Climate-Aquatics Blog #47:
Part 6, Mechanisms of change in fish populations: Interacting effects of flow & temperature

This onion has some layers to it…

Hi Everyone,
Over the last several blogs we've thought about how climate induced changes in temperature might affect fish survival and growth (Blogs: 45, 46) separately from how flow changes affect the volume of habitat and food availability (Blogs: 44). In reality, however, these changes often occur simultaneously and populations are constantly adjusting their BIDE processes to deal with this variability. So today, we'll look at two recent studies that examined the combined effects of temperature and flow on growth of individuals in fish populations to get a sense of the resulting complexities.

The first study by Xu and colleagues focuses on a brook trout population in Massachusetts (graphic 1). Electrofishing rodeos were conducted 4 times (once during each season) each year from 2000 – 2007 and captured fish were tagged and measured. When some of these fish were captured during subsequent rodeos, their difference in size from the previous capture was used to estimate growth. Stream temperature and flow were monitored continuously over the course of the study, and as you might imagine, varied considerably within and among years. When the growth rates are averaged across years by season, a strong signal emerges wherein rates are highest during spring and low during other seasons (upper right panel in graphic 1). Notice, however, the error bars associated with those estimates. Those bars represent the amount of inter-annual variation in growth rates that occurred for that season during the 8 years of study. Examined in more detail (lower right panel in graphic 1), that variation relates to the temperature and flow conditions that occurred within a year relative to other years. That is, growth was fast during the spring if it was a relatively warm one, but growth was slow if it was a relatively cold one. Interestingly, this relationship isn't consistent for all seasons because warmer temperatures in the summer and fall meant less growth. A similar dynamic occurs with regards to inter-annual variation in flows. Higher flows were good for growth during spring, summer, and fall, but bad during the winter (3 lines associated with each season in the graphic).

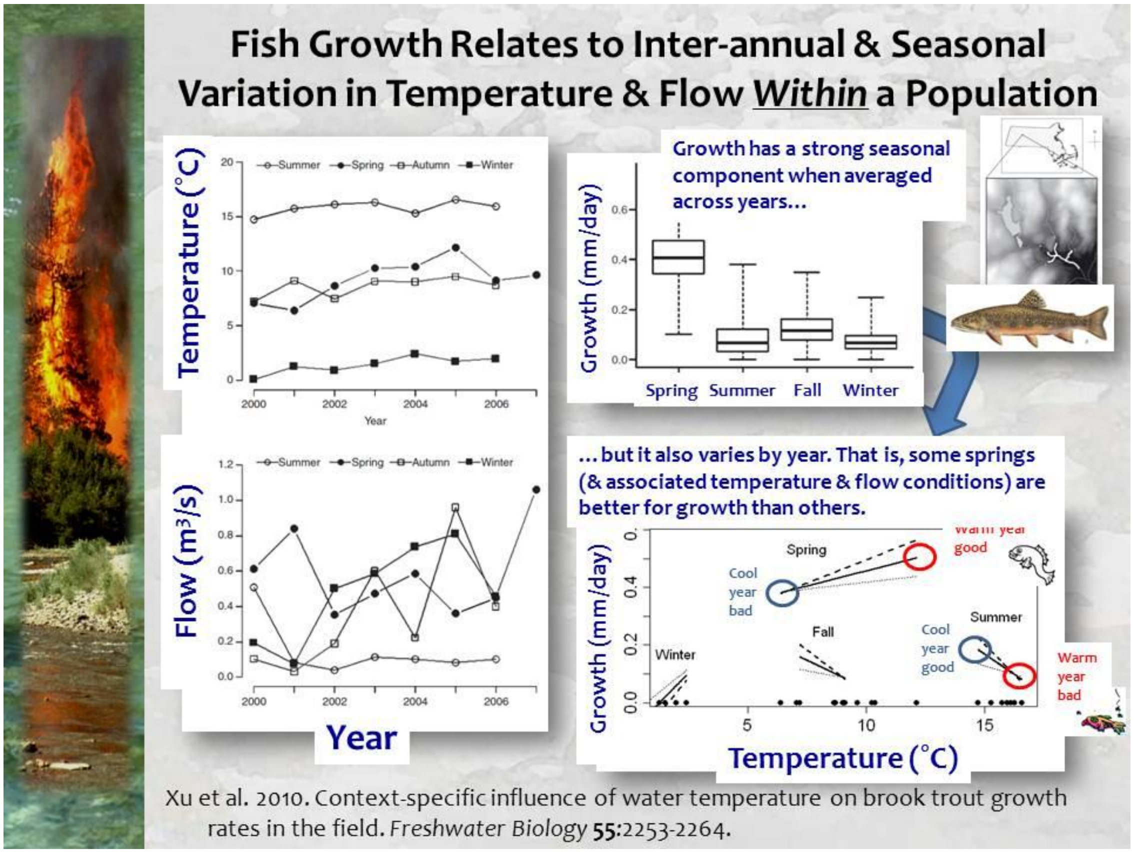
The second study by Crozier and colleagues describes variation in the size of juvenile Chinook salmon across 16 years in 13 different populations from central Idaho streams (graphic 2). Juvenile Chinook were electrofished, captured, and measured each summer and fish lengths were then related to inter-annual variation in temperature and fish density. Although the investigators didn't address flow *per se*, the use of density in this case was a better choice because the huge variation in salmon numbers during the study (almost 3 orders of magnitude) gave a better measure of the variation in the number of mouths to feed and the likely intensity of competitive interactions. Results suggest that juvenile Chinook length was affected by temperature in all of the populations but the nature of the effect was strongly mediated by fish density. When densities were low, warmer temperatures resulted in bigger fish, but just the opposite occurred when densities were high. This pattern was consistent across each of the 13 study populations and suggests competitive interactions may become a more important determinant of fish size in these populations as the climate warms in future decades.

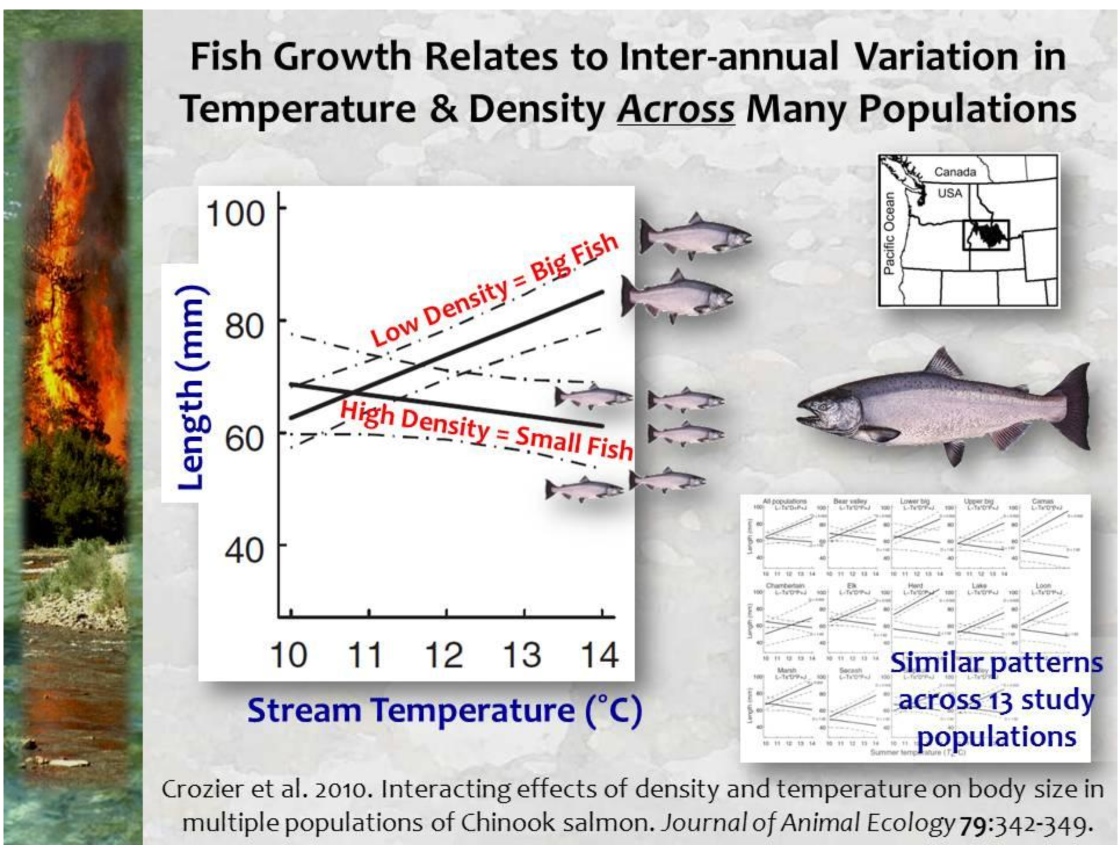
Both studies suggest there are some interesting layers to this climate onion once you start the peeling to look at details within and among populations. But although the effects of climate will be context specific to be sure, the fact that some form of bioclimatic relationship appears in many populations when we look for it also means there are some general relationships at play. Better describing those relationships simply requires more data from more populations, so it's encouraging that much of what's needed can be obtained from trend monitoring data on temperature (Blog #3), flow (Blog #21), and fish abundance (Blog #41) and that these data are out there. One key piece we may sometimes be missing, however, is information about food availability. There's a big literature that describes the importance of food ration size on fish growth and survival and it's possible that some of the variation in fish-climate relationships that today's studies describe among seasons, years, and populations might be resolved if we knew more about fish food. That's a challenge in and of itself, and perhaps moreso now if climate change is altering nutrient availability in streams—a possibility that we'll touch on next time.

Until then, best regards,

Dan

Now Tweeting at Dan Isaak@DanIsaak


Fish Growth Relates to Inter-annual & Seasonal Variation in Temperature & Flow *Within* a Population
Temperature (°C)
Summer
Spring
Autumn
Winter
Year
Flow (m³/s)
Year
Growth has a strong seasonal component when averaged across years…
Growth (mm/day)
Spring
Summer
Fall
Winter
… but it also varies by year. That is, some springs (& associated temperature & flow conditions) are better for growth than others.
Growth (mm/day)
Spring
Cool year bad
Warm year good
Fall
Winter
Summer
Cool year good
Warm year bad
Temperature (°C)
Xu et al. 2010. Context-specific influence of water temperature on brook trout growth rates in the field. *Freshwater Biology* **55**:2253-2264.


Fish Growth Relates to Inter-annual Variation in Temperature & Density *Across* Many Populations
Length (mm)
Low Density = Big Fish
High Density = Small Fish
Stream Temperature (°C)
Canada
USA
Pacific Ocean
Similar patterns across 13 study populations
Crozier et al. 2010. Interacting effects of density and temperature on body size in multiple populations of Chinook salmon. *Journal of Animal Ecology* **79**:342-349.

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 5,452 (& 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 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 to them. If you do not want to be contacted again in the future, please reply to that effect and you will be de-blogged.

Previous Blogs…

Blog #13: Tools for visualizing local historical climate trends
Blog #14: Leveraging short-term stream temperature records to describe long-term trends
Blog #15: Wildfire & riparian vegetation change as the wildcards in climate warming of streams
Blog #23: New studies describe historic & future rates of warming in Northwest US streams
Blog #24: NoRRTN: An inexpensive regional river temperature monitoring network
Blog #25: NorWeST: A massive regional stream temperature database
Blog #26: Mapping thermal heterogeneity & climate in riverine environments
Blog #40: Crowd-sourcing a BIG DATA regional stream temperature model

Climate-Aquatics Hydrology Module
Blog #16: Shrinking snowpacks across the western US associated with climate change
Blog #17: Advances in stream flow runoff and changing flood risks across the western US
Blog #18: Climate change & observed trends toward lower summer flows in the northwest US
Blog #19: Groundwater mediation of stream flow responses to climate change
Blog #20: GIS tools for mapping flow responses of western U.S. streams to climate change
Blog #21: More discharge data to address more hydroclimate questions
Blog #22: Climate change effects on sediment delivery to stream channels

Climate-Aquatics Cool Stuff Module
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
Blog #31: Global trends in species shifts caused by climate change
Blog #32: Empirical evidence of fish phenology shifts related to climate change
Blog #33: Part 1, Fish distribution shifts from climate change: Predicted patterns
Blog #34: Part 2, Fish distribution shifts from climate change: Empirical evidence for range contractions
Blog #35: Part 3, Fish distribution shifts from climate change: Empirical evidence for range expansions
Blog #36: The "velocity" of climate change in rivers & streams
Blog #37: Part 1, Monitoring to detect climate effects on fish distributions: Sampling design and length of time
Blog #38: Part 2, Monitoring to detect climate effects on fish distributions: Resurveys of historical stream transects
Blog #39: Part 3, Monitoring to detect climate effects on fish distributions: BIG DATA regional resurveys
Blog #41: Part 1, Mechanisms of change in fish populations: Patterns in common trend monitoring data
Blog #42: BREAKING ALERT! New study confirms broad-scale fish distribution shifts associated with climate change

Blog #43: Part 2, Mechanisms of change in fish populations: Floods and streambed scour during incubation & emergence
Blog #44: Part 3, Mechanisms of change in fish populations: Lower summer flows & drought effects on growth & survival
Blog #45: Part 4, Mechanisms of change in fish populations: Temperature effects on growth & survival
Blog #46: Part 5, Mechanisms of change in fish populations: Exceedance of thermal thresholds

Future topics…
Climate-Aquatics Management Module

Climate-Aquatics End Game