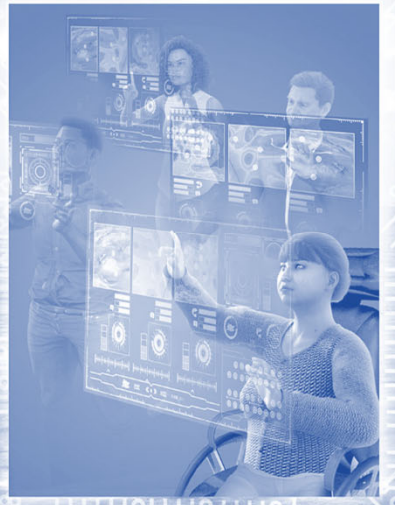

Ecosystem Interaction Changes as a Function of Climate

Ocean Life session
Decadal Survey of Ocean Sciences
February 16, 2024

Steve Murawski
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overview

- Co-evolution and adaptation of species and communities under climate change and variability,

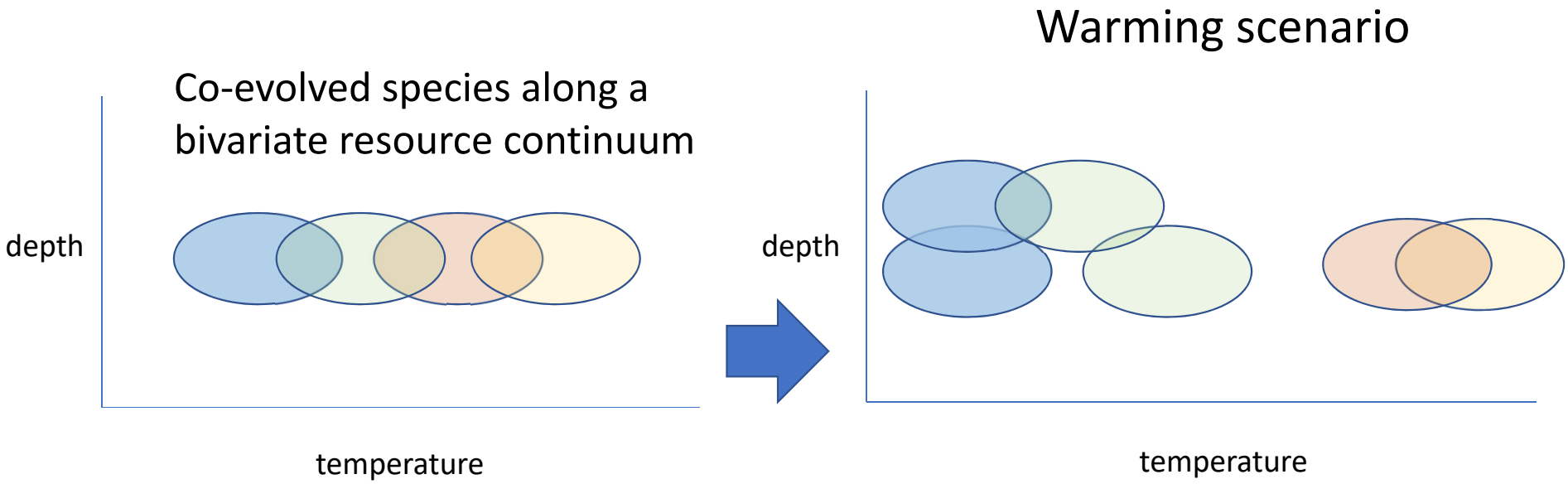
- Some examples of evolving communities and potential changes in ecosystem dynamics,

- Some proposed recommendations to better understand evolving systems.

Potential Biological Responses to Climate Change (warming, sea level rise, OA, etc.)

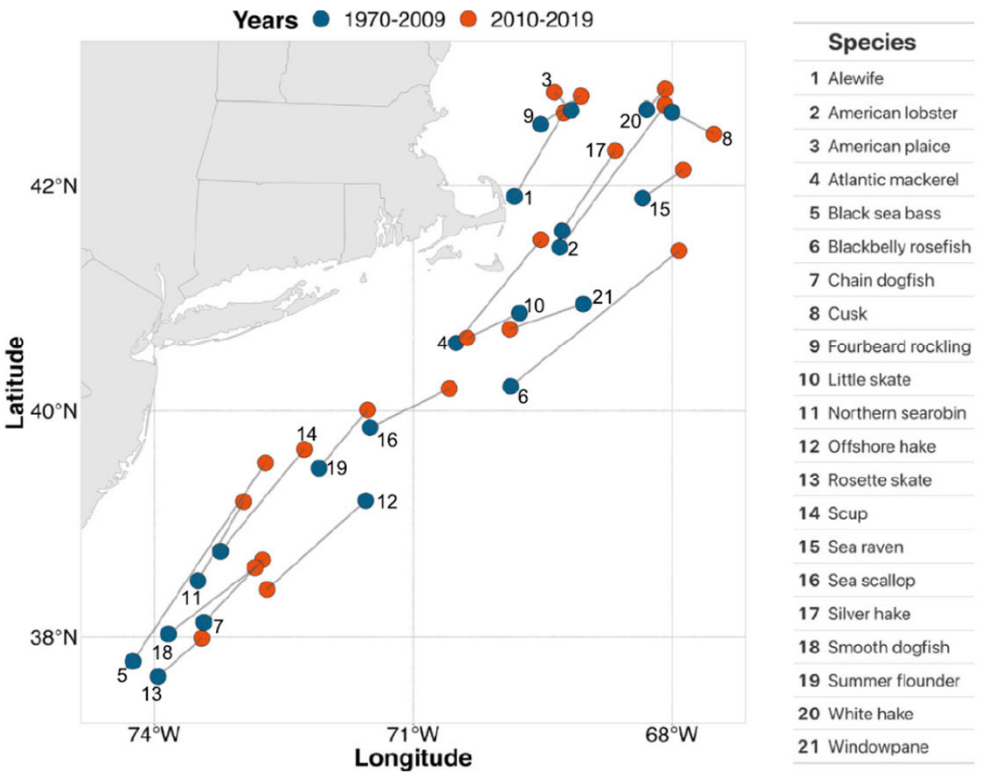
- Metabolic rates (mostly +),
- Productivity (growth, mortality, +/-),
- Primary Production (mostly +),
- Trophic interactions (difficulty to predict due to spatial processes),
- Competition/predation,
- Depensatory mortality and Allee effects at low population sizes, *
- Invasions/extinctions,
- Host/parasite and disease implications,
- Often confounded with other factors (fishing, eutrophication etc.).

Doney, S.C., et al. 2024. Climate change impacts on marine ecosystems. Annual Reviews in Marine Science. 20124:11-37



many implications for dynamical processes

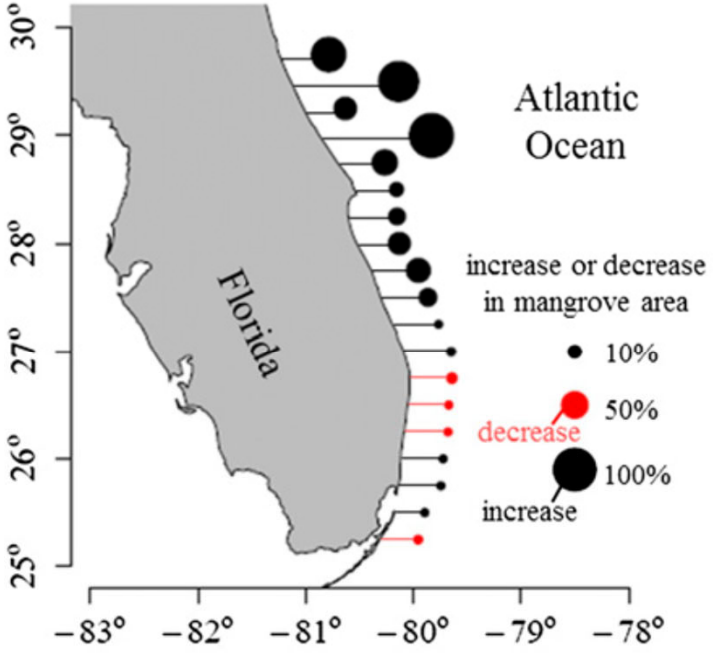
Åkesson, A. et al. 2021. The importance of species interactions in eco-evolutionary community dynamics under climate change. Nature Communications https://doi.org/10.1038/s41467-021-24977-x

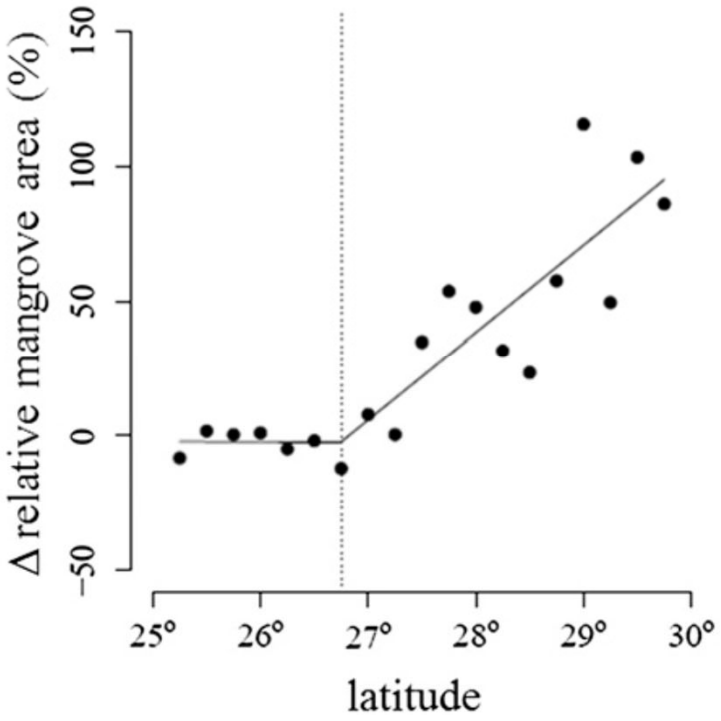


Species	
1	Alewife
2	American lobster
3	American plaice
4	Atlantic mackerel
5	Black sea bass
6	Blackbelly rosefish
7	Chain dogfish
8	Cusk
9	Fourbeard rockling
10	Little skate
11	Northern searobin
12	Offshore hake
13	Rosette skate
14	Scup
15	Sea raven
16	Sea scallop
17	Silver hake
18	Smooth dogfish
19	Summer flounder
20	White hake
21	Windowpane

Mills, K.E., et al. 2024. Multispecies population-scale emergence of climate change signals in an ocean warming hotspot. ICES Journal of Marine Science, 1–15 https://doi.org/10.1093/icesjms/fsad208

Climate Change Impacts Ecosystem Engineering Species



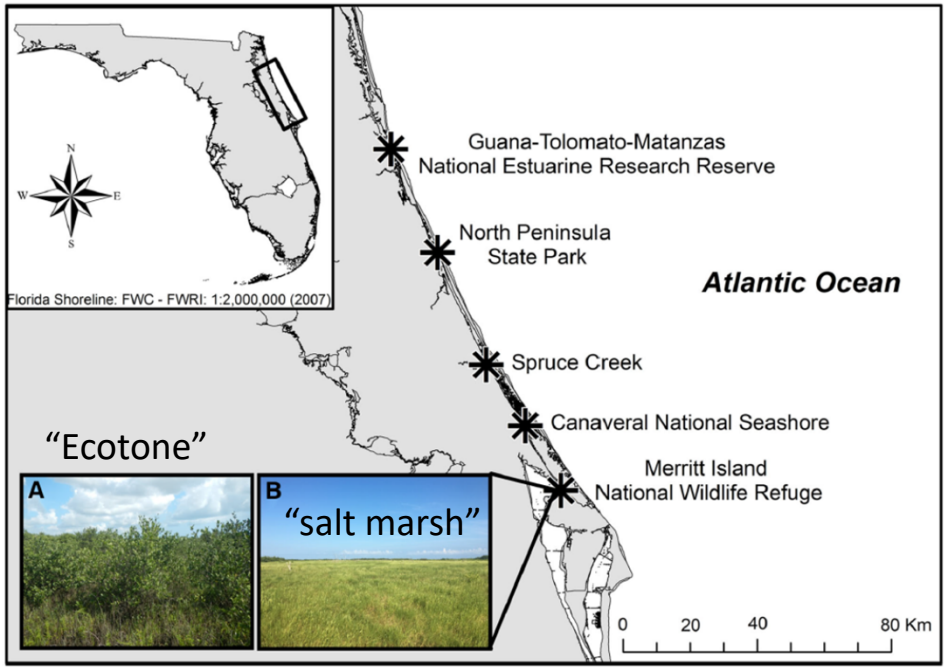


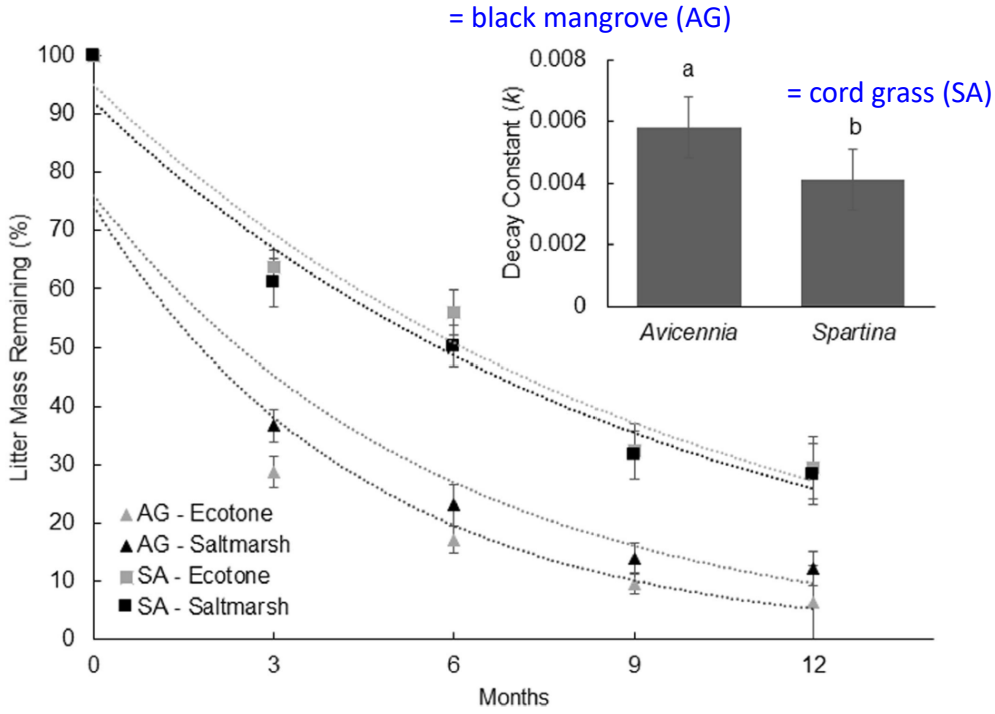
So What?

"March of the mangroves" – global phenomenon

Cavanaugh, K.C., et al. 2014. Poleward expansion of mangroves is a threshold response to decreased frequency of extreme cold events PNAS 111: 723–727.

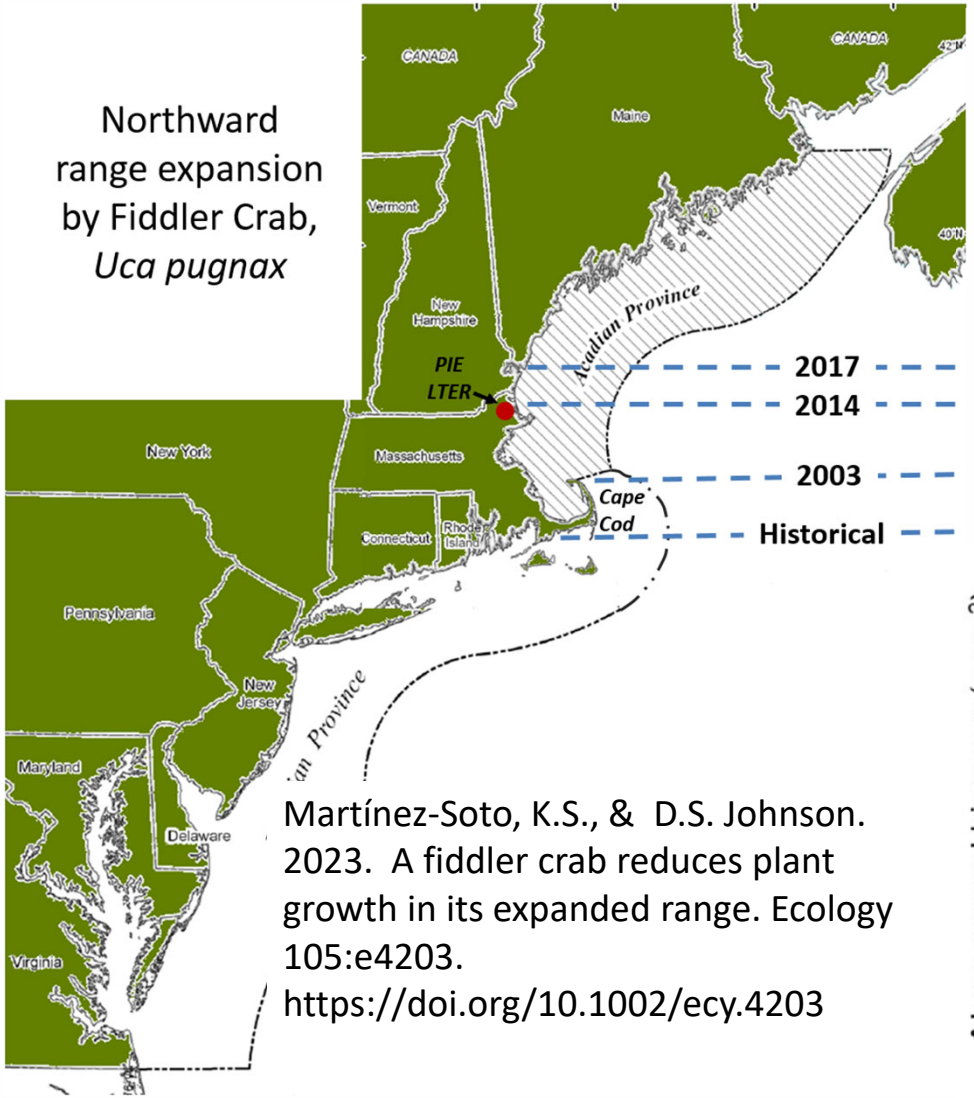
Altered rates and magnitude of organic matter decomposition and nutrient cycling due to differences in the structural complexity, litter quality, and other ecophysiological traits of foundation species

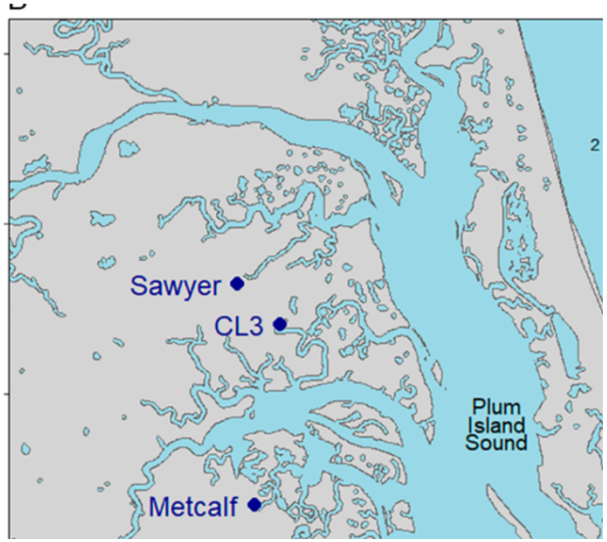




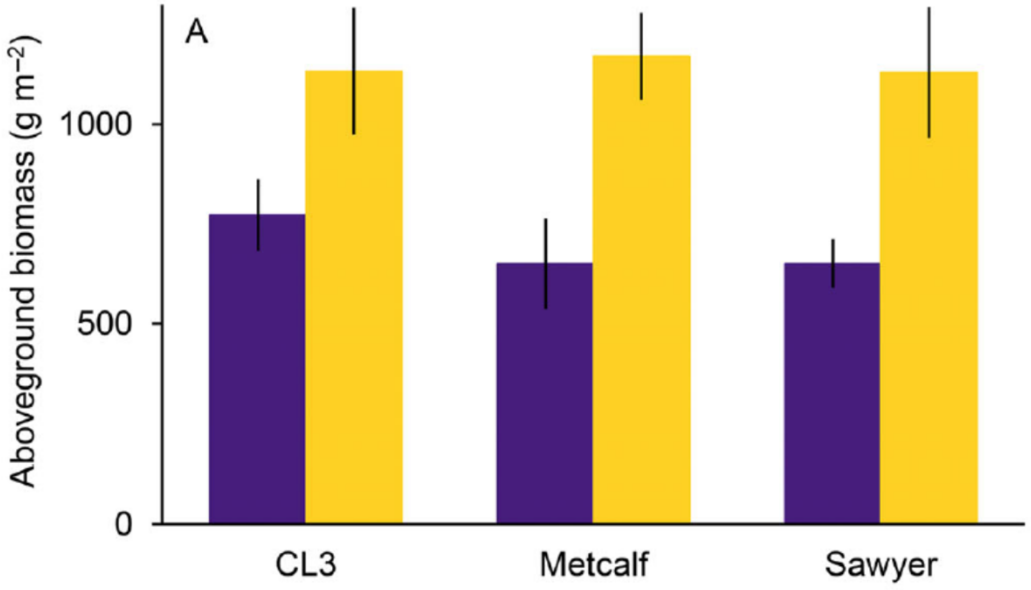
Simpson, L.T., et al. 2021. Mangrove Encroachment Alters Decomposition Rate in Saltmarsh Through Changes in Litter Quality. Ecosystems (2021) 24: 840–854 https://doi.org/10.1007/s10021-020-00554-z

Northward range expansion by Fiddler Crab, *Uca pugnax*





LTER NETWORK



Martínez-Soto, K.S., & D.S. Johnson. 2023. A fiddler crab reduces plant growth in its expanded range. Ecology 105:e4203. https://doi.org/10.1002/ecy.4203

Findings and Recommendations to consider

Finding: Although the phenomenon of distributional shifts in response to global warming has been studied extensively, proportionally little information on ecosystem dynamical responses has been generated (e.g., changes in nutrient cycling, metabolic rates, vital rates)

Recommendation: Consider a program of ecosystem-based research on systems undergoing rapid change to discern impacts on changes in ecosystem processes determining the productivity implications of warming and associated factors.

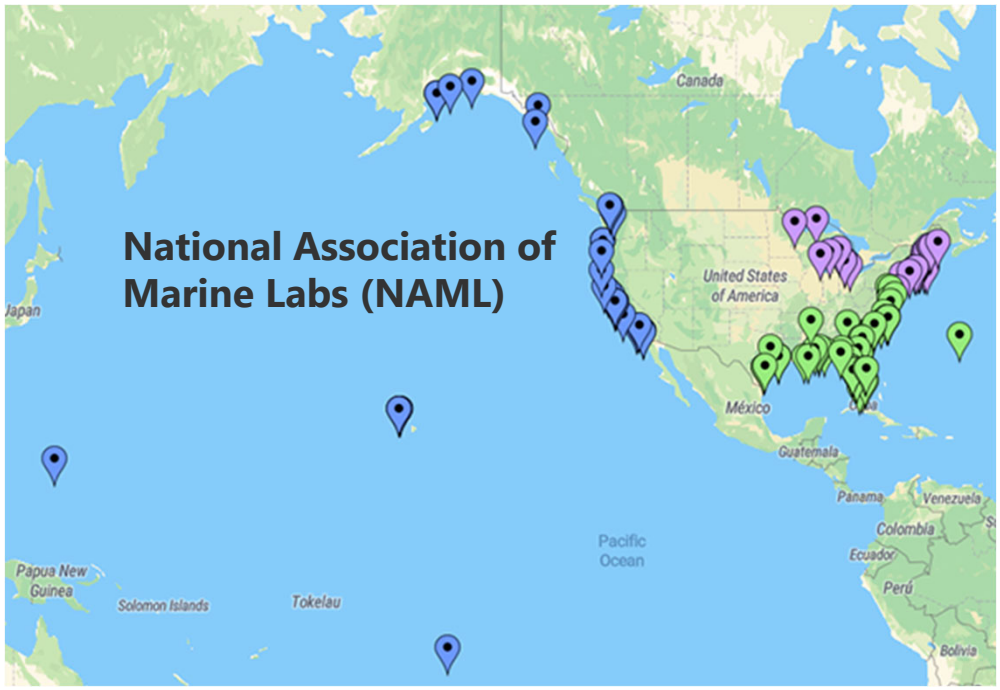
Findings and Recommendations to consider (cont.)

Finding: NOAA and other mission-oriented agencies invest heavily in ongoing time series to monitor species and communities especially on the continental shelves, but data are generally not available for coastal regions where climate effects may be most extreme.

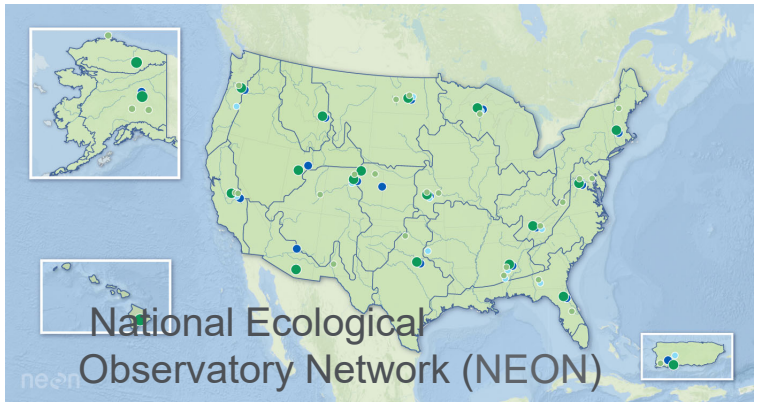
Recommendation: Consider establishing a virtual marine phelology network with established coastal marine laboratories (NAMML), NERRS sites, LTERs, coastal NEON sites, etc. This may also include efforts to intercalibrate state-sponsored survey programs.

Finding: The USA GLOBEC (Global Ocean Ecosystem Dynamics) and CAMEO (Comparative Analysis of Marine Ecosystem Organization) were joint agency/academic programs emphasizing simultaneous top-down and bottom-up effects on marine ecosystems. However, both ended prior to the most recent decade when climate change impacts have become more acute

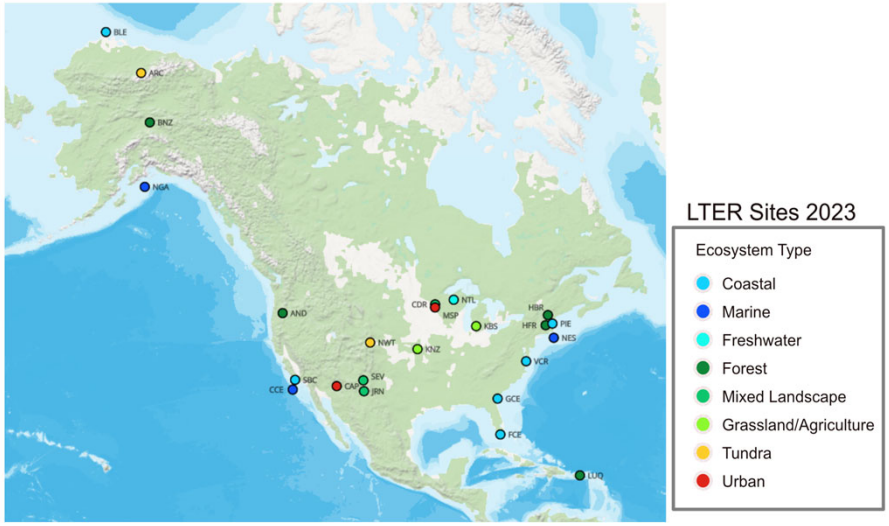
Recommendation: Consider developing a new joint academic/government initiative to address climate impacts on ecosystems, funded at a decadal scale.

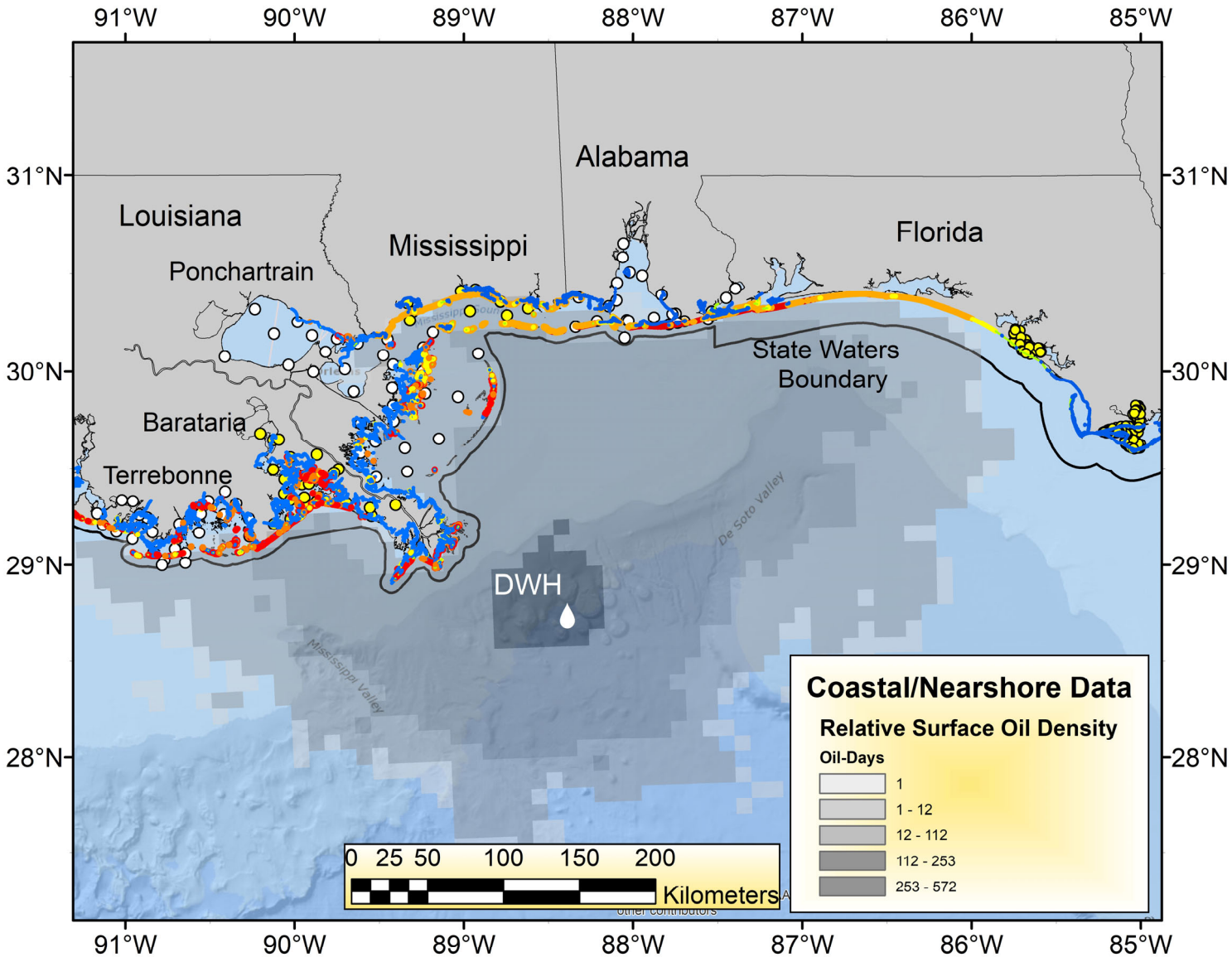


National Estuarine Research Reserves



Establishing a virtual phenology network?





Most states have a variety of standardized surveys for various taxa

(e.g., state trawling surveys in Gulf of Mexico states

U.S. GLOBEC

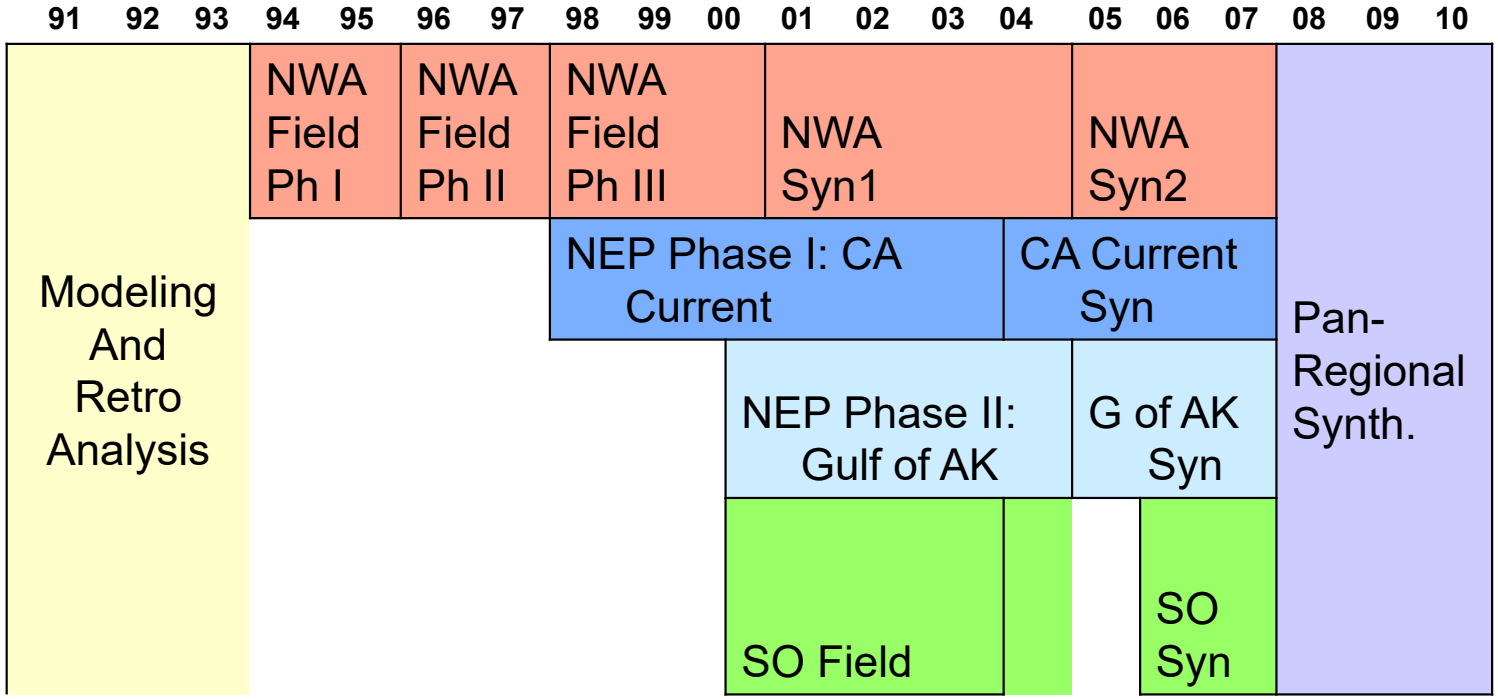
Global Ocean Ecosystems Dynamics

GOAL: Identify how a changing global climate will affect the abundance and dynamics of marine animal populations

STRATEGY: Focus on processes linking climate variables -> physical processes in the ocean-> population dynamics of marine animals

OUTCOME: Knowledge of the coupling between physical and biological processes that can inform assessments and predictions of the impact of climate change on marine ecosystems

Long-Term Funding GLOBEC Phases

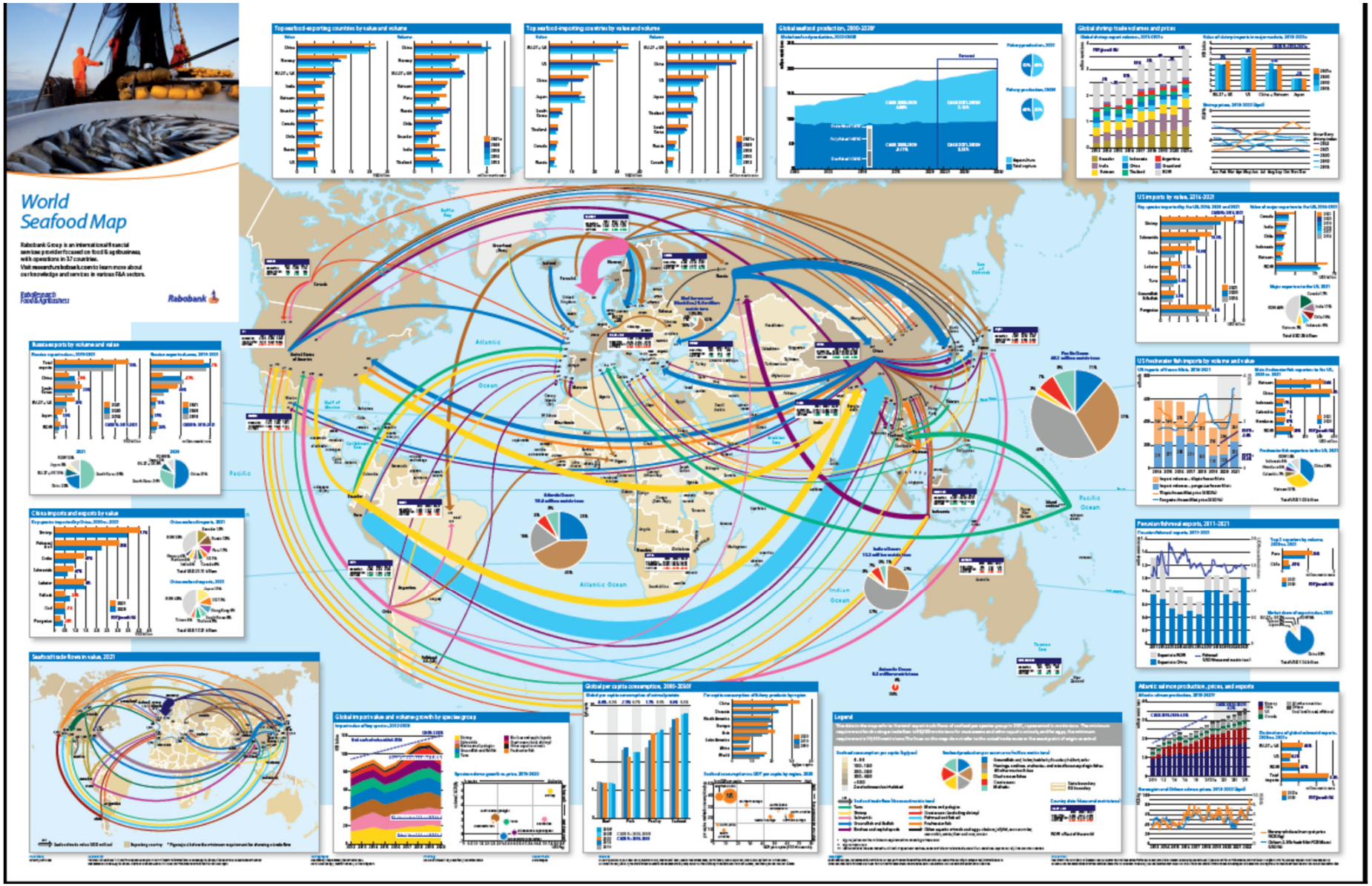


Findings and Recommendations to consider (cont.)

Finding: Much of what we know about climate change impacts on marine ecosystems comes from the global north, but the impacts may be as - or more - severe in the global south. The south also generates substantial fishery landings exported to northern countries in Europe, North America and Asia*.

Recommendation: Consider establishing a program funded by multiple US federal agencies (e.g., USAID, NOAA, NSF) to establish a research vessel and cooperative marine research program in, e.g., South America or Oceania, to build capacity, provide information critical to climate adaptation and expand educational and training opportunities.

* The Norwegian Agency for Development Cooperation (Norad) and the Institute of Marine Research in Norway support the Nansen Project, stationing a top-of-line research vessel in Africa to address this disparity. https://www.fao.org/in-action/eaf-nansen/en/


World
Seafood Map
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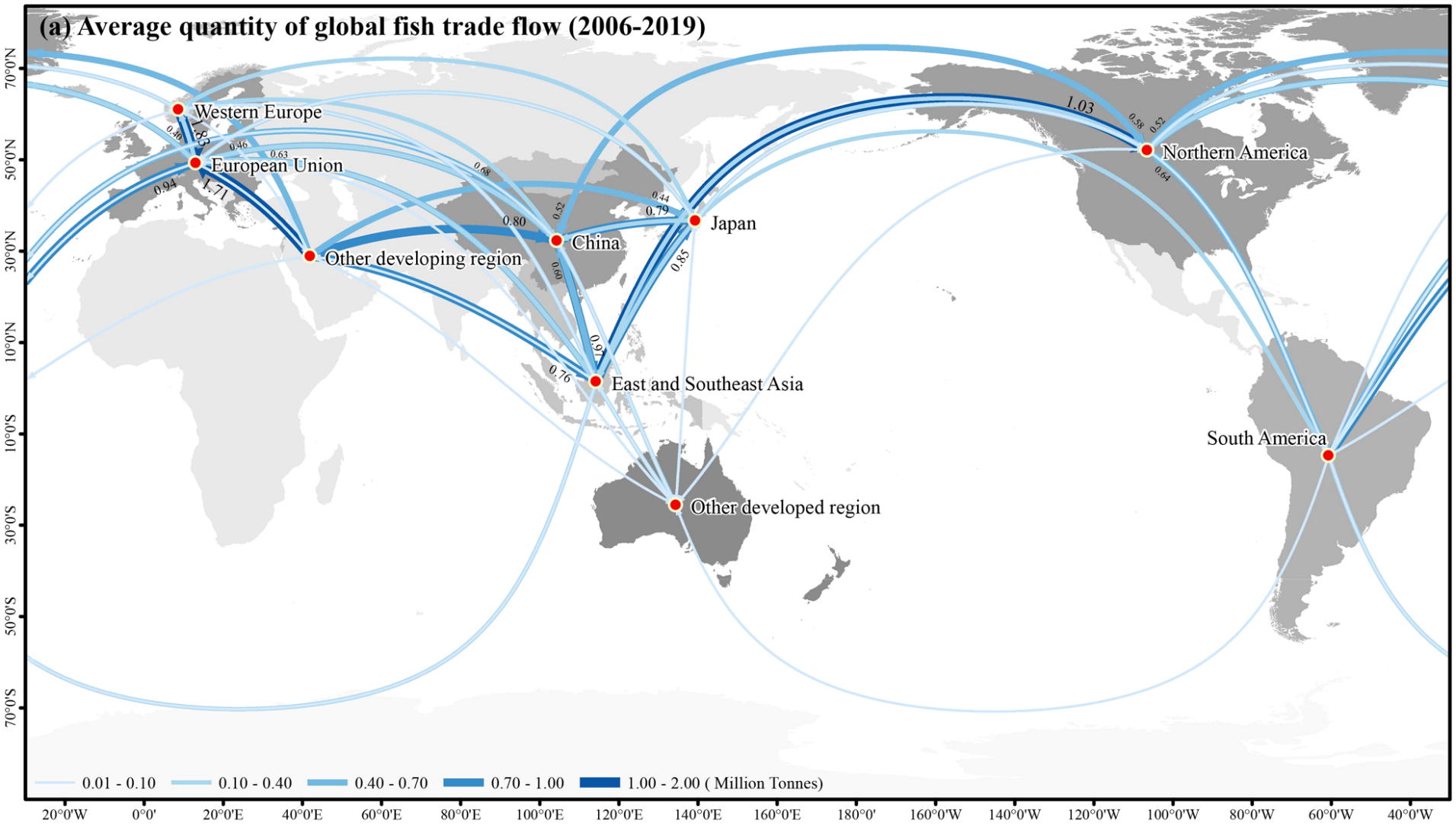
Rabobank
Top seafood-exporting countries by value and volume
Top seafood-importing countries by value and volume
Global seafood production, 2000-2220F
Global shrimp trade volumes and prices
US imports by value, 2016-2021
Russia exports by volume and value
US freshwater fish imports by volume and value
China imports and exports by value
Peruvian fishmeal exports, 2011-2021
Seafood trade flows in value, 2021
Global import value and volume growth by species group
Global per capita consumption, 2000-2030F
Legend
Atlantic salmon production, prices, and exports

Back-up slides


Thank you…..questions?


(a) Average quantity of global fish trade flow (2006-2019)
Western Europe
European Union
Other developing region
China
Japan
Northern America
East and Southeast Asia
South America
Other developed region
0.40
1.83
0.46
0.63
0.94
1.71
0.68
0.80
0.52
0.44
0.79
0.60
0.85
0.97
0.76
1.03
0.58
0.52
0.64
70°0'N
50°0'N
30°0'N
10°0'N
10°0'S
30°0'S
50°0'S
70°0'S
20°0'W
0°0'
20°0'E
40°0'E
60°0'E
80°0'E
100°0'E
120°0'E
140°0'E
160°0'E
180°0'
160°0'W
140°0'W
120°0'W
100°0'W
80°0'W
60°0'W
40°0'W
0.01 - 0.10
0.10 - 0.40
0.40 - 0.70
0.70 - 1.00
1.00 - 2.00 (Million Tonnes)

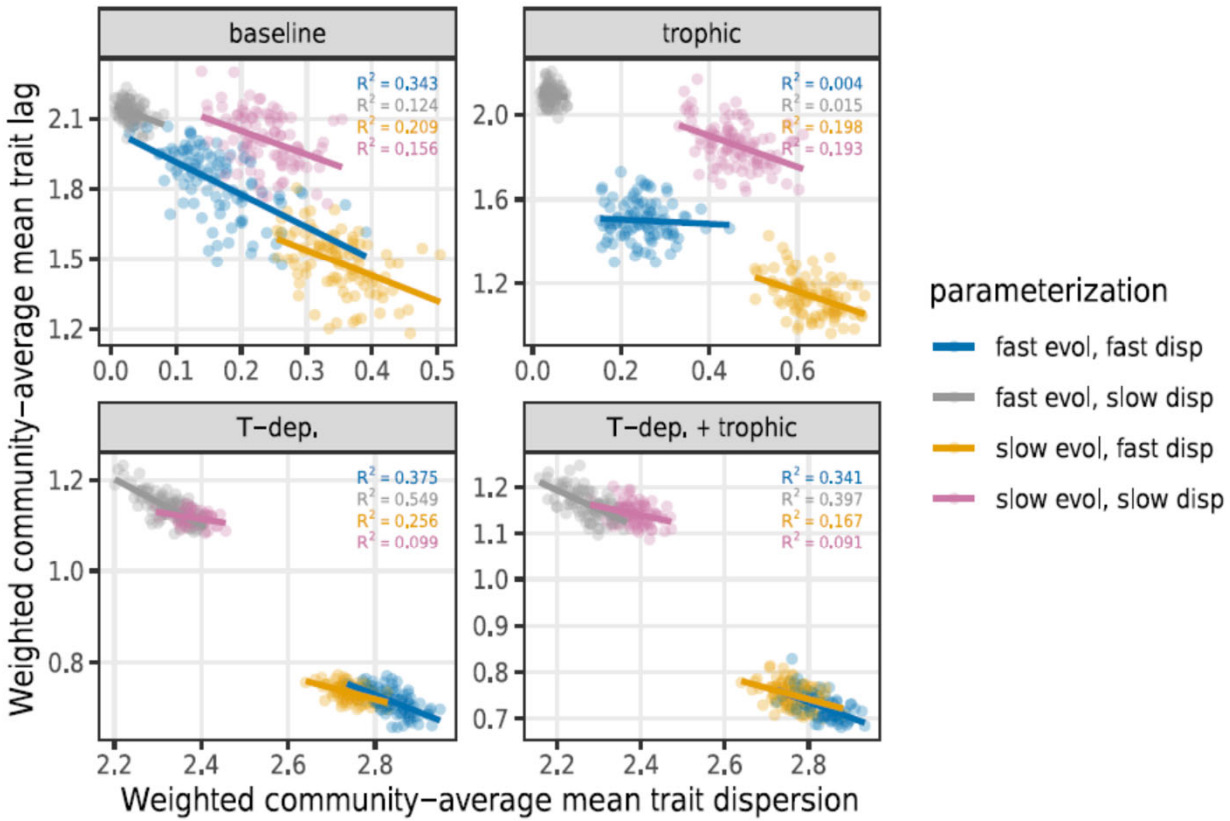
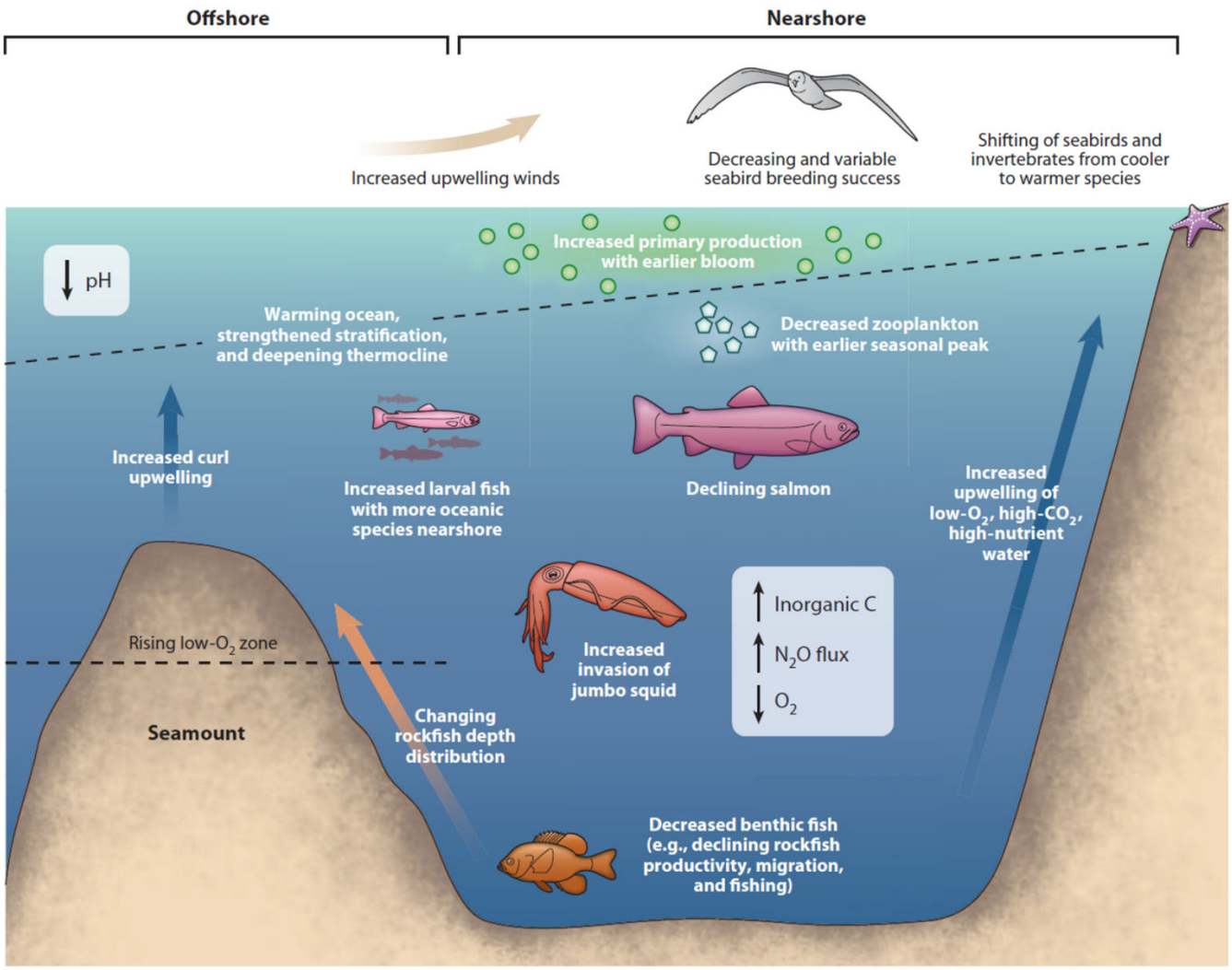


Fig. 7 The ability of communities in four different models (panels) to track local climatic conditions (ordinate), against observed variation in traits within those communities (abscissa). Larger values along the ordinate indicate that species' temperature optima are lagging behind local temperatures, meaning a low ability of communities to track local climate conditions. Both quantities are averaged over the landscape and time from the beginning to the end of the climate change period, yielding a single number for every community (points). The greater the average local diversity of mean temperature optima in a community, the closer it is able to match the prevailing temperature conditions. Species' dispersal ability and available genetic variance (colors) are clustered along this relationship.


Offshore
Nearshore
Increased upwelling winds
Decreasing and variable seabird breeding success
Shifting of seabirds and invertebrates from cooler to warmer species
pH
Increased primary production with earlier bloom
Warming ocean, strengthened stratification, and deepening thermocline
Decreased zooplankton with earlier seasonal peak
Increased curl upwelling
Increased larval fish with more oceanic species nearshore
Declining salmon
Increased upwelling of low-O_2, high-CO_2, high-nutrient water
Rising low-O_2 zone
Increased invasion of jumbo squid
Inorganic C
N_2O flux
O_2
Seamount
Changing rockfish depth distribution
Decreased benthic fish (e.g., declining rockfish productivity, migration, and fishing)

The CAMEO program is designed to address these issues by supporting research under five themes:
(1) **Connectivity of Marine Ecosystems** defines the fundamental structural and functional attributes of ecosystems and interactions among ecosystems;
(2) **Responsiveness of Ecosystems to Perturbations,** examines the factors that control ecosystem responses to perturbations and stresses;
(3) **State Transitions and Stability** identifies equilibrium states of ecosystems and the role of attributes (e.g. resilience, biodiversity) in determining the transitions between these states (4) **Human Society and Marine Ecosystems** examines the critical interactions between humans and marine ecosystem processes; and
(5) **Comparative Analysis, Synthesis and Forecasting** explores new approaches of synthesizing existing information on ocean ecosystems and predicting the response to fishing and climate variation and change.

- Depensatory mortality and Allee effects at low population sizes re: resource recovery

  - Sustainability of the parts vs. the system as a whole (e.g., are SS MSY's attainable?)