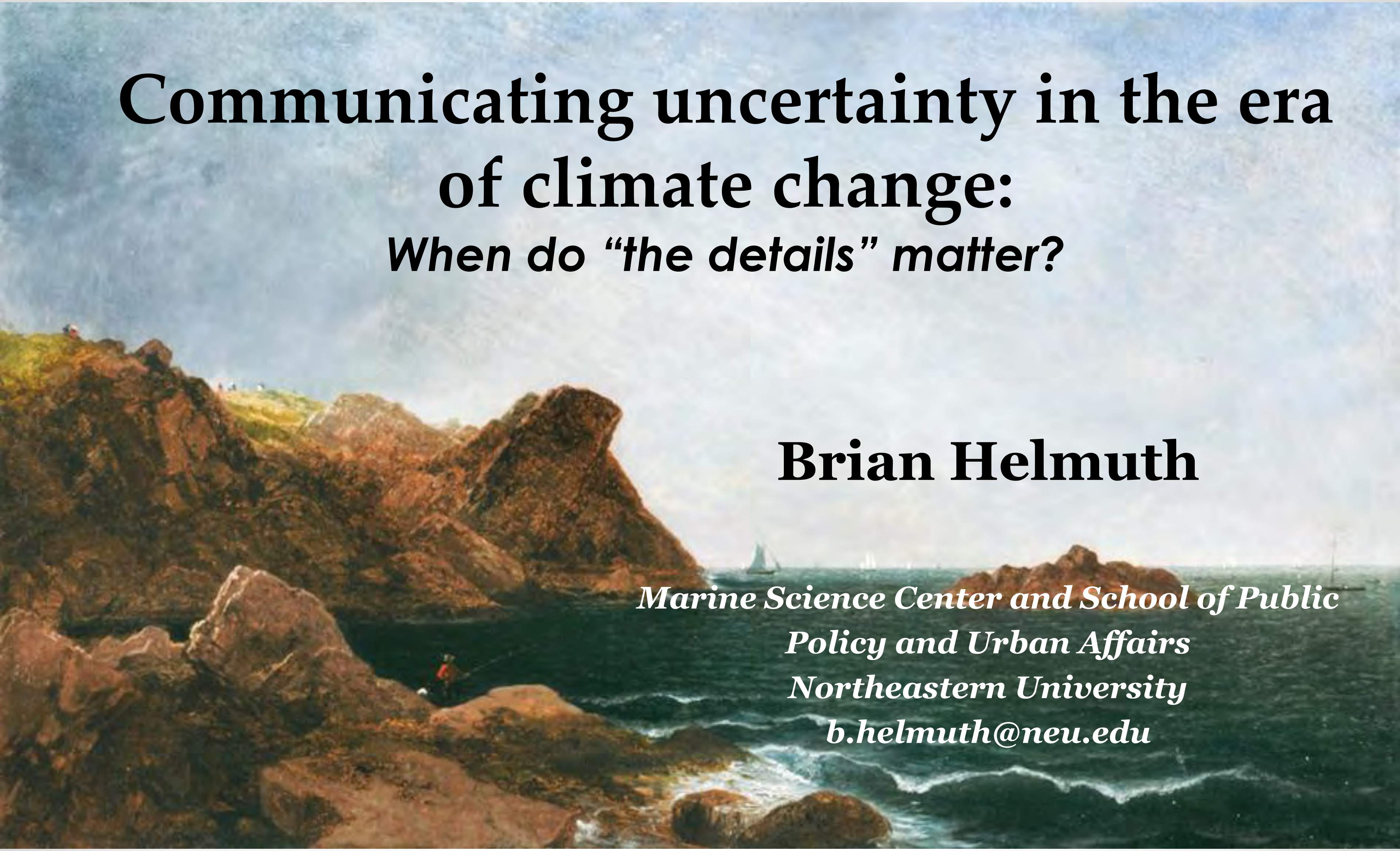
Communicating uncertainty in the era of climate change:

When do "the details" matter?



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“Remember that all models are wrong; the practical question is how wrong do they have to be to not be useful...”

...

-George E.P. Box, “*Empirical model-building and response surfaces*”

Warming is Not a Uniform Process

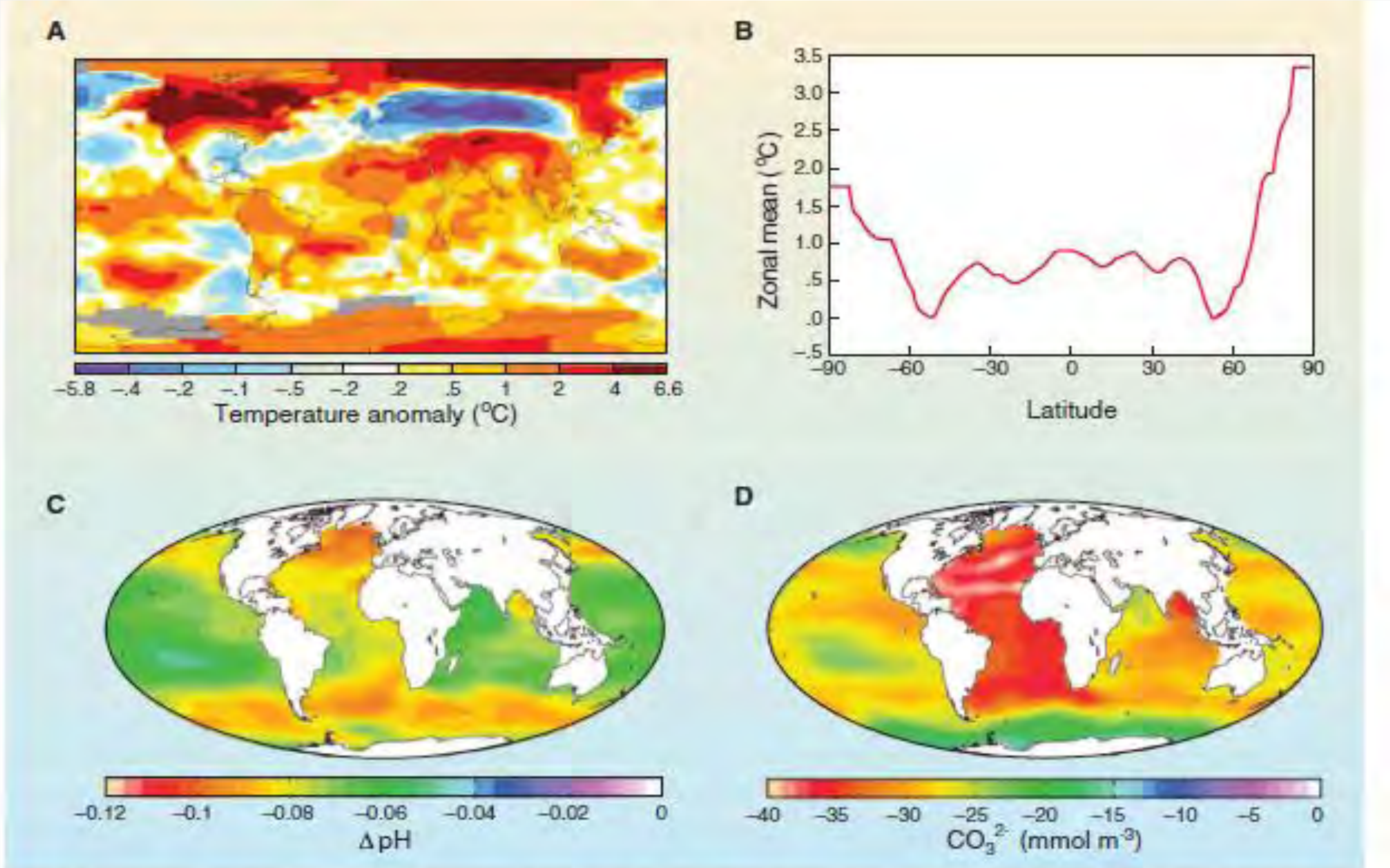


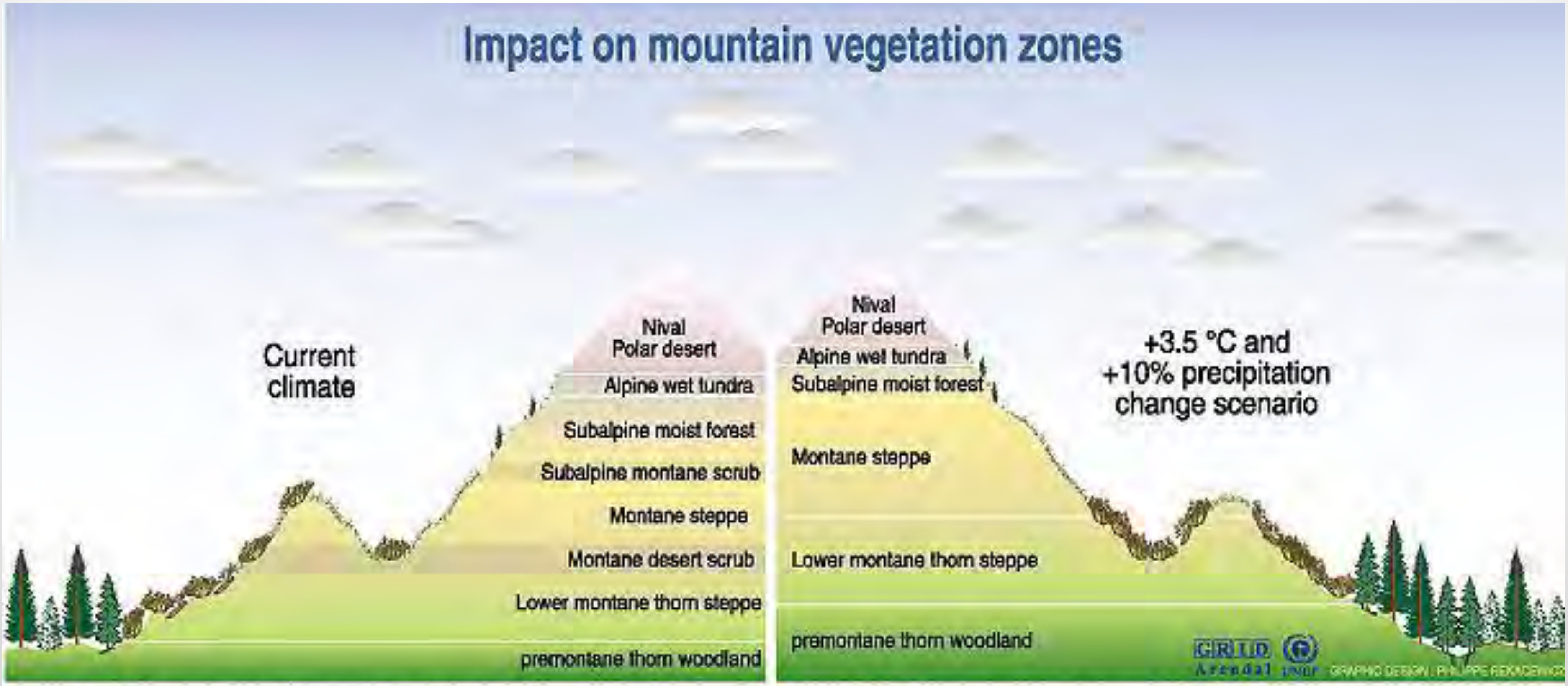
Fig. 1. Recent changes in ocean temperature, acidity, and carbonate ion concentration. (**A**) Surface temperature anomaly for January 2010 relative to the mean for 1951–1980. (**B**) The same data presented in (A) as a function of latitude. (**C**) Estimated change in annual mean sea surface pH between the pre-industrial period (1700s) and the present day (1990s). (**D**) Estimated change in annual mean sea surface carbonate ion concentration between the pre-industrial period (1700s) and the present day (1990s). [Credits: (A) and (B) NASA Goddard Institute for Space Studies; (C) and (D) Global Ocean Data Analysis Project (57)]

Hoegh Guldberg and Bruno 2010

- “A 1°C increase in average surface temperature”

Climate change impacts: Are generalizations enough?

- Poleward and altitudinal range shifts are expected……



Sources: Martin Beniston, Mountain environments in changing climates, Routledge, London, 1994; Climate change 1995, Impacts, adaptations and migration of climate change, contribution of working group 2 to the second assessment report of the Intergovernmental panel on climate change (IPCC), UNEP and WMO, Cambridge press university, 1996.

Climate adaptation requires explicit predictions

- Regional-scaled models are becoming increasingly important to account for variability in environmental change
- Species all respond differently to environmental change: which commercially and ecologically important species will be “winners” vs. “losers”
- How do we create “guard rails” to avoid rapid nonlinear changes (tipping points)

Organisms are affected by weather, not climate

"Climate (30+ year trends) trains the weather, but weather throws the Punches"

Deke Arndt (NOAA), *State of the Climate in 2009*

Ecological impacts of climate change: How do we test our ability to predict the future?

- We are using models "trained" with current conditions to predict responses under novel conditions
- How do we "know what we don't know"? And how do we increase our ability to predict (and prevent) "surprises" such as tipping points?
- Are we measuring the right things at the right scales?
-

Model skill and stationarity

- *Model skill* = degree of correspondence between model predictions and field observations
- *Model stationarity*= ability of a model generated from data collected at one place/time to predict processes at another place/time

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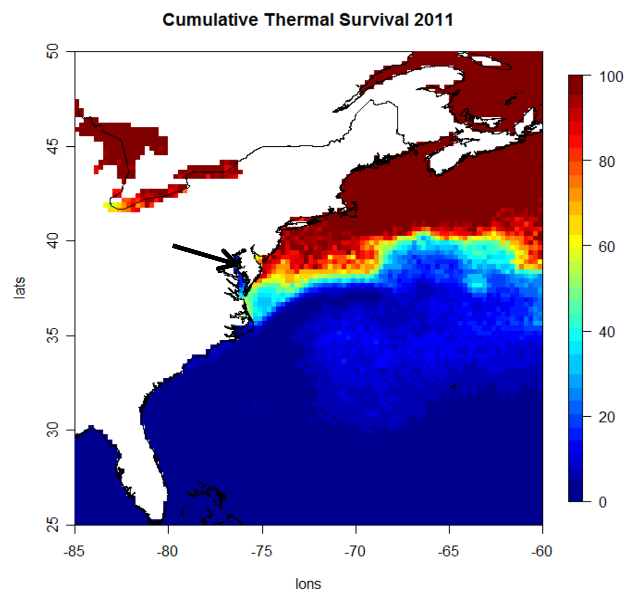
- **Climate change models- especially correlative models- assume stationarity in time**

Testing model stationarity with and without mechanism

Lethal temperatures

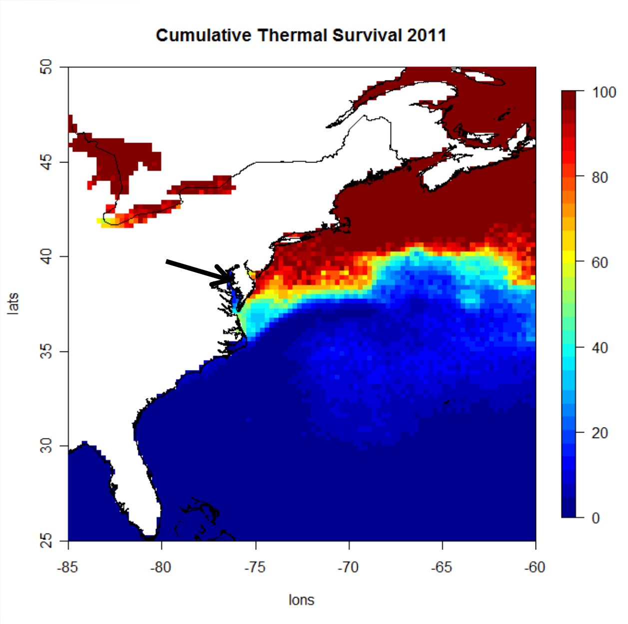


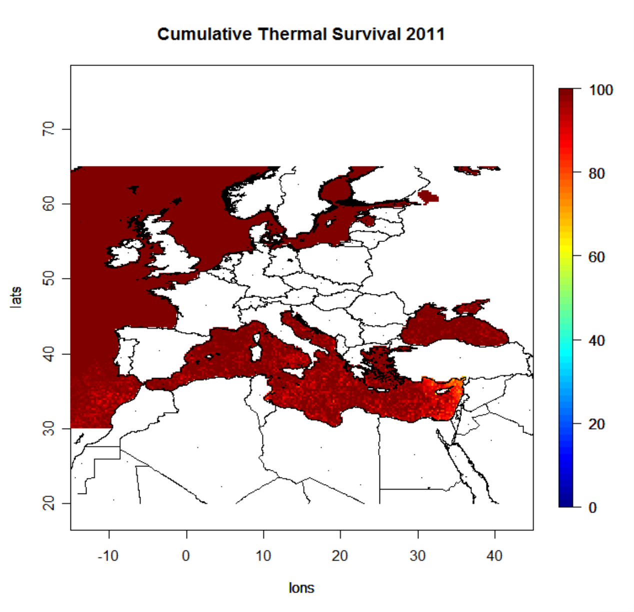
Model of mussel (*M. edulis*) distribution based on lethal temperatures

Jones et al. 2010 J. Biogeography

Model that works for the US fails in Europe

Lethal temperatures





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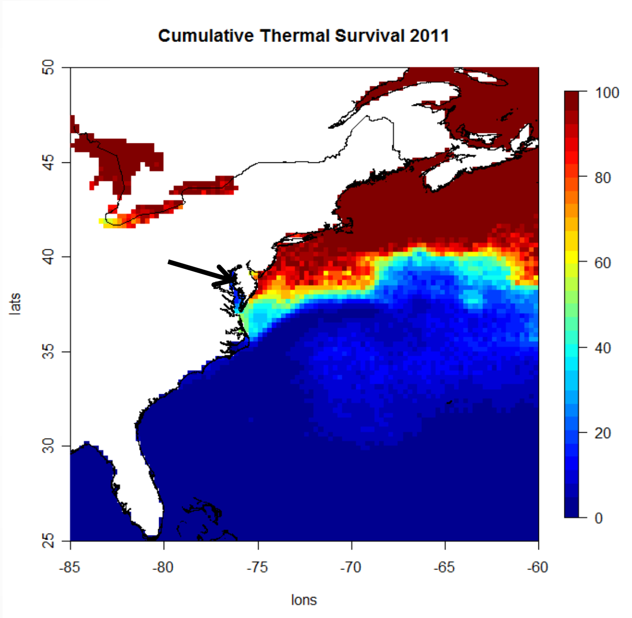
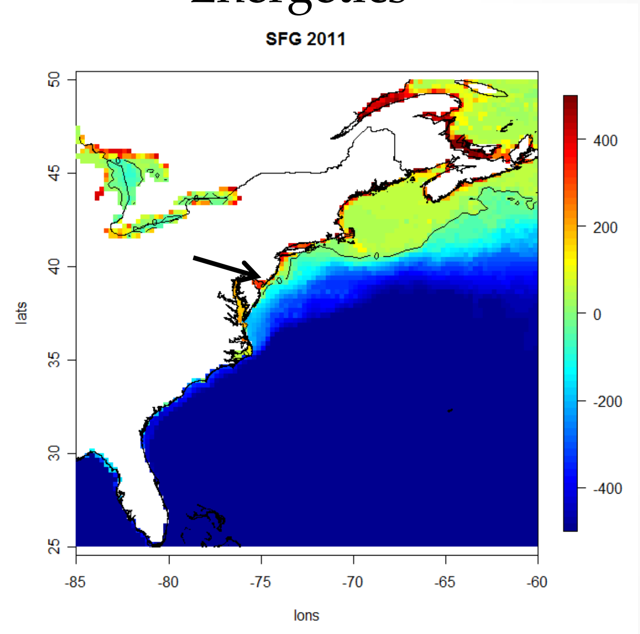


Energetics

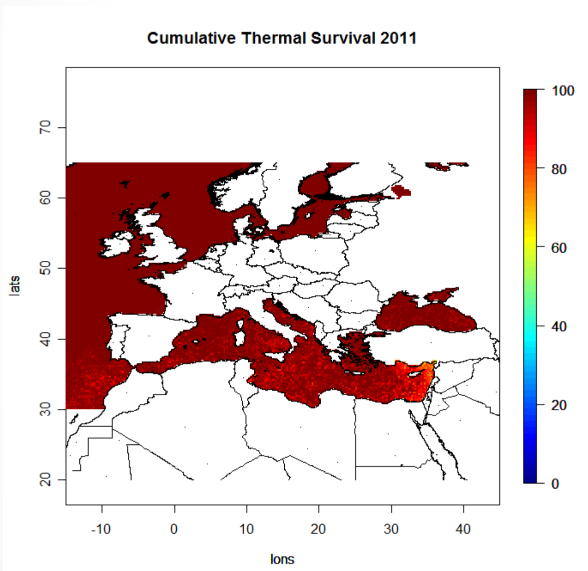


Two models of mussel (*M. edulis*) distribution- one with details and one without give similar results

(Woodin, Hilbish, Helmuth, Jones and Wethey 2013)

Testing model stationarity with and without mechanism

Lethal temperatures



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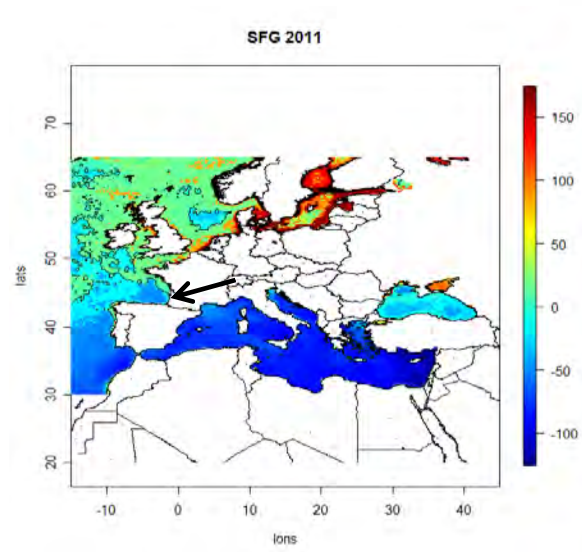


Lethal model fails miserably when applied to Europe; Energetics model does well

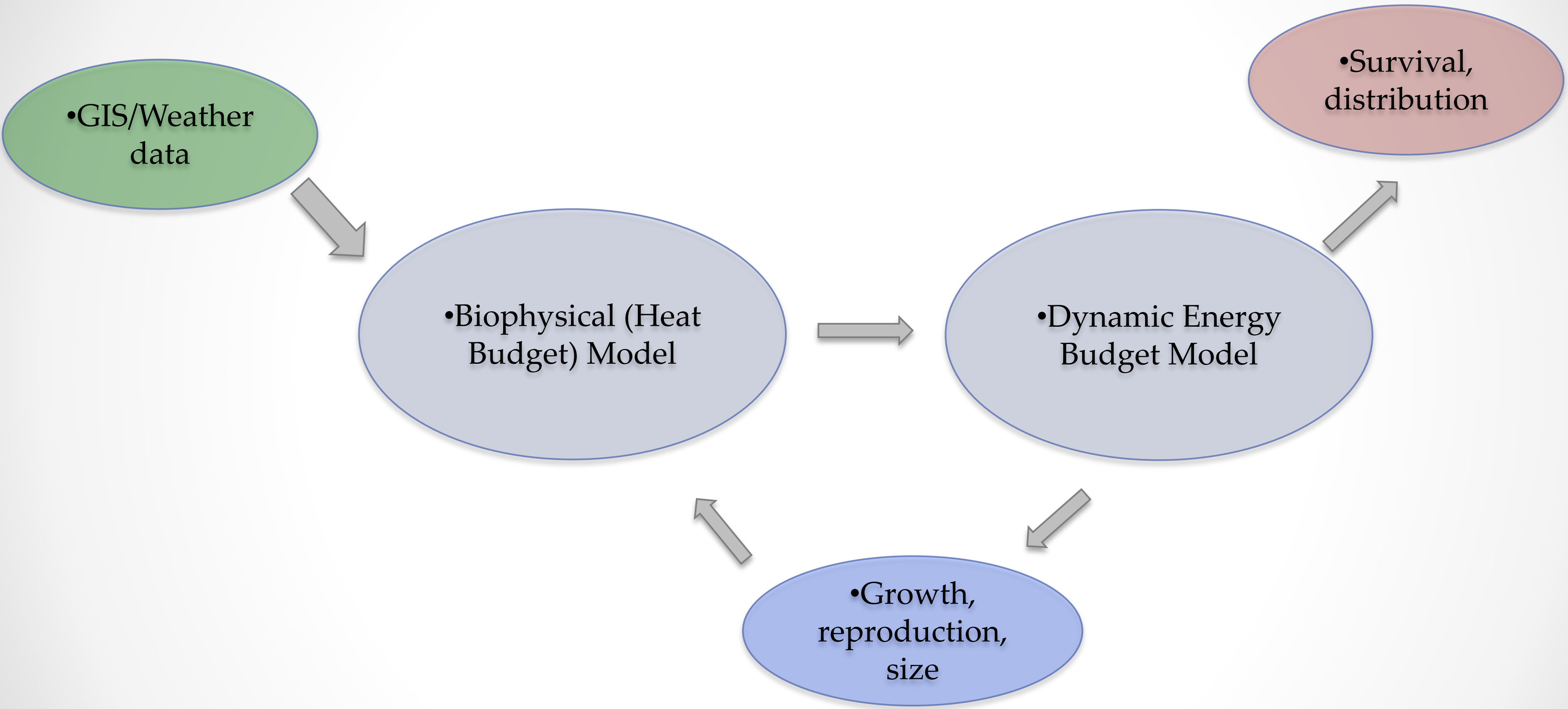
(Woodin, Hilbish, Helmuth, Jones and Wethey, 2013)

- *When are “details” (of physiology, local environmental conditions, etc.) important, and when do they just add unnecessary complexity?*

- *What is signal and what is “noise”*

- *How does uncertainty and complexity affect public understanding and acceptance of scientific recommendations?*

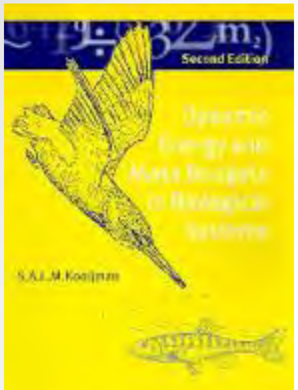
Linking weather to physiological response over biogeographic scales

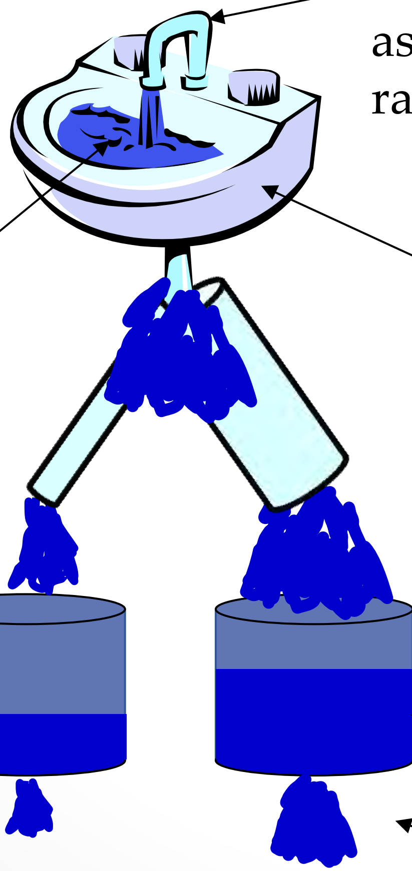


Kearney, Simpson, Raubenheimer and Helmuth 2010 *Phil. Trans. Royal Society B* 365: 3469-3483

Dynamic Energy Budget Theory

The organism as a sink



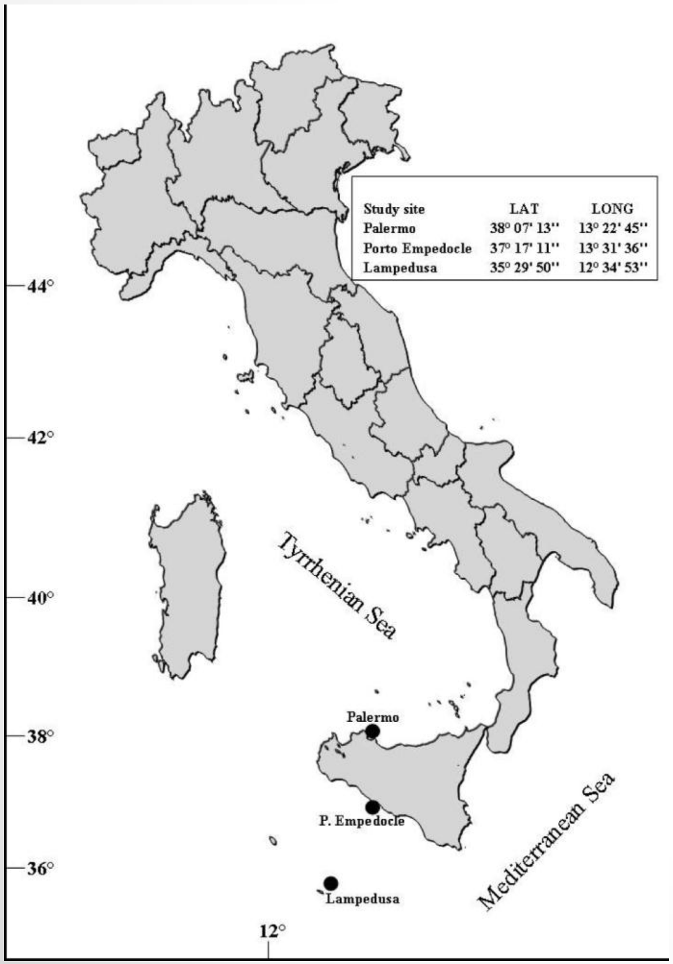


Slide courtesy M. Kearney

Coupled Biophysical-DEB model outputs:

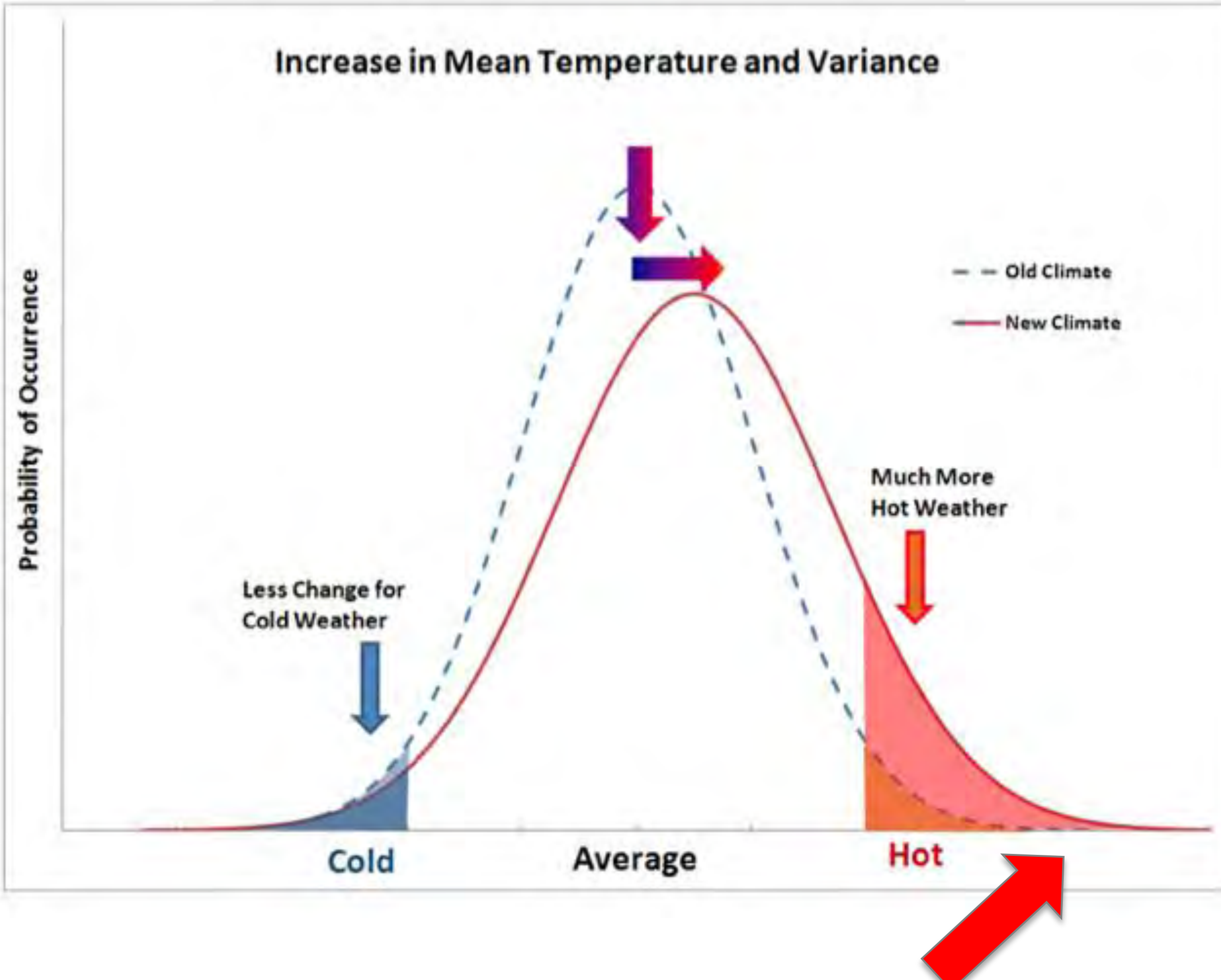
- Maximum body size
- Growth rate
- Reproductive output (number of eggs)
- Time to puberty
- All can effectively be folded into indicators for commercially and ecologically important species

What this approach can tell us about the importance of "the details"



- Lethal aerial exposures limit distribution in Palermo
- At Porto Empedocle and Lempedusa (more *southern* sites) repeated exposures to elevated but <u>sublethal</u> temperatures set intertidal limits (reproductive failure)
- Both cumulative stress and extremes can restrict distributions

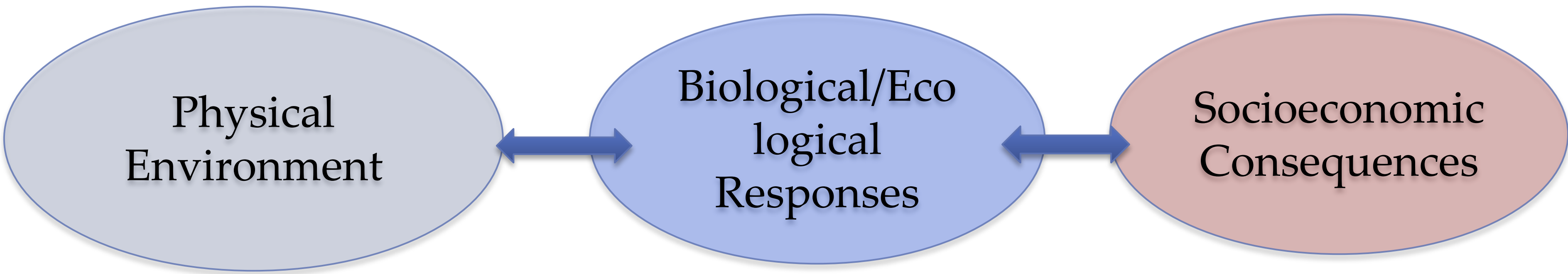
Risk = Probability of occurrence x impact



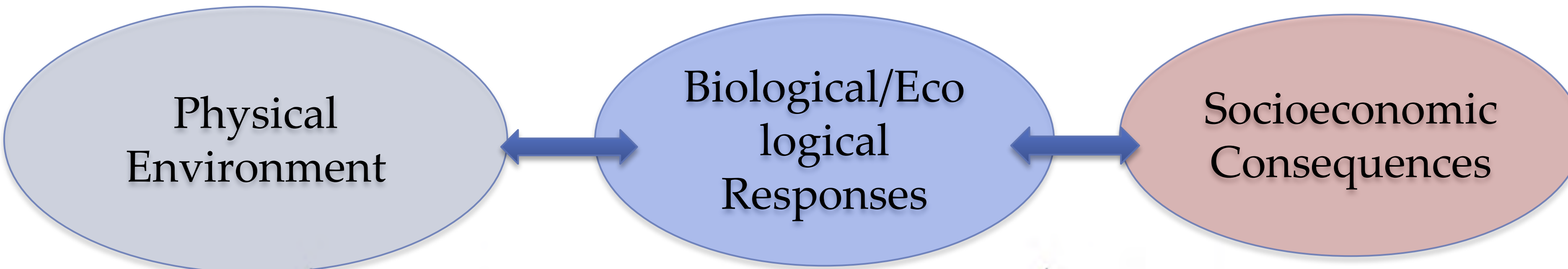
How do small details add up to create very bad things?

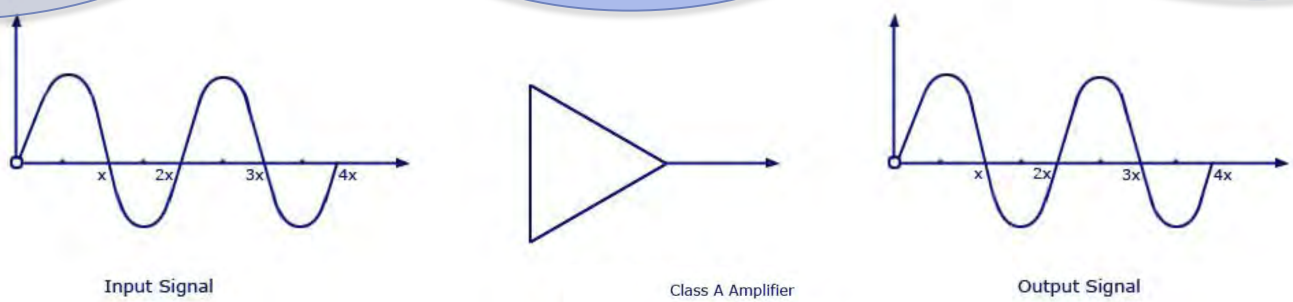
www.ipcc.ch

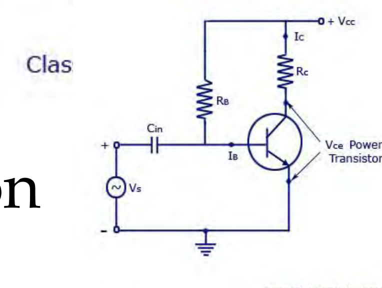
Environmental Signal Analysis: Sensitivity of Coupled Socio-Ecological Systems



Environmental Signal Analysis: Sensitivity of Coupled Socio-Ecological Systems







www.CircuitsToday.com

The "details" of each transition amplify or damp the signal

Explicit predictions build trust: can we communicate more than generalizations?

- Goodwin and Dahlstrom (2011): Being "vulnerable" by exposing one's self to failure builds trust: the antithesis of "wisdom handed down from on high"

Explicit predictions build trust: can we communicate more than generalizations?

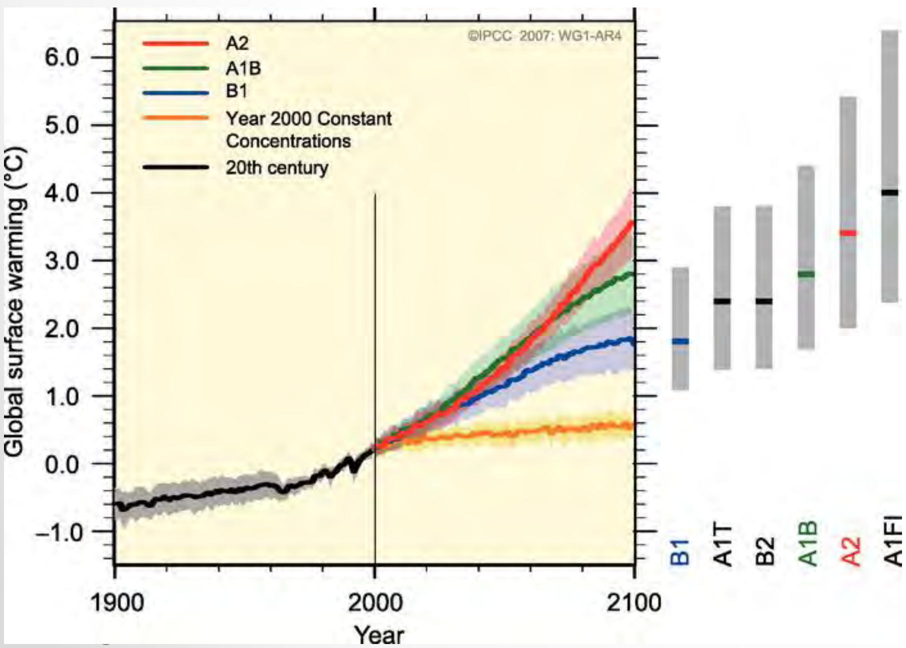
- Making scientists "vulnerable" through explicit, testable predictions about climate change can help to build trust with the public?
- For example, Leiserowitz et al. (2010): 60% level of trust by public of meteorologists (vs ~45% news media)

Uncertainty does not mean inaction

Economics theory tells us that willingness to pay depends on:

- *Perceived risk (what are the chances that my house will burn down?)*
- *Cost of action (how much will insurance cost me?)*
- *Potential cost of inaction (how much will it cost if my house does burn down?)*

There are often inconsistences and disconnects about how we talk about climate change, both with the public and within the scientific community: organisms (and people) aren't affected by changes in averages



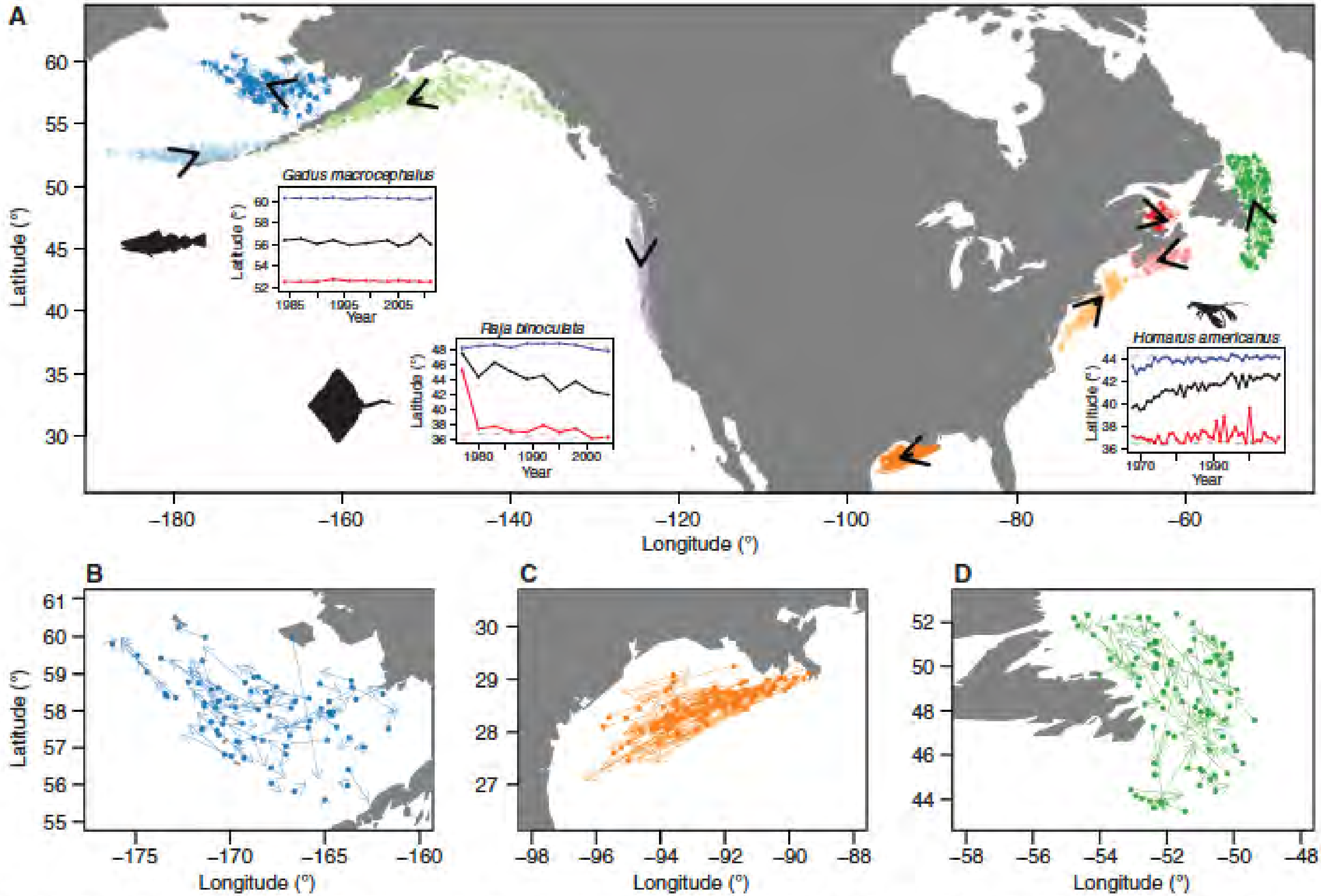
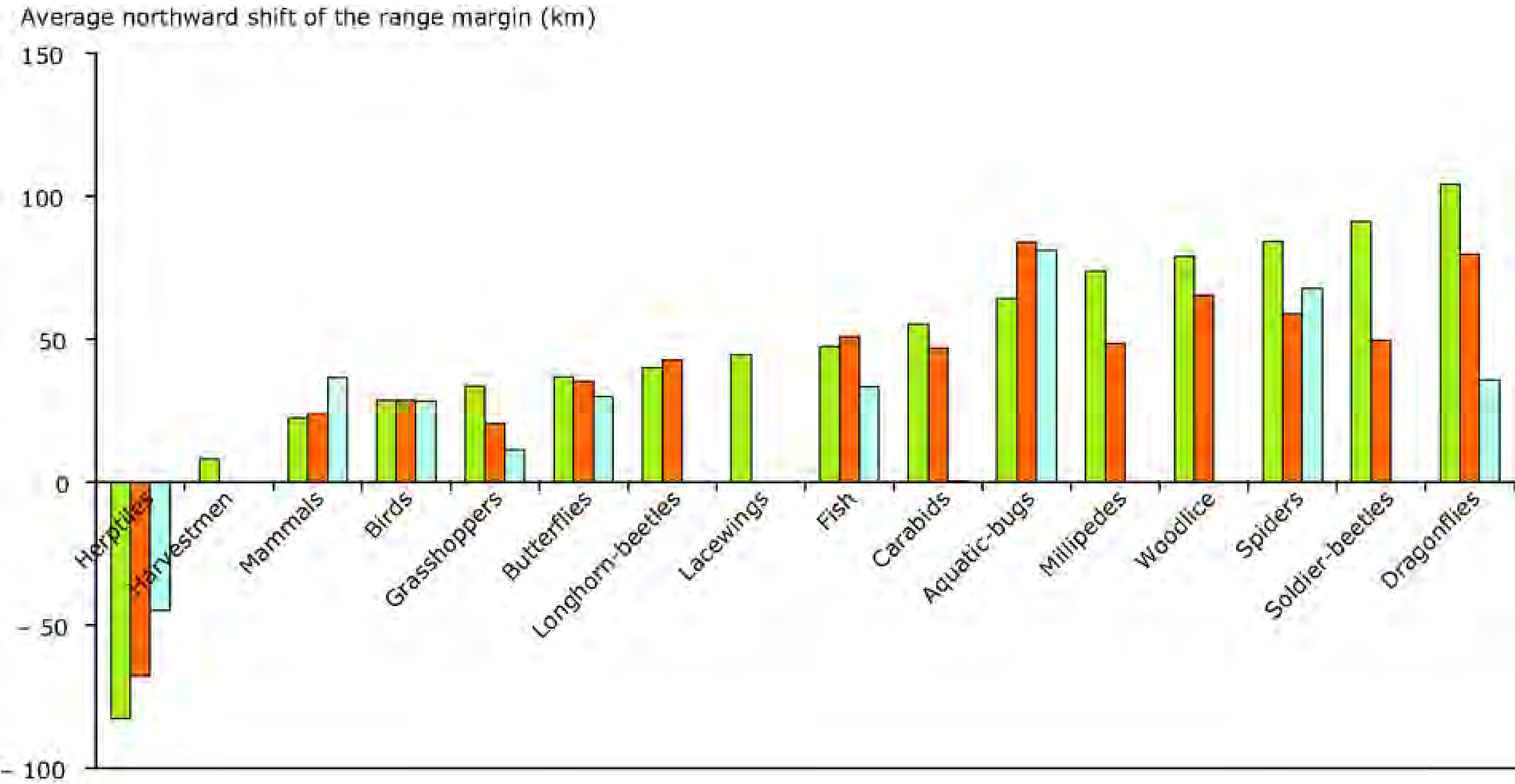


Fig. 1. Shifts in the distribution of marine taxa. **(A)** Vectors show the average shift in latitude and longitude for each taxon (colors) and the mean shift in each region (black). Insets show the mean (black), maximum (blue), and minimum (red) latitude of detection for Pacific cod (*Gadus macrocephalus*) in the Gulf of Alaska, big skate (*Raja binoculata*) on the U.S. West Coast, and American lobster (*Homarus americanus*) in the Northeast. Gray dashed lines in insets indicate the range of surveyed latitudes. Detailed views are also shown of **(B)** the Eastern Bering Sea, **(C)** the Gulf of Mexico, and **(D)** Newfoundland.

Pinsky et al. 2013 *Science* 341: 1239-1242



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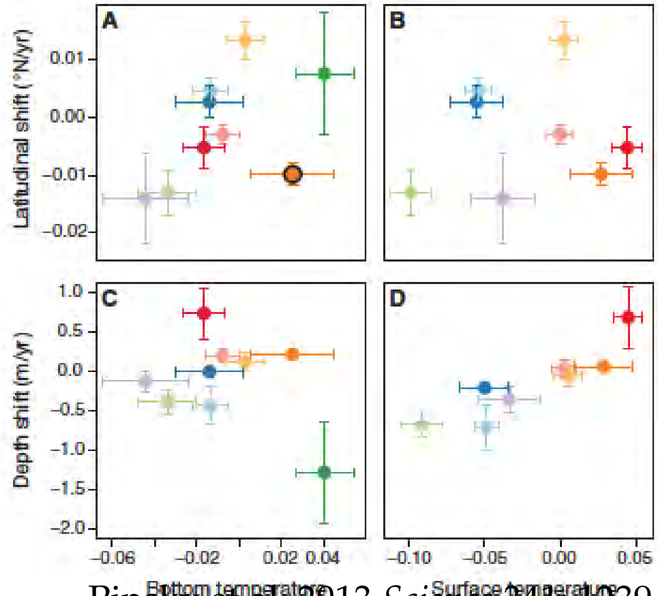
Organisms don't care about average temperature

Fig. 2. Relationships between sea temperature change and assemblage shifts. **(A)** Latitude shifts versus bottom temperature (the black circle marks the Gulf of Mexico), **(B)** latitude shifts versus surface temperature, **(C)** depth shifts and bottom temperature, and **(D)** depth shifts and surface temperature. Positive depth shifts are toward deeper water. Error bars show standard errors, and colors match the taxon vectors in Fig. 1.



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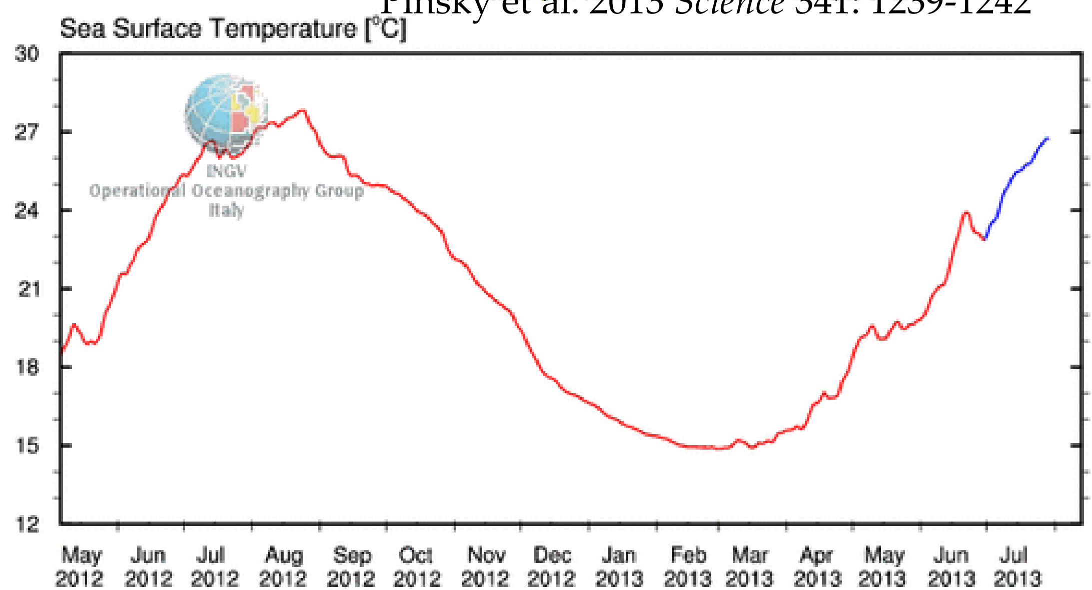

Organisms don't care about average temperature: they care about what that "climate" means to "weather"

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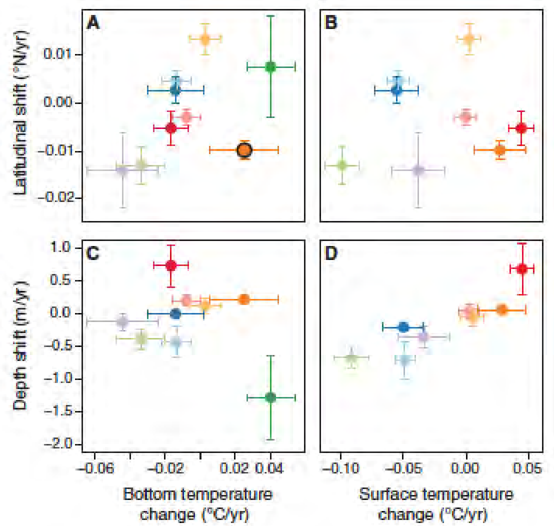

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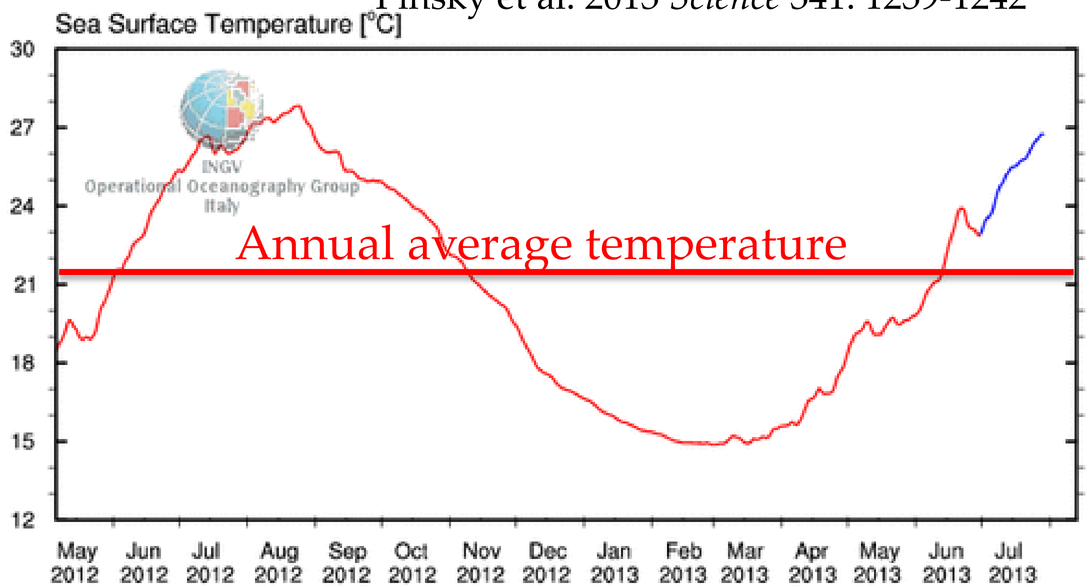

Engaging the public

- *Embrace the variability and uncertainty that underlies climate change impacts*
- *Emphasize net impacts – and variability- without resorting to sweeping generalizations*
- *Climate change is a threat multiplier that interacts with other stressors (which perhaps are easier to control)*

Climate Science

- We need to remember that climate is an indirect indicator of change in the things we care about
- Organisms don’t care about *climate* (or things like annual averages) directly but they do care about how climate changes *weather* (both extreme events and cumulative stress)
- Comparing species under, e.g. “contemporary average temperatures” against“+2°C scenarios” probably won’t tell us much

Thank you

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- Collaborators: Sean Connell, Chris Harley, Michael Kearney, Nova Mieszkowska, Bayden Russell, Gianluca Sará, David Wethey
- Helmuth lab:, Francis Choi, Nick Colvard, Shadow Gulledge, Nicole Kish, Alli Matzelle, Jenn Mocarski, Cristián Monaco, Jessica Torossian, Mackenzie Zippay

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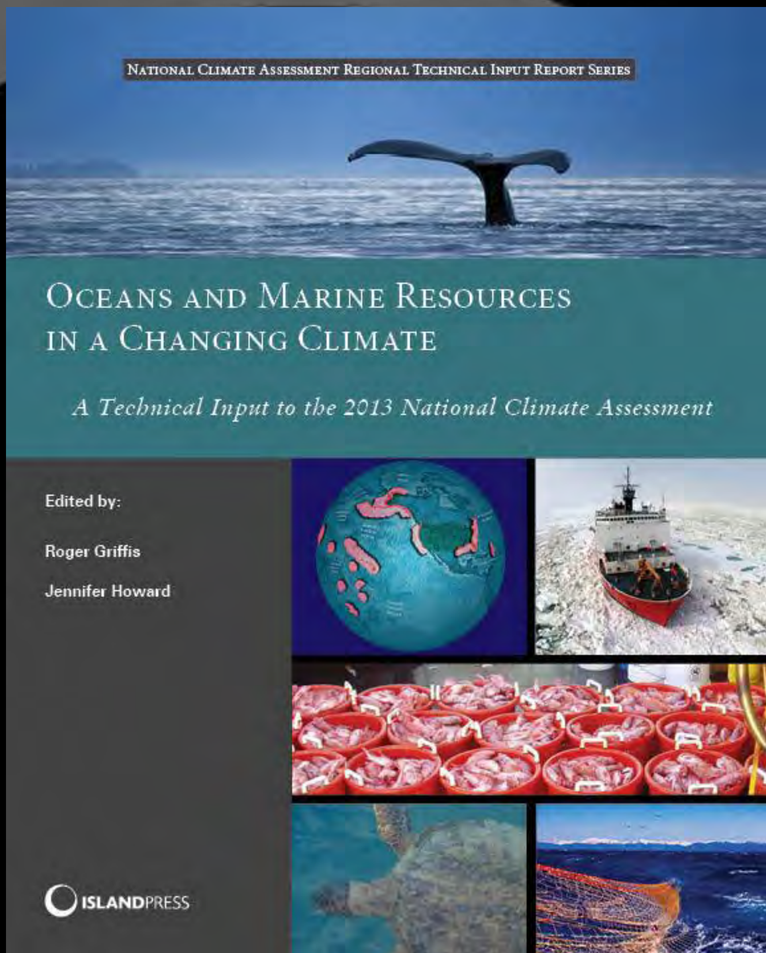

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