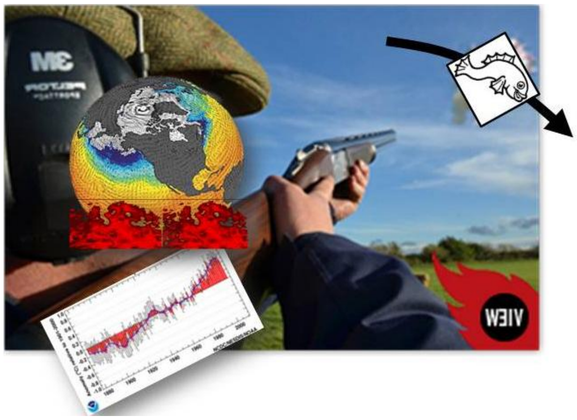
Climate-Aquatics Blog #50:
Part 9, Mechanisms of change in fish populations: Evolutionary responses



…Climate shooting at a moving fish target

Hi Everyone,

Another mechanism that adds an interesting twist to the climate response of fish populations is evolution. As we saw in earlier blogs (#'s 31 and 32), fish and other critters can, and are, adjusting to climate change by shifting their phenologies in terms of migration dates, breeding seasons, maturation, etc. At the boundaries of distributional ranges they're also exposed to warmer thermal regimes and shifting into new (blog #35), and out of old (blog #34), geographic locations. Those shifts keep the bulk of a species within a climate niche similar to the historical one, but near the margins of that niche selective pressures should come into play to allow individuals and populations with certain genetic traits to do better or worse over time. An important question is whether evolution could happen fast enough that it helps species adapt to climate change and provide additional resilience.

In our first study by Kovach and colleagues (hyperlinked here: https://s3-us-west-1.amazonaws.com/akssfapm/APM_Uploads/2008/45965/.pdf/%E2%80%A6%20of%20the%20Royal%20%E2%80%A6%202012%20Kovach-1.pdf) the authors examined migration timing in Alaskan pink salmon runs over a 30-40 year period encompassing some 17 generations (graphic 1). As temperatures in the natal stream warmed over this period, the adults showed a trend towards earlier migration dates for spawning. In addition to those good long-term time series, the authors also possessed historical records on genetic alleles and knew which of those markers represented subpopulations of later migrants within the population. What they found was a decrease in allelic frequencies of the later fish, suggesting that at least some of the changes in this population during previous decades had a genetic basis and the patterns observed weren't merely a case of phenotypic plasticity.

In our second study by Narum and colleagues (hyperlinked here: http://www.researchgate.net/publication/235773332_Thermal_adaptation_and_acclimation_of_ectotherms_from_differing_aquatic_climates/file/e0b4951b0dd0cc477f.pdf), a common garden experiment was run with redband trout to determine whether fish from populations that had evolved in colder environments (mountain populations) would respond differently to a heat shock than those from warmer environments (desert populations; Graphic 2). Fish from both populations were exposed to an identical short-term thermal stress and then monitored for the expression of heat shock genes. In days subsequent to the thermal shock, the fish from the desert population (interestingly) showed smaller expression of these genes relative to the mountain populations and poorer short term survival. The mountain fish showed higher gene expression and short term survival, but these fish also had elevated levels of heat shock proteins that incurred physiological costs, & which may have contributed to poorer longer term survival. The authors concluded that the two populations had evolved different strategies for dealing with thermal stress, and that thermal adaptive response might allow some populations to better cope with climate change in the future. We don't have the multigenerational perspective of the Kovach study to give us a sense of how fast that could happen, but again, there appears to be some flexibility in the genome.

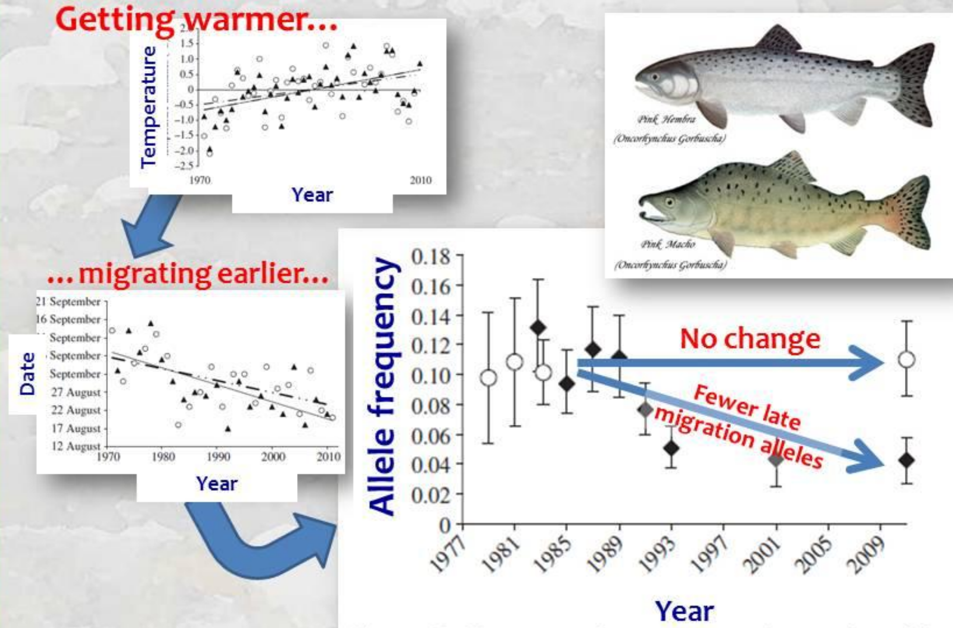
That flexibility will help take the edge off the environmental changes fish populations have to deal with as the climate warms, but it's not likely to be all peaches and cream as evolution rides to the rescue here either. It will certainly help, but anytime an organism changes, there are tradeoffs, consequences, and limits because there's no free lunch in nature & everyone's on a tight budget. In an extreme case like the Fraser river sockeye example (blog #46), the tradeoff can be rather severe as adults returning earlier from the ocean (perhaps good for that life stage) precipitated a disastrous upriver migration involving metabolic immolation during especially warm years. In other cases, a trait under selection is simply going to be constrained by how much, or how fast, it can change relative to the pace of environmental change. A trout, for example, isn't ever going to live very long in water that's 30˚C, and by the time it could do so a few million generations from now, it would have evolved into something we didn't recognize as a trout (think bullhead or carp). A nice framework for thinking more about these tradeoffs was published by Crozier and colleagues several years ago (graphic 3; hyperlinked here: http://faculty.washington.edu/hueyrb/pdfs/Crozier%20et%20al%20Evol%20Appl%202008.pdf).

So as if we didn't already have enough moving parts in this globally changing system we're trying to understand, it turns out that we're shooting at a bit of a moving target here. The fact that evolution happens is part of what makes biology so infinitely interesting, & why I'm always compelled to inform my physical scientist friends that fish science isn't rocket science (with it's boring & immutable universal constants)—it's way harder. Biological complexity, adaptive capacity, and the drive to procreate & replicate suggests many fish populations will find a way to persist regardless of what we, & the climate, throw at them. But there are also limits to biological resilience, and times when the environments that a local population or species has persisted in for hundreds or thousands of years and generations, no longer meet the requirements of a particular species. At that point, that place on Earth is no longer habitat for that species. We know from the fossil record that species come and go, but there's also now evidence that anthropogenic climate change is pushing some critters over the brink. Next time out we'll review the evidence for climate-mediated extinctions of aquatic organisms as we wrap up this module on "Mechanisms of Change in Fish Populations."

Until next time, best regards,
Dan

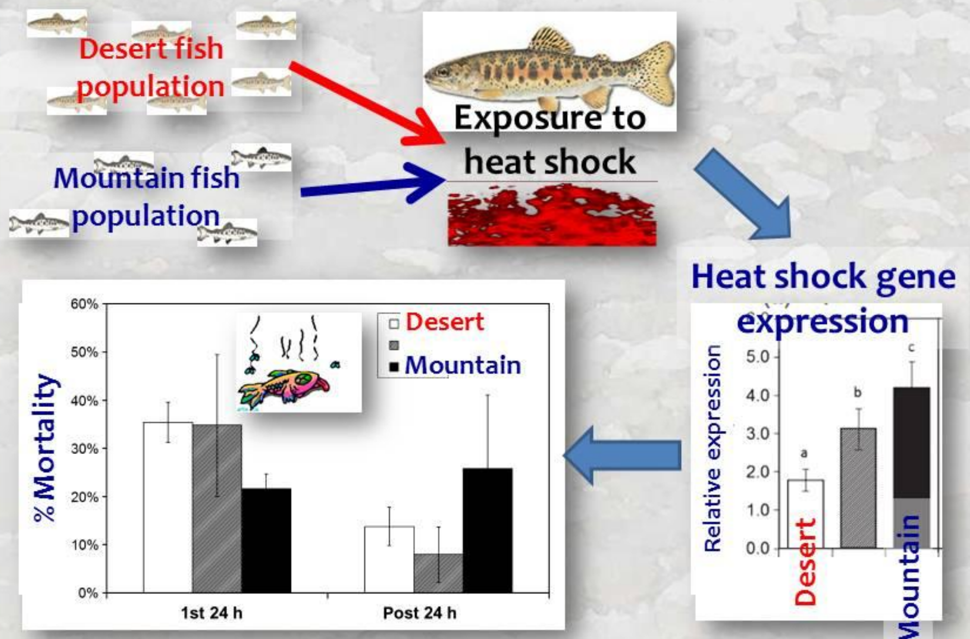
Now Tweeting at Dan Isaak@DanIsaak

Genetic Changes Related to Earlier Migration Timing in Pink Salmon…



Kovach et al. 2012. Genetic change for earlier migration timing in a pink salmon population. *Proceedings of the Royal Society B: Biological Sciences* **279**:3870-3878.

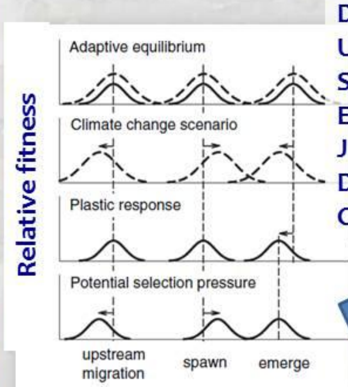
Genetic Differences Related to Thermal Tolerances in Redband Trout…

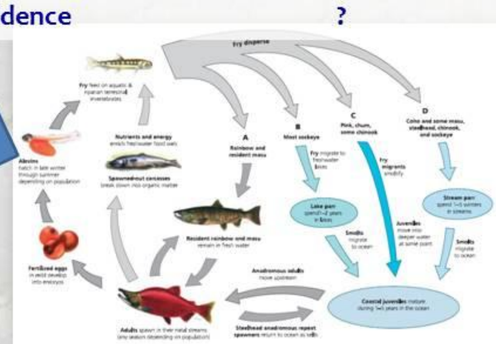


Narum et al. 2013. Thermal adaptation and acclimation of ectotherms from differing aquatic climates. *Molecular ecology* Doi:10.1111/mec.12240.

Evolution Involves Tradeoffs & Some Traits are More Malleable Than Others

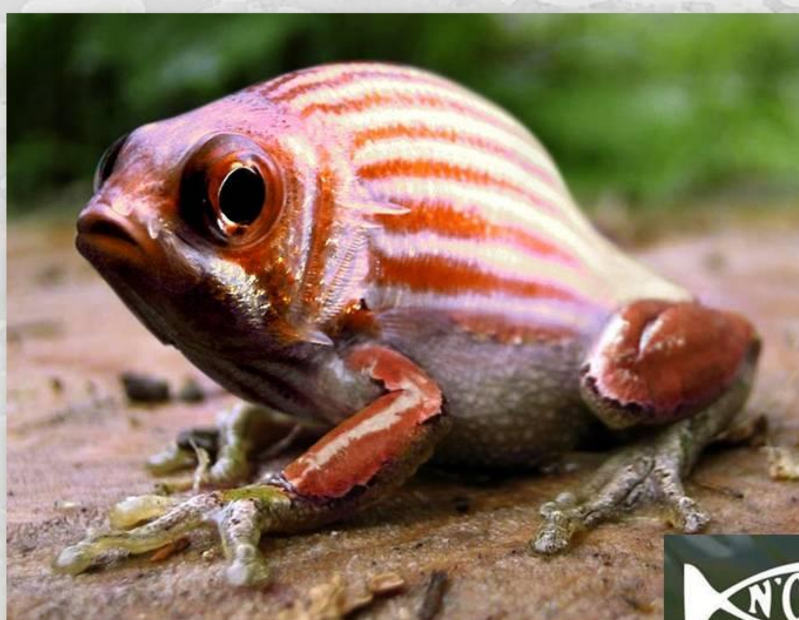
Trait	Evolutionary Potential
Heat tolerance	Low
Disease resistance	Low/moderate
Upstream migration time	High
Spawning date	High
Emergence date	Low
Juvenile growth rate	Low
Downstream migration time	?
Ocean residence	?





Crozier et al. 2008. Potential responses to climate change in organisms with complex life histories: evolution and plasticity in Pacific salmon. *Evolutionary Applications* 1:252-270.

Evolution Can Help, but Perhaps Not This Much Anytime Soon…



N'CHIPS

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 5,688 (& 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 #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

Future topics…

Climate-Aquatics Management Module

Climate-Aquatics End Game