Climate-Aquatics Blog #45:
Part 4, Mechanisms of change in fish populations: Temperature effects on growth & survival

What the hail's going on with temperature?

Hi Everyone,
Hope the 4th was good to all. Crazy, record setting heatwave across much of the American West, followed by a crazy sort of cold in some places. They had a foot of hail fall in the desert Southwest if you hadn't heard (http://www.komonews.com/news/offbeat/Massive-storm-dumps-nearly-2-feet-of-hail-in-New-Mexico-214299611.html)!

Regardless of the extreme, temperature is important—and especially so if you're an ectotherm constrained to life in a flowing ribbon of water like our favorite critters. So this time we're doing the first of two blogs highlighting the strong control that temperature has on fish populations. The first paper by Neuheimer & Taggart is a longtime favorite that links fish growth/size-at-age to temperature (hyperlinked here: http://sites.google.com/site/abneuheimer/Neuheimer_Taggart_2007.pdf). The thermal metric they highlighted was the growing degree-day, which is the equivalent of 1˚C over a 24 hour period. A day in which the average temperature was 12˚C would have 12 degree-days, a month in which the average temperature was 12˚C would have 360 degree-days (12˚C x 30 days), etc. The premise is simple, but powerful, because if you know the growing degree-days a fish experiences in its early developmental phases, you can predict the heck out of how long it will be at a certain age (graphic 1). Moreover, this one simple metric has strong explanatory power across many species, freshwater/marine environments, temperate/tropical areas, constant/variable temperatures, and laboratory/field studies as demonstrated by Neuheimer & Taggart. And fish length/size at a young age is a big determinant of survival and/or subsequent life history trajectory.

The degree-day also figures prominently in our next 2 studies, which are companion papers by Coleman & Fausch. In the first of these two papers, the duo conducted a laboratory study to examine how different thermal regimes affected the survival of age-0 cutthroat trout from egg emergence/fry swim-up through the next 6 months (graphic 2; study hyperlinked here: http://warnercnr.colostate.edu/~kurtf/400web/Field%20trip%20assignment/Native%20cutthroat/

Coleman%20and%20Fausch%202007%20TAFS%20Lab.pdf). Fish fed similar rations survived very differently, with those in the coldest treatment surviving at less than half the rate of those in intermediate and warm treatments. Warm, in this case, is relative because the study was designed to provide inference about conditions in high-elevation (~10,000 feet) streams of the Colorado Rockies. The "warm" treatment, therefore, consisted of temperatures that averaged 10˚C, which based on personal experience, is cold enough to make your hand start hurting after a few seconds of immersion.

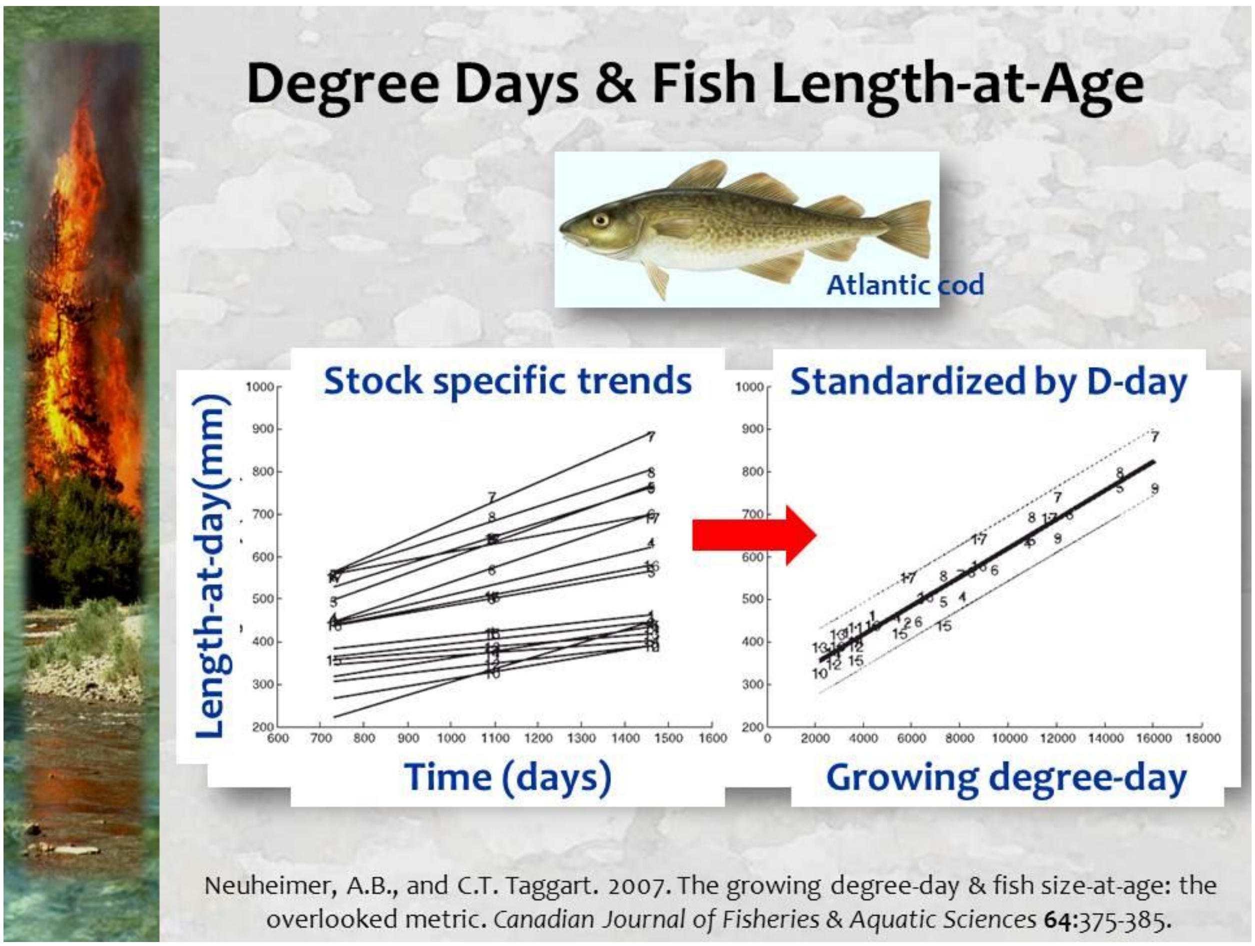
Lots of lab studies have baked fish at various temperatures, but what sets Coleman and Fausch's baking apart is the companion paper that tested/translated the laboratory results to field settings (graphic 3; study hyperlinked here: http://warnercnr.colostate.edu/~kurtf/400web/Field%20trip%20assignment/Native%20cutthroat/Coleman%20and%20Fausch%202007%20TAFS%20Field.pdf). Through fry surveys and temperature measurements conducted across several streams, they documented a relationship between fry length and degree-days that was very similar to the laboratory relationship. This, combined with earlier research on other aspects of these populations, gave them insight regarding why some streams, despite nearly pristine conditions, rarely supported cutthroat trout recruitment. They concluded that approximately 900 degree days were needed during the growing season for cutthroat trout to consistently reproduce in these streams and support a self-sustaining population. Below that threshold, age-0 cutthroat emerge too late in the summer and grow too slowly to be able to make it through their first winter when things are really cold for a really long time.

It's a bit ironic to be focusing on how *cold* temperatures regulate fish populations in a warming world, but there are plenty of places globally (Blog #35) where cold temperatures have served as a barrier to colonization by new species and recruitment bottlenecks for young fish are likely to be a common limiting factor. As such, it's important to fully understand the processes in these streams and specifically where these bottlenecks occur geographically across a river network as these areas could serve as future climate refuges for the native species we're often trying to conserve or be the places where non-native invasions become most likely with additional warming (Blog #38). It's worth noting, also, that the basic pieces for operationalizing these concepts broadly are very obtainable because there are only two main things we need to know: 1) what are the thermal constraints/thresholds associated with juvenile recruitment as per Coleman and Fausch and 2) the geographic locations where these thermal constraints occur. That information can be developed from local stream temperature monitoring (Blogs #'s 3, 24, 26) or accurate model predictions (Blog #'s: 7, 40) to give us the necessary baseline maps. Then we can plug and chug through the stream climate velocity calculations (Blog #36) to see how far/fast those areas with thermal constraints would shift based on various warming scenarios (Blog #23). It's still an open question whether fish populations will keep apace of these shifts (Blog #42), but we should, at least, be able to accurately predict where key thermal habitats exist for species x, y, or z at times 1 and 2 across riverscapes. That, in turn, will let us identify potential trouble-spots where it might make sense for us to intervene.

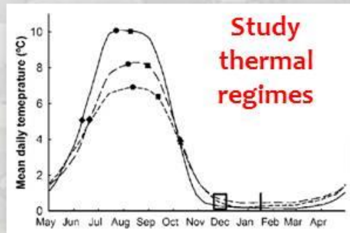
So we've only scratched the surface of all that's going on in the busy arena of thermal biology for fishes and next time we'll highlight a few papers that focus on the hot side of the thermal spectrum. But before closing, I wanted to point readers to two good reviews on this subject, "Burning questions for coldwater stream fishes." by McCullough & colleagues (hyperlinked here: www.esd.ornl.gov/~zij/mypubs/climate/McCullough09-Burning.pdf). And the more mundanely titled, "Climate change effects on fisheries" by Pörtner and Peck (hyperlinked here: http://www.researchgate.net/publication/47793443_Climate_change_effects_on_fishes_and_fisheries_towards_a_cause-and-effect_understanding/file/9fcfd507e6e0698c40.pdf). The latter focuses more on oceanic fisheries but still contains a lot of good information on thermal mechanisms that regulate fish populations and is by two of the world's leading metabolic ecologists.

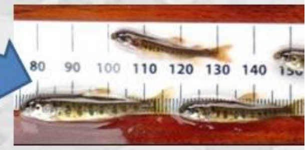
Until next time, best regards,

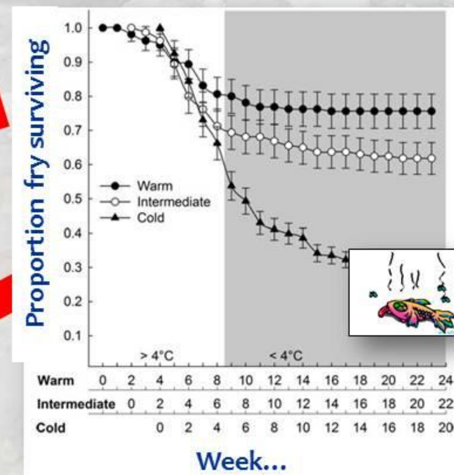
Dan

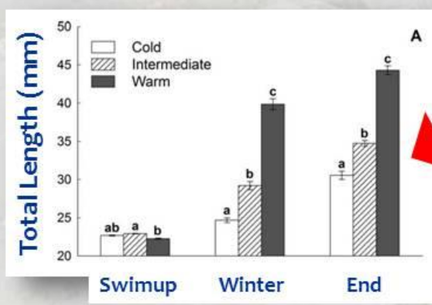


Temperature effects on fry survival in the laboratory…



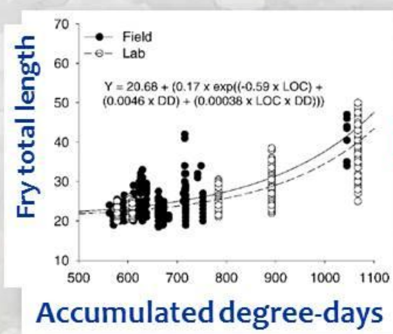


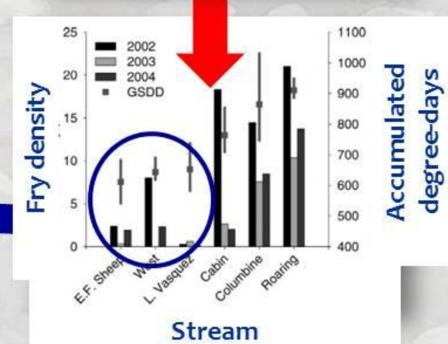




Coleman & Fausch. 2007. Cold summer temperature regimes cause a recruitment bottleneck in age-0 Colorado river cutthroat trout reared in laboratory streams. *Transactions of the American Fisheries Society* **136**:639-654.

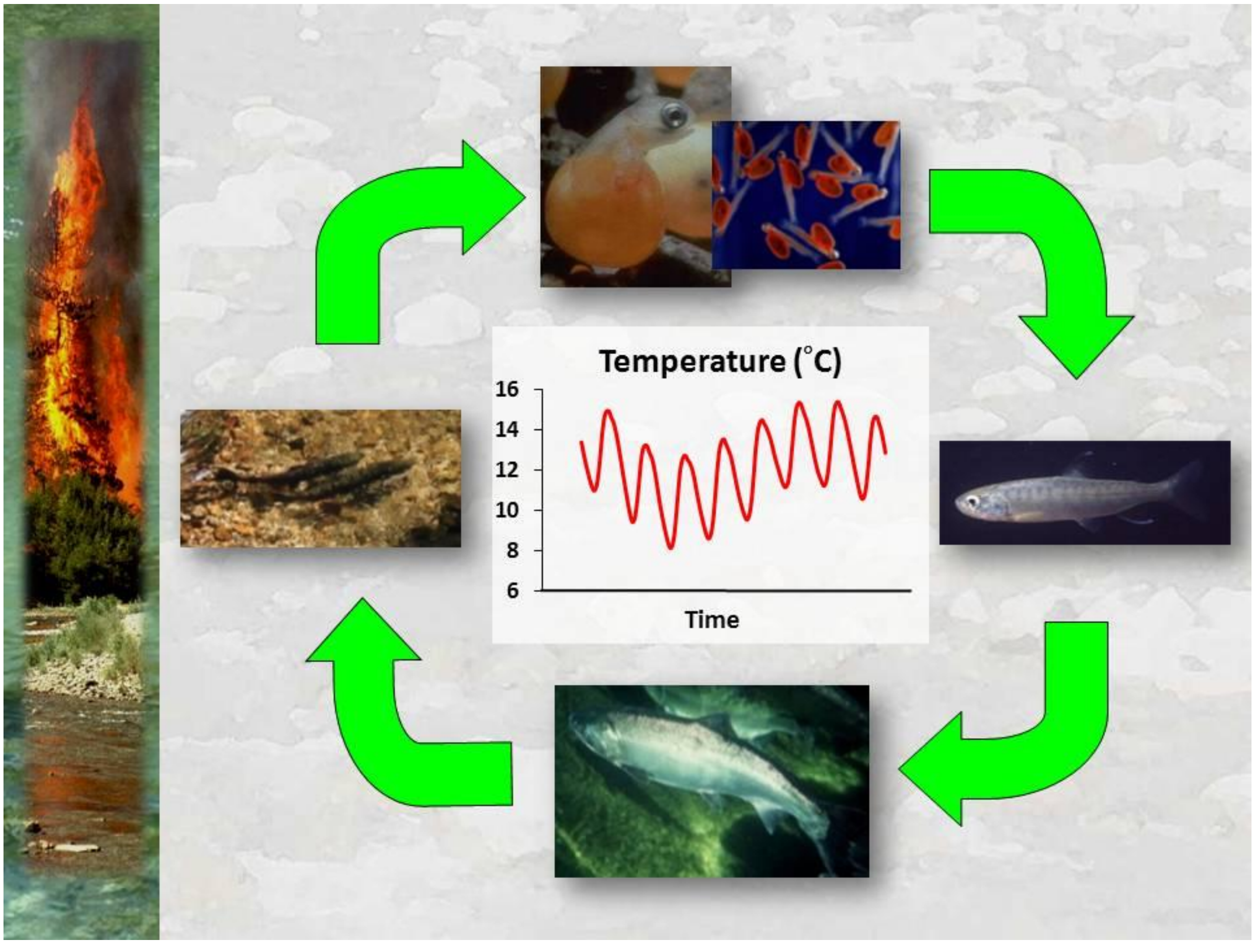
… translate to field settings in the Colorado Rockies…





… to help identify streams that were too cold for juvenile recruitment

Coleman & Fausch. 2007. Cold summer temperature limits recruitment of Age-0 cutthroat trout in high-elevation Colorado streams. *Transactions of the American Fisheries Society* **136**:1231-1244.



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 5,402 (& 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…

Climate-Aquatics Overviews

Blog #1: Climate-aquatics workshop science presentations available online
Blog #2: A new climate-aquatics synthesis report

Climate-Aquatics Thermal Module

Blog #3: Underwater epoxy technique for full-year stream temperature monitoring
Blog #4: A GoogleMap tool for interagency coordination of regional stream temperature monitoring
Blog #5: Massive air & stream sensor networks for ecologically relevant climate downscaling
Blog #6: Thoughts on monitoring air temperatures in complex, forested terrain
Blog #7: Downscaling of climate change effects on river network temperatures using inter-agency temperature databases with new spatial statistical stream network models
Blog #8: Thoughts on monitoring designs for temperature sensor networks across river and stream basins
Blog #9: Assessing climate sensitivity of aquatic habitats by direct measurement of stream & air temperatures
Blog #10: Long-term monitoring shows climate change effects on river & stream temperatures
Blog #11: Long-term monitoring shows climate change effects on lake temperatures
Blog #12: Climate trends & climate cycles & weather weirdness
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

Future topics…
Climate-Aquatics Management Module