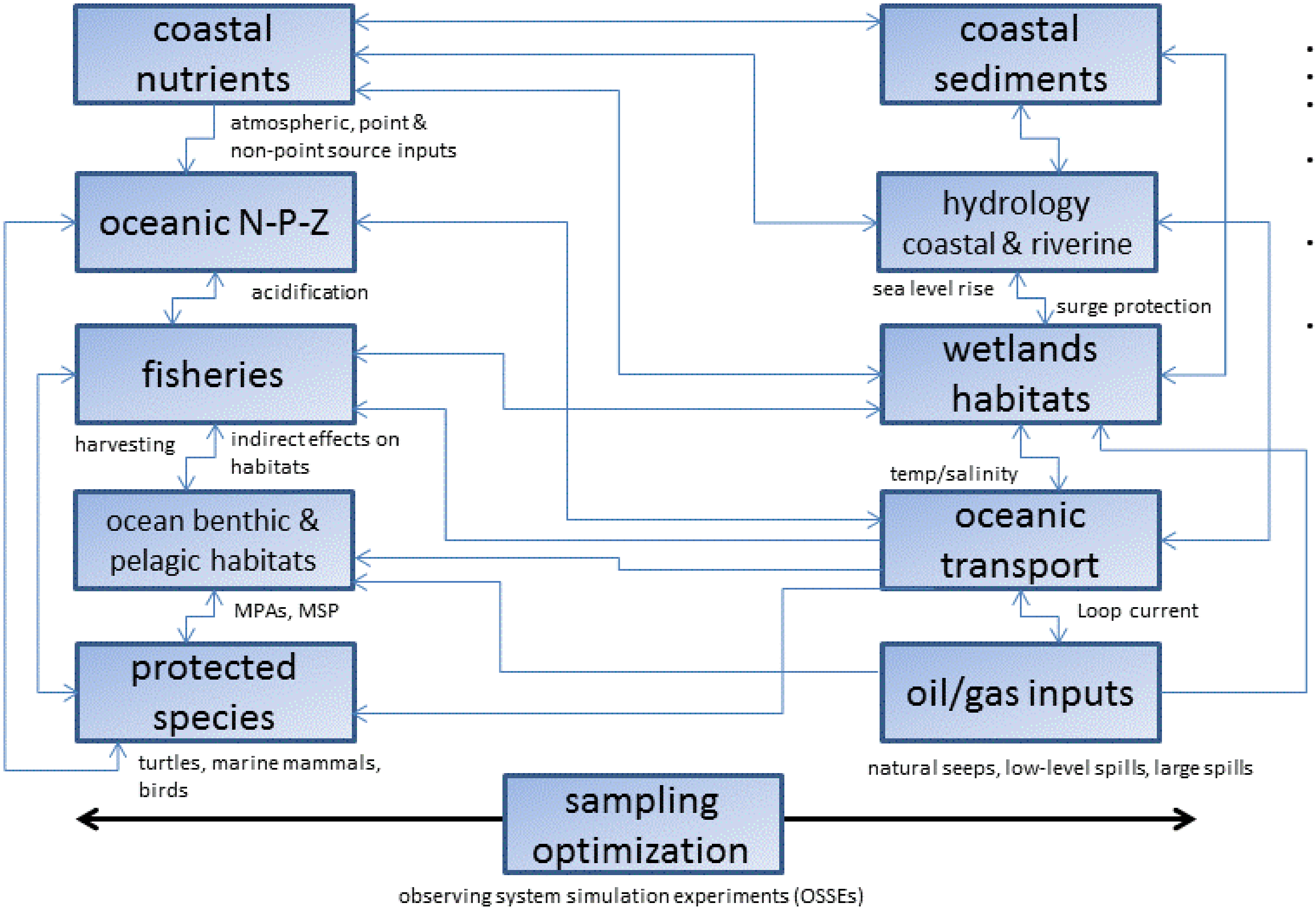


Ocean Color - Phytoplankton





Earth Systems Modeling approach to regional dynamics



Modeling Foci:

- Hydrodynamic transport
- Sources and sinks
- Fate and effects
- Spatial planning & connectivity
- Food webs & species interactions
- Time & space scales of natural variability
- Ecosystem services & human dimensions

End Notes….

- **As with most science, much of the "first order" science we have done has shown just how complicated things are. They point the way towards a mix of comparative studies, paleoecology and laboratory analyses – reductionistic approaches will not reveal complex interactions**

- **Need to understand how species respond not only on a taxonomic basis but in the presence of other species (competitors & prey)**

- **We need a mechanism to assemble the global patterns of environmental information and biological data. IPCC cannot do it. In AR-4 only 3% of ecological data sets were marine vs. 70% of the planet….. (point emphasized at Sendai)**

- **Who will step up to organize such a marine atlas?**