Climate-Aquatics Blog #31: Global trends in species shifts caused by climate change

They’re on the march…

Hi Everyone,
Hope summer was a good for everyone, if a bit on the warm side. We’re presently ¾’s of the way through what’s likely to again rank in the top 10 of the Earth’s warmest years since consistent instrumental records were begun in the late 19th Century. And it may well prove to be the warmest year ever for the U.S. where large swaths of the country have experienced extended drought and 10’s of thousands of new maximum temperature records have been set (graphic 1). With that sobering prelude, it seems like a relevant time to begin the Climate-Aquatics Module in earnest. Everything through the previous 30 blogs has been mainly foreplay, since what we really care about are FISH, & figuring out how this whole climate change thing may affect them. And this is where it gets a bit more complicated, because now we have not only the physics of stream habitats and their response to climate forcing (Blog Modules 1 & 2), but we’re dropping a slippery fish that evolves and exhibits behavioral plasticity on top of that shifting habitat template. This is why I tell my physical scientist friends that biology is not rocket science, it’s way harder.

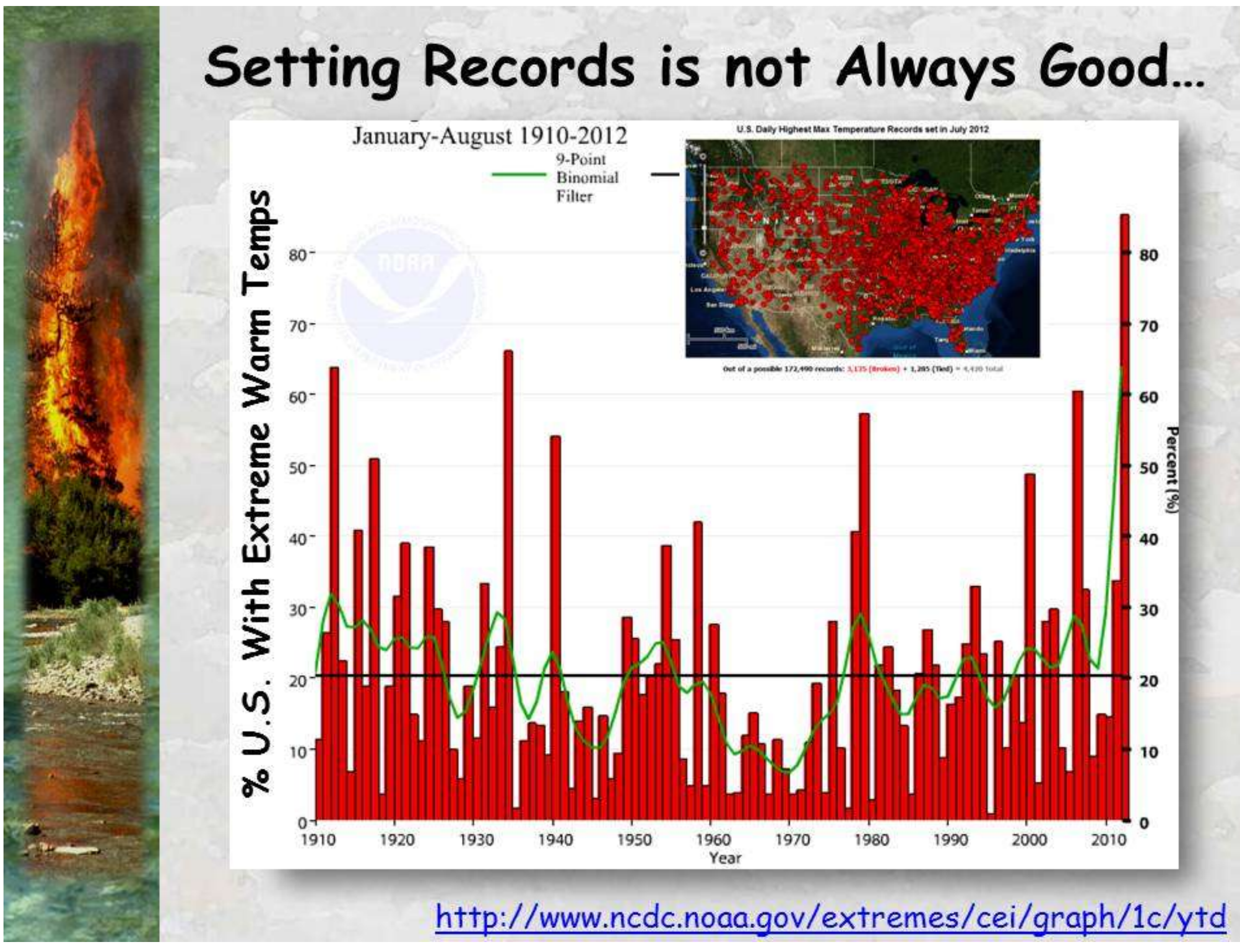
Though challenging, it’s also quite doable given the tools, techniques, and datasets available to us & we’ll step through what is known and unknown regarding climate effects on fish as we work through this module. Before getting too far into those details, however, it’s good to establish a mechanistic rationale for why we’d expect fish to be affected by climate change. Perhaps the primary reason is simply that they (& most other aquatic organisms) are ectotherms, meaning that their physiology and metabolic efficiency is dictated by temperatures in the surrounding environment (attached paper by Portner and Farrell 2008; graphic 2). As we’ve seen in several previous blogs, those temperatures have generally been increasing (blog #’s 10, 11, 13, 23). Accompanying temperature increases, other trends in stream environments are apparent such as runoff timing and flood frequency (Blog #17), declining summer baseflows (Blog #18), & alteration of sediment regimes (Blog #22). The combination of these trends creates a shifting set of habitat conditions, what I call a dynamic *disequilibrium*, that differs fundamentally from the dynamic *equilibrium* we’ve long assumed. Some fish species and populations in some areas may benefit from these changes whereas many others will not. Our challenge is understanding and predicting the biological effects, with enough resolution, and far enough in advance that it’s possible to make intelligent decisions about what to do and where to do it so that we’re managing and conserving efficiently this century.

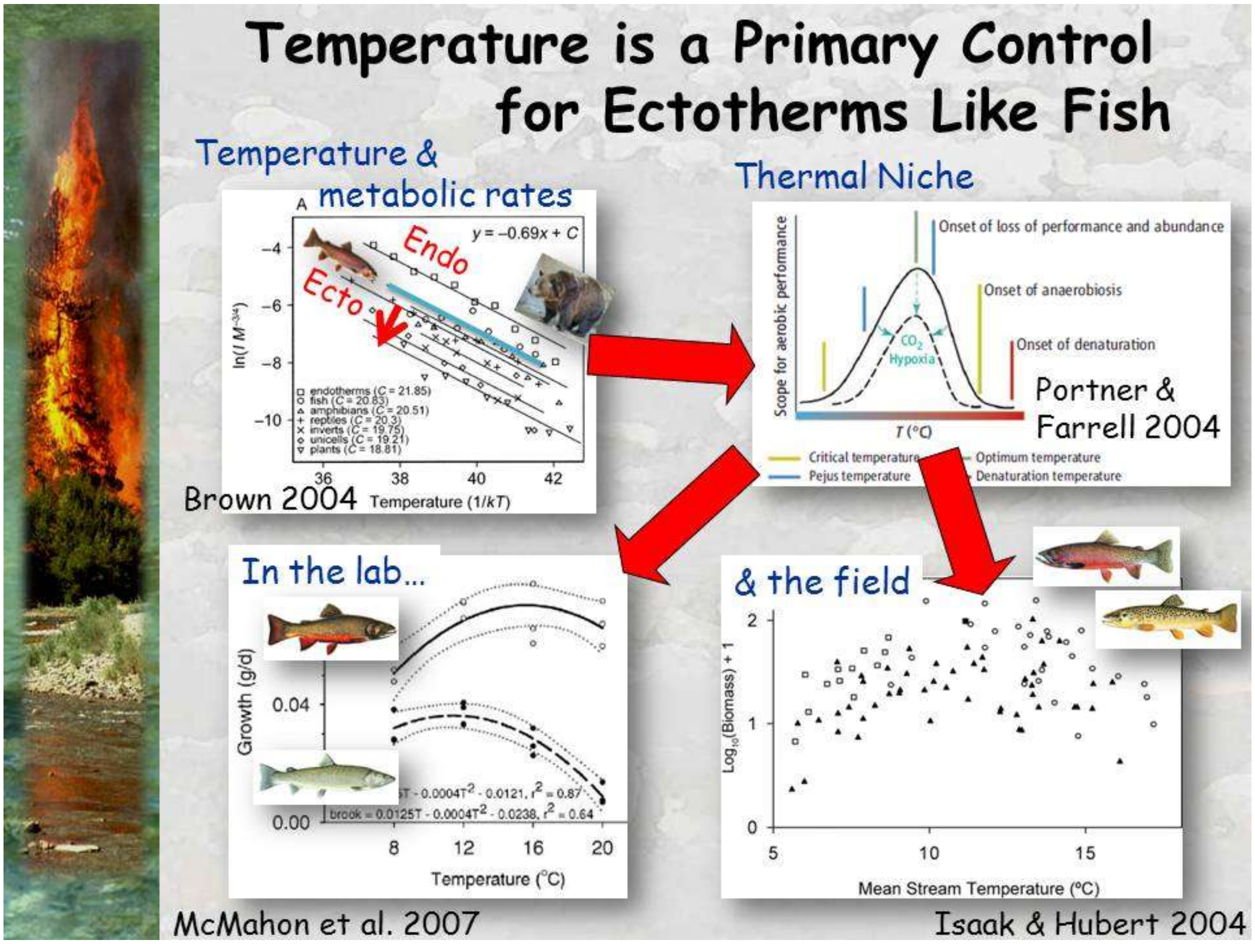
Before starting on that topic next time, however, there’s an important paper I wanted to pass along. It’s a bit out of date, having been published in 2003, before we just passed through the Earth’s warmest decade in recent centuries. It’s a review paper by Parmesan and Yohe that does a meta-analysis of trends in species distributions and phenologies inferred from long-term monitoring records. Dozens of plant and animal taxa are included and some 1,700 individual species assessed. The conclusion a decade ago was that species weren’t waiting around for climate change to happen, they’ve been marching to its drumbeat for many decades now.

Significantly higher proportions of species distributions have been shifting to cooler areas (at higher elevations or poleward) and advancing the timing of their phenologies than would be expected by random chance. The estimated global rates of distribution shifts are 6.1 kilometers/decade (or 6.1 meters/decade higher in steep areas; graphic 3) and phenologies are advancing 2.3 days/decade (graphic 4). If you read the paper, you'll notice that not many of those 1,700 species were fish (& none were freshwater fish), so see what we've learned in the last decade throughout the rest of this Climate Aquatics biology module.

Until next time, best regards,

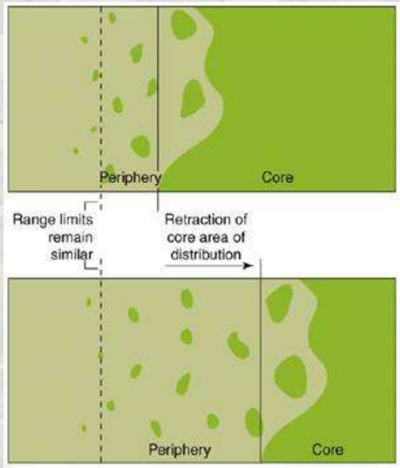
Dan




Temperature is a Primary Control for Ectotherms Like Fish
Temperature & metabolic rates
Endo
Ecto
y = −0.69x + C
ln(I M^-3/4)
endotherms (C = 21.85)
fish (C = 20.83)
amphibians (C = 20.51)
reptiles (C = 20.3)
inverts (C = 19.75)
unicells (C = 19.21)
plants (C = 18.81)
Temperature (1/kT)
Brown 2004
Thermal Niche
Onset of loss of performance and abundance
Onset of anaerobiosis
Onset of denaturation
CO2 Hypoxia
Scope for aerobic performance
T (°C)
Critical temperature
Pejus temperature
Optimum temperature
Denaturation temperature
Portner & Farrell 2004
In the lab...
Growth (g/d)
brook = 0.0125T - 0.0004T2 - 0.0238, r2 = 0.64
Temperature (°C)
McMahon et al. 2007
& the field
Log10(Biomass) + 1
Mean Stream Temperature (°C)
Isaak & Hubert 2004

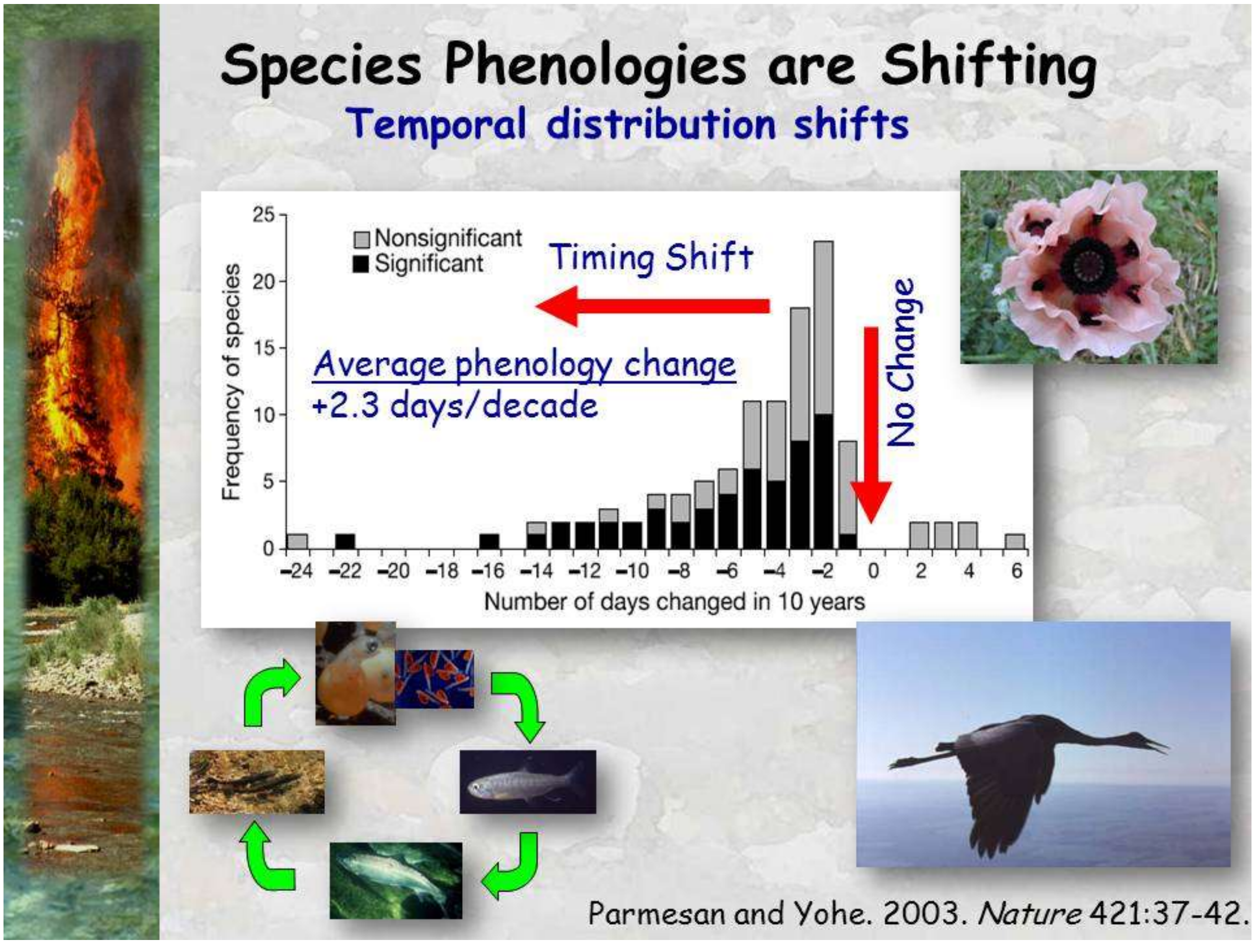
Species Distributions are Shifting

Spatial distribution shifts



Average global rate of
<u>distribution shift across taxa =</u>
6.1 km/decade poleward
OR
6.1 m/decade higher

Parmesan and Yohe. 2003. *Nature* 421:37-42.



Welcome to the Climate-Aquatics Blog. For those new to the blog, previous posts with embedded graphics can be seen by clicking on the hyperlinks at the bottom or by navigating to the blog archive webpage on our Forest Service site at: (http://www.fs.fed.us/rm/boise/AWAE/projects/stream_temp/stream_temperature_climate_aquatics_blog.html). To discuss these topics with other interested parties, a Google discussion group has also been established and instructions for joining the group are also on the webpage. The intent of the Climate-Aquatics Blog and associated discussion group is to provide a means for the 4,398 (& growing) field biologists, hydrologists, anglers, students, managers, and researchers currently on this mailing list across North America, Europe, and Asia to more broadly and rapidly discuss topical issues associated with aquatic ecosystems and climate change.

Messages periodically posted to the blog will highlight new peer-reviewed research and science tools that may be useful in addressing this global phenomenon. Admittedly, many of the ideas for postings have their roots in studies I and my colleagues have been a part of in the Rocky Mountain region, but attempts will be made to present topics & tools in ways that highlight their broader, global relevance. Moreover, I acknowledge that the studies, tools, and techniques highlighted in these missives are by no means the only, or perhaps even the best, science products in existence on particular topics, so the hope is that this discussion group engages others doing, or interested in, similar work and that healthy debates & information exchanges will occur to facilitate the rapid dissemination of knowledge among those most concerned about climate change and its effects on aquatic ecosystems.

If you know of others interested in climate change and aquatic ecosystems, please forward this message and their names can be added to the mailing list for notification regarding additional science products on this topic. If you do not want to be contacted regarding future such notifications, please reply to that effect and you will be removed from this mailing list.

Blog #27: Part 1, Spatial statistical models for stream networks: context & conceptual foundations
Blog #28: Part 2, Spatial statistical models for stream networks: applications and inference
Blog #29: Part 3, Spatial statistical models for stream networks: freeware tools for model implementation

Climate-Aquatics Biology Module
Blog #30: Recording and mapping Earth's stream biodiversity from genetic samples of critters

Future topics…
Climate-Aquatics Management Module