Climate-Aquatics Blog #56:
New studies provide additional evidence for climate-induced fish distribution shifts & associated mechanisms

Hi Everyone,
Apologies for the lapse in blogging but blog-rate is inversely related to the number of deadlines I'm behind on in my day job. Nonetheless, we're back with a bang this time to highlight two significant new studies in the climate-aquatics realm before working our way back into the management module over the summer. The first of these studies, by Eby and colleagues (hyperlinked here: http://www.plos.org/wp-content/uploads/2013/05/pone-9-6-eby.pdf), focuses on juvenile bull trout in the Bitterroot valley of western Montana. Using a study design that consisted of resurveying historical sites across broad environmental gradients (as per blog's: 38, 39, 42), the investigators simply asked whether bull trout occurred at as many sites in the second set of surveys (17-20 years later) as had occurred in the first set (graphic 1). They found that site extirpations were 3x more common than site colonizations, which indicated a decline in the species' distribution across the watershed. More interesting, however, were the subsequent models wherein site extirpations were linked to stream covariates such as stream width, elevation, occurrence of non-native species, slope, etc. In those models, the strongest predictors were elevation and stream temperature—with the probability of extirpation being highest in the lowest and warmest sites (graphic 2). Those results are what we'd expect from the most basic predictions made by the bioclimatic models—that species distributions will shift away from historical habitats at the warm edge of a thermal niche (Blog 33).

The Eby results thus reveal the concordance between bull trout and polar bears to answer the question posed above. Because in addition to both critters being cute and cuddly, each is essentially trapped on top of its respective world. Polar bears atop an Arctic icecap that shrinks a little more each year (see here for an amazing historical reconstruction: https://www.youtube.com/watch?v=H-BbPBg3vj8). And bull trout atop mountain-top islands where they are restricted to extremely cold waters with their upstream retreats blocked by streams that are too steep and/or small to provide suitable habitats (graphic 3). One of the big questions now for bull trout is whether the changes in the Bitterroot are indicative of other areas across the species range in western North America. Given the general concordance of regional warming trends in past decades (blogs 13 & 23), one would expect range contractions elsewhere, but broader resurvey efforts are needed to provide confirmation of that (graphic 4).

Another important question raised by the Bitterroot bull trout study is why? That is, what exactly is happening at those distributional boundaries to cause a shift? That question is explored in more detail by Ayllon and colleagues (hyperlinked here: www.researchgate.net/publication/258956310_Thermal_carrying_capacity_for_a_thermally-sensitive_species_at_the_warmest_edge_of_its_range/file/60b7d529b7cc425204.pdf) who examined age-structured dynamics in brown trout populations across northern Spain. The short of it is that warmer temperatures appeared to exacerbate density dependent mechanisms regulating those populations. Moreover, the effects of temperature were most pronounced on the youngest fish and in the warmest temperatures, which would tend to reduce the long-term prospects for a species' at thermally marginal sites (graphic 5).

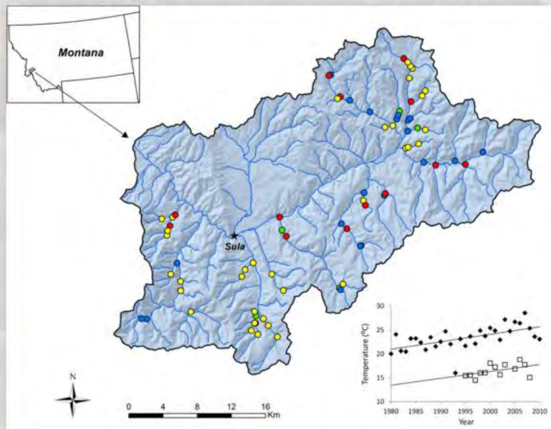
So this climate change thing continues to become a bit more real as we get better estimates and an understanding of its effects on aquatic critters. It may not exactly be a beneficial thing to some of the species we care about, but it shouldn't be all gloom and doom either. Because even as it's happening, we're also rapidly adapting and finding innovative solutions to cope with the changes—which is the critical & empowering part. So next time out, I'll highlight what will become a seminal set of climate aquatic studies wherein they've done it all—maintained long-term monitoring records for a fish species of concern, described mechanistic linkages between climate and declining population trends, developed spatially-explicit predictive models to show where habitats & populations are at greatest risk in the future, identified subsets of those habitats that are most likely to serve as climate refugia, and tapped an ongoing funding mechanism so that on-the-ground conservation actions can be precisely targeted to protecting & conserving those refugia. The origins of the work may come as a bit of a surprise but if I've learned anything the last several years it's that there are a lot of really smart, dedicated people in the global aquatics community doing amazing things in the climate arena & we want to learn everything we can from them.

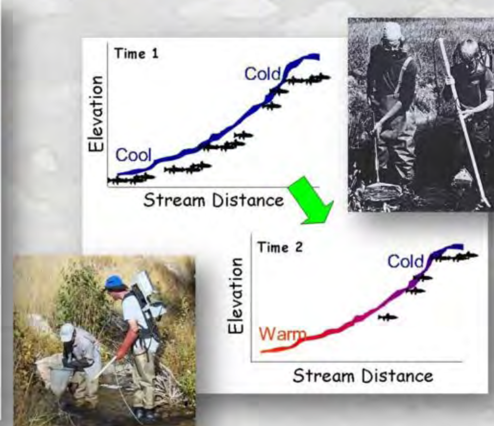
Until next time, best regards,
Dan

Tweeting at Dan Isaak@DanIsaak

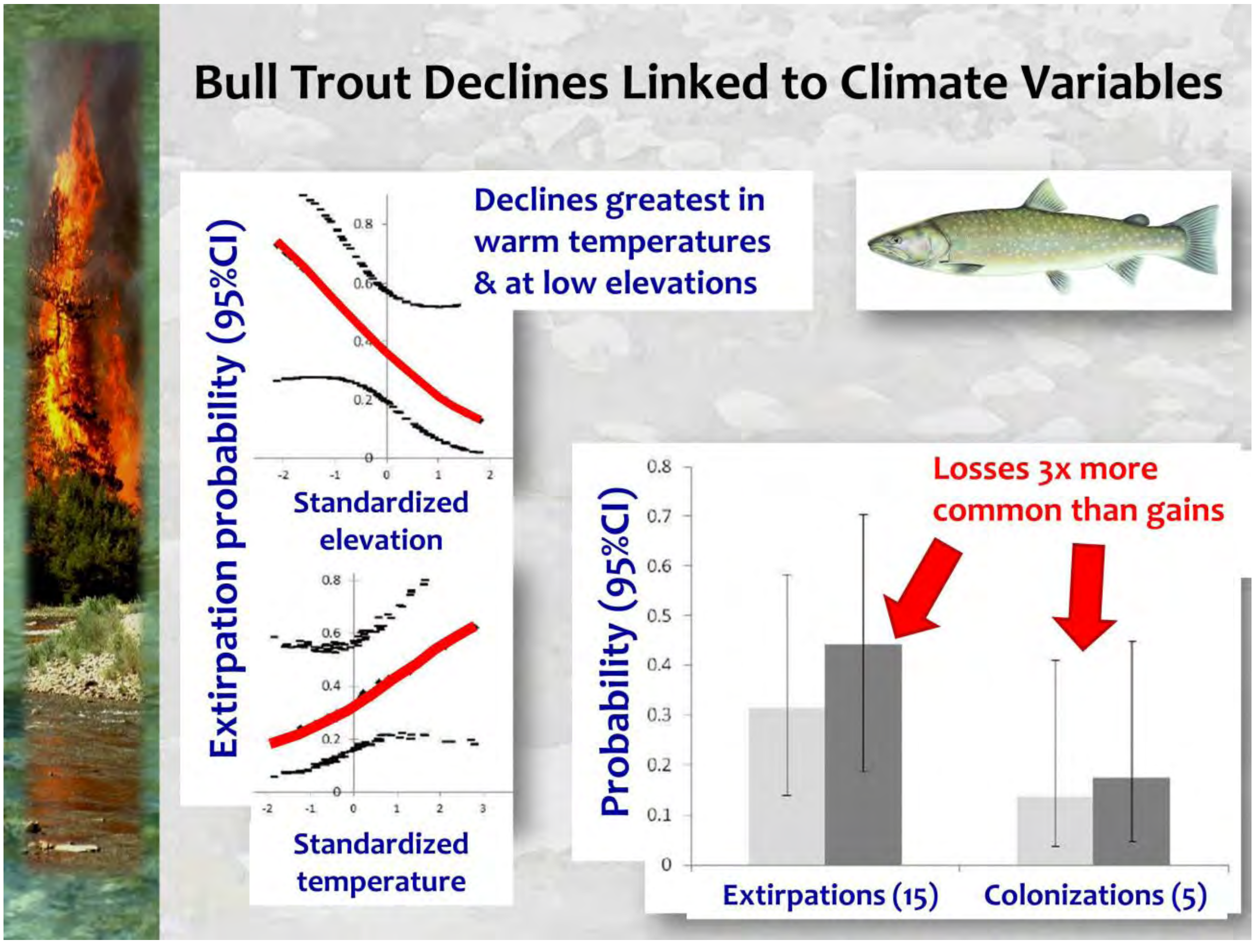
Resurveys of Bull Trout in Montana's Bitterroot Basin

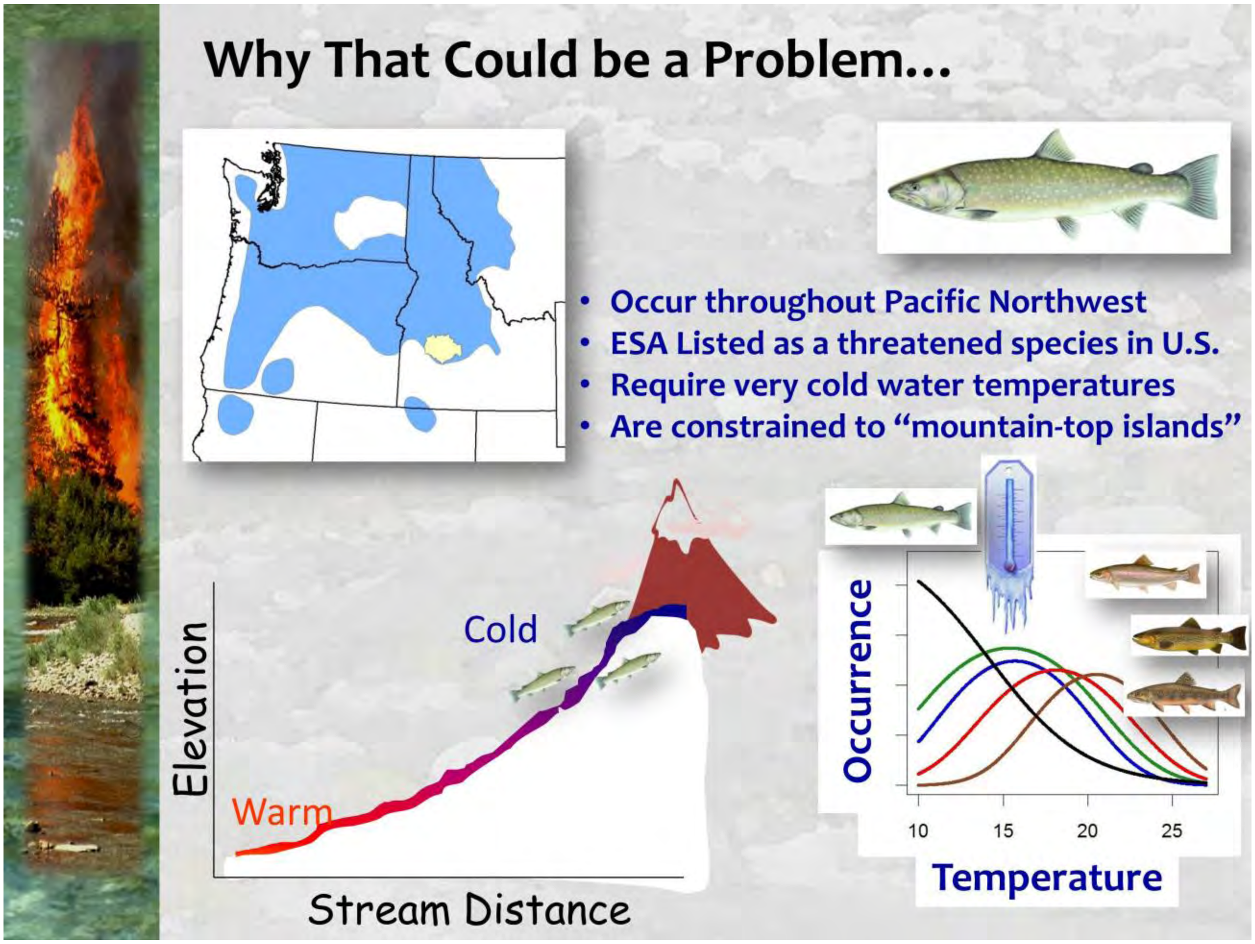
- 74 sites resurveyed 17-20 years after initial surveys
- Sites resurveyed across broad environmental gradients
- Changes in site occupancy between times 1 & 2 described



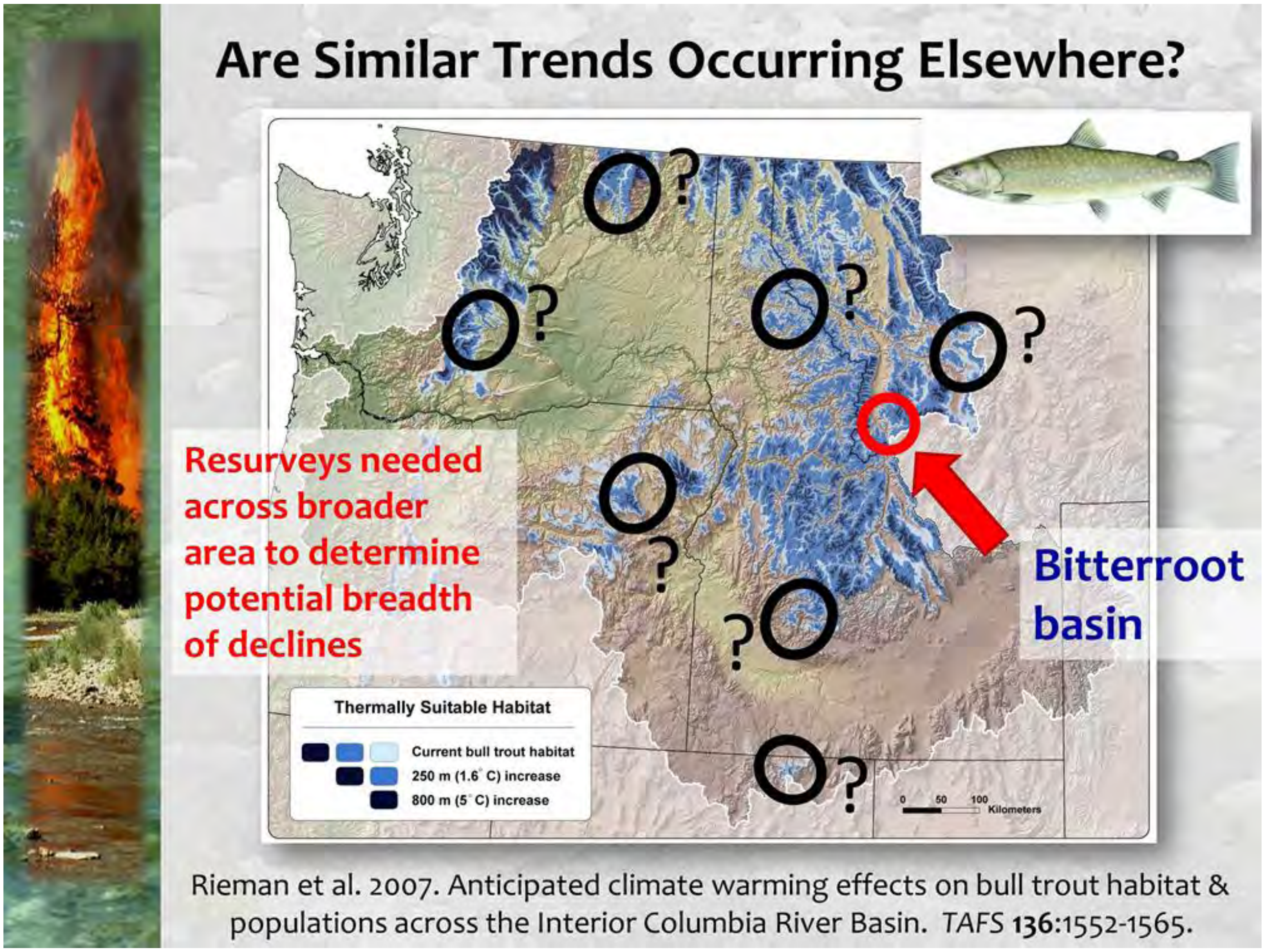


Eby et al. 2014. Evidence of climate-induced range contractions in bull trout in a Rocky Mountain watershed, U.S.A. *PLoS One* 9(6): e98812. doi:10.1371/journal.pone.0098812

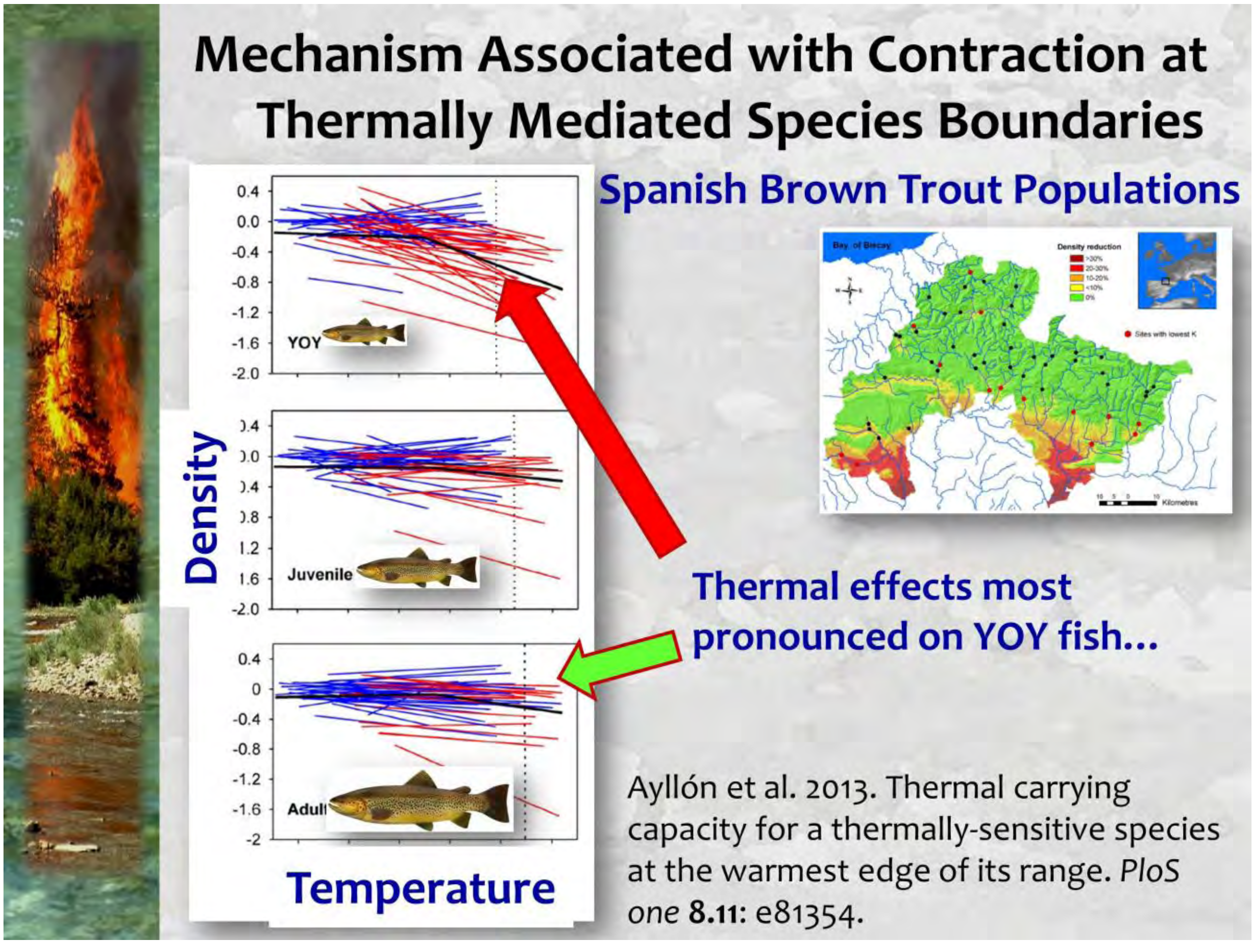

Bull Trout Declines Linked to Climate Variables
Declines greatest in warm temperatures & at low elevations
Extirpation probability (95%CI)
Standardized elevation
Standardized temperature
Losses 3x more common than gains
Probability (95%CI)
Extirpations (15)
Colonizations (5)



Why That Could be a Problem…
• Occur throughout Pacific Northwest
• ESA Listed as a threatened species in U.S.
• Require very cold water temperatures
• Are constrained to "mountain-top islands"
Cold
Warm
Elevation
Stream Distance
Occurrence
10
15
20
25
Temperature



Are Similar Trends Occurring Elsewhere?
Resurveys needed across broader area to determine potential breadth of declines
Bitterroot basin
Thermally Suitable Habitat
Current bull trout habitat
250 m (1.6° C) increase
800 m (5° C) increase
0 50 100 Kilometers
Rieman et al. 2007. Anticipated climate warming effects on bull trout habitat & populations across the Interior Columbia River Basin. TAFS 136:1552-1565.



Mechanism Associated with Contraction at Thermally Mediated Species Boundaries
Spanish Brown Trout Populations
Density
YOY
Juvenile
Adult
Temperature
Thermal effects most pronounced on YOY fish…
Bay of Biscay
Density reduction
Sites with lowest K
Kilometres
Ayllón et al. 2013. Thermal carrying capacity for a thermally-sensitive species at the warmest edge of its range. PloS one 8.11: e81354.

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 here: (http://www.fs.fed.us/rm/boise/AWAE/projects/stream_temp/stream_temperature_climate_aquatics_blog.html). The intent of the Climate-Aquatics Blog is to provide a means for the 8,004 (& growing) field biologists, hydrologists, anglers, students, managers, and researchers currently on this mailing list across North America, South 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 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 my colleagues & I have been conducting in the Rocky Mountain region, but attempts will be made to present topics & tools in ways that highlight their broader, global relevance. 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 occur to facilitate the rapid dissemination of knowledge among those concerned about climate change and its effects on aquatic ecosystems.

If you know 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
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
Blog #47: Part 6, Mechanisms of change in fish populations: Interacting effects of flow and temperature
Blog #48: Part 7, Mechanisms of change in fish populations: Changing food resources
Blog #49: Part 8, Mechanisms of change in fish populations: Non-native species invasions
Blog #50: Part 9, Mechanisms of change in fish populations: Evolutionary responses
Blog #51: Part 10, Mechanisms of change in fish populations: Extinction
Blog #52: Review & Key Knowable Unknowns
Blog #53: DNA Barcoding & Fish Biodiversity Mapping

Climate-Aquatics Management Module
Blog #54: Part 1, Managing with climate change: Goal setting & decision support tools for climate-smart prioritization

Blog #55: Part 2, Managing with climate change: Streams in channels & fish in streams

Future topics…
Climate-Aquatics End Game