Communicating uncertainty in the era of climate change: When do “the details” matter?

Brian Helmuth

Marine Science Center and School of Public Policy and Urban Affairs
Northeastern University
b.helmuth@neu.edu
“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

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......
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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• *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

• 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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Lethal temperatures

Energetics

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

(Woodin, Hilbish, Helmuth, Jones and Wethy 2013)
Testing model stationarity with and without mechanism

Lethal temperatures

Energetics

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

- GIS/Weather data
- Biophysical (Heat Budget) Model
- Dynamic Energy Budget Model
- Survival, distribution
- Growth, reproduction, size

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

The organism as a sink

- resource assimilation rate
- structure
- reserve pool
- reproduction/maturation
- maturity maintenance
- growth
- somatic maintenance & growth overheads

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 Lampedusa (more southern sites) repeated exposures to elevated but sublethal 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?
Environmental Signal Analysis: Sensitivity of Coupled Socio-Ecological Systems
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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 inconsistencies 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.
Organisms don’t care about average temperature

Pinsky et al. 2013 *Science* 341: 1239-1242
Organisms don’t care about average temperature: they care about what that “climate” means to “weather”

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

*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 theexion vectors in Fig. 1.*

*Figure showing annual average temperature.*
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.
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Northeastern University
Marine Science Center
Nahant, MA 01908
http://www.northeastern.edu/helmuthlab
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Jennifer Howard

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