Climate-Aquatics Blog #44:
Part 3, Mechanisms of change in fish populations: Lower summer flows & drought effects on growth & survival

Ever wonder how fish fossils happen?

Hi Everyone,
Similar to the last blog, this time we'll again consider how a climate-induced hydrologic pattern may affect BIDE processes in fish populations. But instead of too much water at certain times & places, this time the problem is too little water. Specifically, the trend in recent decades toward decreasing summer flows across significant parts of the western U.S. (blog #18). These declines aren't trivial, amounting to decreases of 20% or more in average flows across broad regions over the last 50 years & driven by varying combinations of earlier snowmelt runoff (blogs #16 and #17; which leaves less water late in the year) and subregional trends in total precipitation (increasing in some places, decreasing in others; graphic 1).

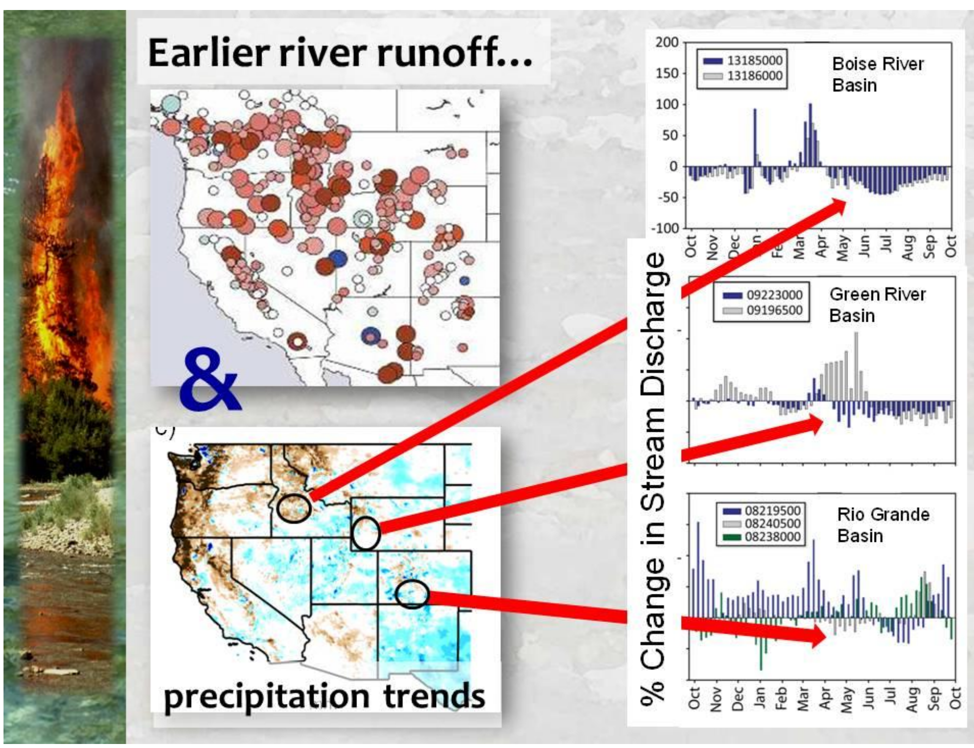
Because the amount of water in a stream channel is the most fundamental determinant of fish habitat, these declines obviously have important and direct biological consequences. Most obviously, fish need some minimum amount of flow to live, so those places in a channel network where this minimum isn't consistently met won't have fish. We often think of these areas as the transition points in headwaters where flows go from being intermittent to perennial (graphic 2), but as Lake points out in our first paper (hyperlinked here: http://www.southwestnrm.org.au/sites/default/files/uploads/ihub/lake-ps-2003-ecological-effects-perturbation-drought-flowing-waters.pdf), there are many in networks where natural factors may cause minimum fish flows not to occur. If summer flows trend lower in the future, it would be expected that many of these areas will expand from where they have occurred historically. And in these new areas, no water will mean no fish—it's as simple as that (though perhaps in a few million years we get a few nice fossils if the changes caught a few fish off guard). Another important consideration is how flow reductions will interact with the infrastructure we've built throughout many river basins. For example, one issue that commonly occurs in mountain basins is a restriction in fish movement past some road crossings and culverts (graphic 2). As flows decline, these restrictions could occur at a larger proportion of road crossings and serve to fragment otherwise continuous habitat.

But thankfully, climate change isn't likely to cause all (or even many) of our streams to completely dry up and blow away. So the other important question is how flow reductions affect fish within the majority of the network that still retains sufficient flows? What does 20% or 30% or 40% less flow really mean from the standpoint of a population? Probably many things, and as always, the answer is going to be somewhat context and species specific. But this next paper by Harvey and colleagues (hyperlinked here: http://www.waterrights.ca.gov/hearings/docs/caw/exhibits/sc_10.pdf) did a nice job of exploring these questions for drift-feeding rainbow trout through a manipulative field experiment. Working in a California stream, the authors blocked off consecutive sections and diverted flow out of half the sections for one summer. They then measured the amount of aquatic insect drift, fish growth, and fish survival over a 6 week period (graphic 3). Not surprisingly, less water moving through the diverted sections of stream translated to fewer insects drifting downstream. And with a skimpier buffet line, fish growth shrank accordingly. The study was not of a duration sufficient to determine whether fish survival rates would have been affected, but growth rates in fish are often strongly correlated with survival. At the very least, some hungry fish would have eventually been forced to try emigrating from the study reaches to find habitats with more food. And emigration brings with it another set of mortality risks associated with predation or the possibility of not finding productive habitats.

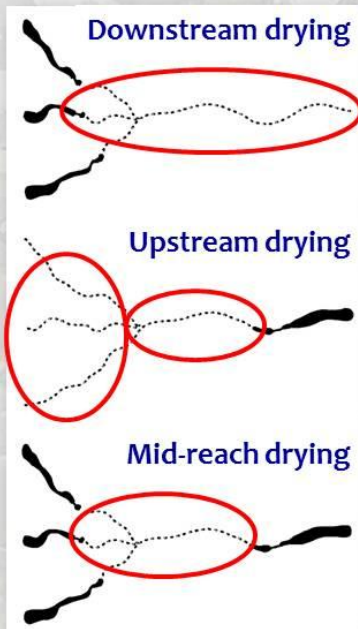
So next time, we'll flip over to the temperature side of things and think more about thermal biology before highlighting a couple recent studies that looked at the combined effects of flow and temperature on fish growth & survival. For aficionados of self-thinning theory, you'll start to see some strong parallels as there's a logical intersection here between that body of work and stream climatology that should synergize to rapidly improve our understanding of mechanisms by which climate regulates fish population dynamics.

Until then, best regards,

Dan



Flow Intermittency Happens in Several Places

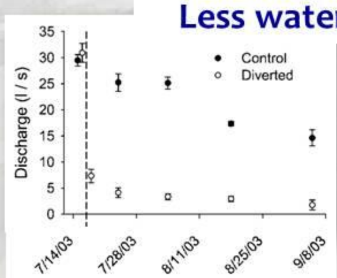


Infrastructure May Exacerbate Fragmentation from Flow Reductions

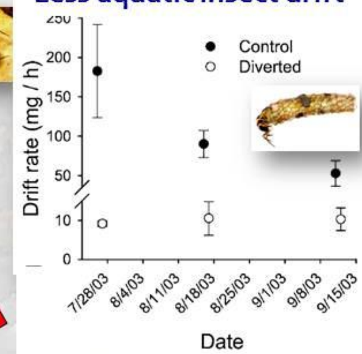
Lake. 2003. Ecological effects of perturbation by drought in flowing waters. *Freshwater Biology* **48**:1161-1172.

Flow declines & decreased fish growth

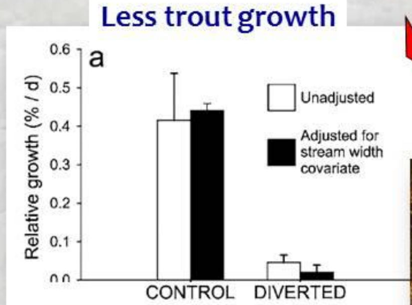
Less water

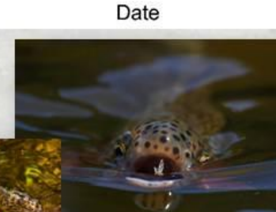


Less aquatic insect drift



Less trout growth



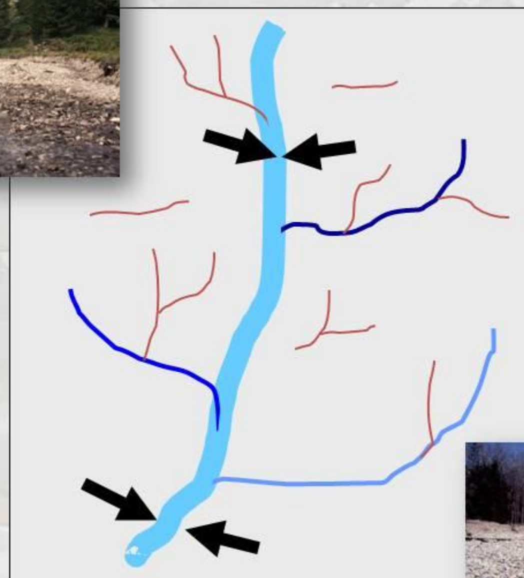


You are a bug.
I will eat you

Harvey et al. 2006. Reduced streamflow lowers dry-season growth of rainbow trout in a small stream. *Transactions of the American Fisheries Society* **135**:998-1005.

Summer Flow Decreases ~

Smaller, more fragmented, less productive habitats…



Warning: this slide contains graphic material that some viewers may find objectionable…

fish out of water… never a pretty site

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 5,373 (& 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

Future topics…

Climate-Aquatics Management Module