Climate-Aquatics Blog #58: Managing with climate change, part 3: Maintaining & improving riparian vegetation & stream shade

Keep it shaded, Keep it cool

Hi Everyone,
This time we're back to part 3 of the management module and specific things we can do to ameliorate climate change effects on aquatic ecosystems. Previously, we talked about goal setting (we can't get there if we don't know where there is; Blog #54) and keeping that most vital of fluids—water—in streams where fish can use it (Blog #55). One of the additional benefits of the later is that the more of it there is, the cooler it tends to stay. And in a warming world that revolves around the ectothermic organisms we love, staying cool is the name of the game. The most effective way to keep streams cool, because a stream's heat budget is dominated by direct solar radiation (graphic 1), is simply to minimize their exposure to direct sunlight. Nature has invented a lovely thing to help us do that, which we call a riparian zone because the lush and verdant vegetation growing there often differentiates it from adjacent areas and vegetation types.

The vegetation in riparian zones is not only good for shielding our aquatic friends from that fiery orb in the sky, but for attracting humans and our domestic animal friends to spend a goodly amount of time in these areas. In fact, we've spent so much time there we've tended to leave riparian areas in various states of disrepair. That's not been a good thing for streams in the past, but now presents a significant opportunity as we look for adaptation strategies to deal with future change. Because in those places where riparian vegetation has been significantly degraded, facilitating regrowth and dense vegetation near streams to provide shade could offset significant amounts of warming. In some places, as the study by Cross and colleagues illustrates (graphic 2; study attached), that local cooling effect could be the determining factor in whether a stream hosts a specific species of fish 50 or 100 years from now. In an interesting twist on a similar theme, Lawrence & colleagues (graphic 3; Hyperlinked here: http://faculty.washington.edu/cet6/pub/Lawrence_et_al_2014_Eco_Apps_FINAL.pdf) examined how improving riparian shade and colder temperatures might inhibit the upstream colonization of a non-native bass predator. Turns out that keeping it cooler probably helps keep those guys farther downstream, which is a good thing if you're a small salmon rearing in the headwaters. Big fish do have a tendency to eat the small ones when the chance presents itself, so best if they only have one shot at you whence running the gauntlet down to the ocean later in life.

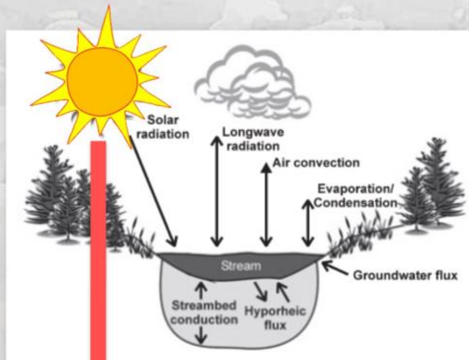
So there's a lot of thermal goodness that could come from riparian restoration, but there are some 2,000,000 kilometers of flowing streams in the U.S. & the magnitude of potential work requires a means of prioritizing. Important questions to ask as we think about where to begin are "how large are the streams that can be cooled by improving shade?" and the derivative, "how much cooler might those streams be made?" It's got to be a sort of sliding scale wherein the returns become ever more diminishing in larger streams as their width starts to minimize the effectiveness of riparian shade. Our third study, by Cristea and Burges, addresses this very issue (graphic 4; study attached). They find that on a small stream with severely degraded riparian conditions, significant cooling can be achieved by restoring riparian vegetation. So much so, in fact, that the restored stream might be cooler than it currently is even under future climate change scenarios. On a larger river, however, riparian restoration had a much smaller thermal benefit, and was not large enough to offset future warming. Ideally, we'd have that sort of information everywhere, rather than a few case history streams, to facilitate strategic assessments and decisions about where to invest, but as always, it's a challenge to scale up from the local. So for the physical scientists/stream climatologists in the audience, there's your chance to address an important need & become famous. Just figure out how to accurately predict everywhere the amount by which riparian vegetation has been altered from its natural state, and how much that alteration affects thermal regimes in the adjacent streams.

Until next time, best regards,
Dan

p.s., since this may be the last time we spend much time blogging about stream temperatures & there's a rapidly growing literature on the topic, I threw together a short bibliography of new, sometimes prominent, sometimes obscure, & occasionally relevant papers from around the globe (graphics 4 & 5).

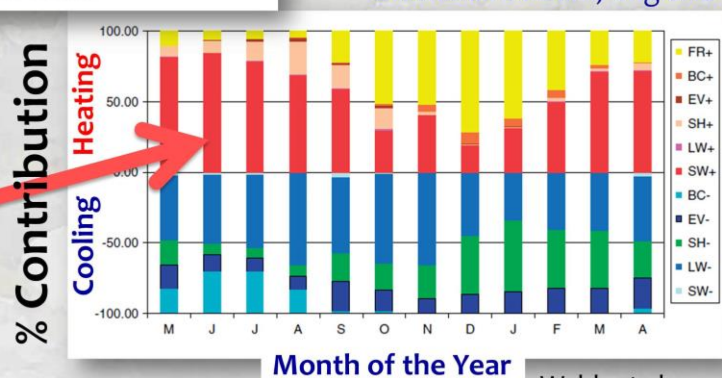
Now Tweeting at Dan Isaak@DanIsaak

Stream Heat Budget Components



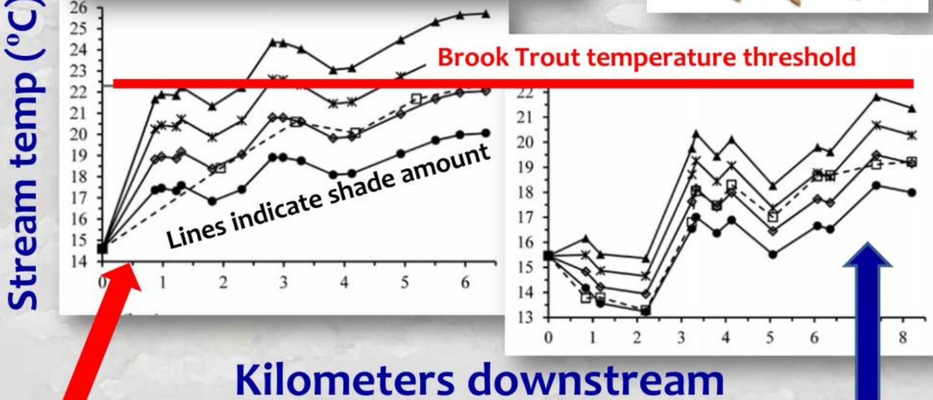
Direct solar radiation is the dominant factor among many…

Monthly heat budget - Black Ball Stream, England



Webb et al. 2008

Riparian Shade & Associated Cooling Could be the Critical Factor for Some Fish Populations in Some Streams…

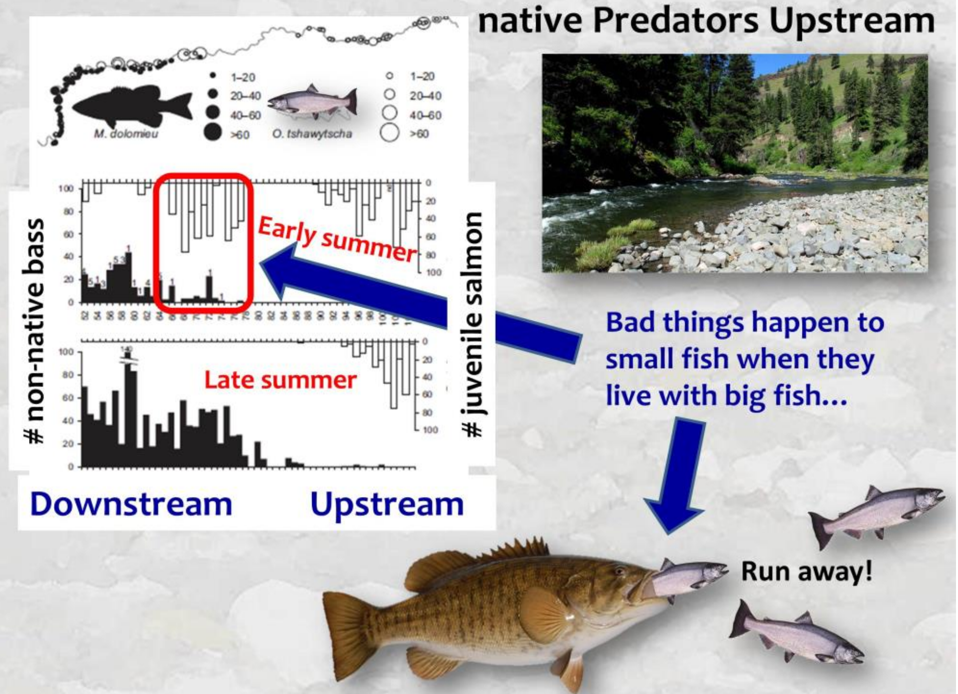


This stream is warm so riparian shade is critical

This stream is cold so riparian shading isn't as critical

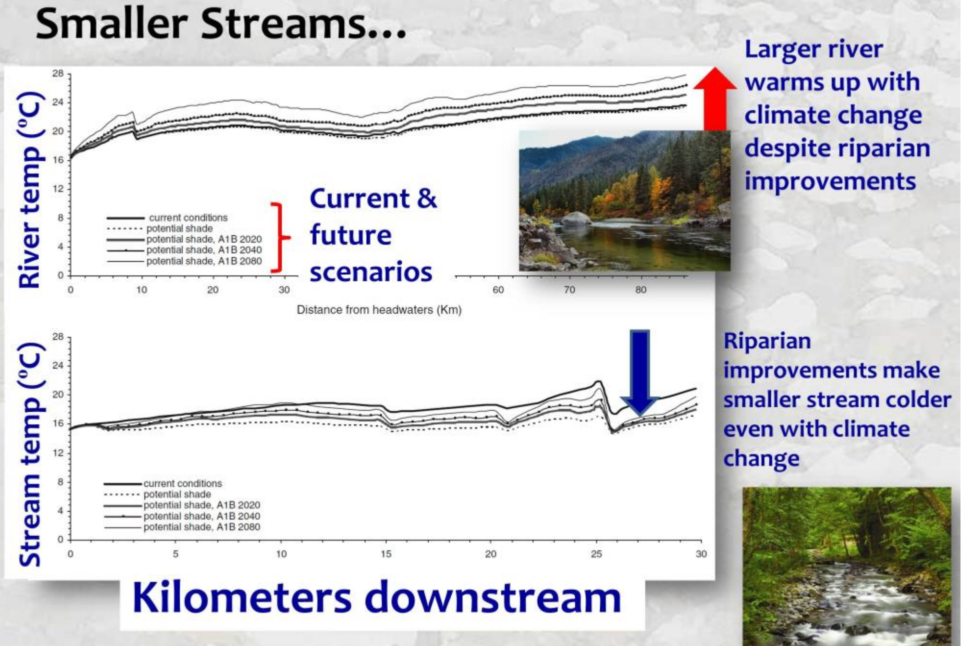
Cross et al. 2013. Influences of riparian vegetation on trout stream temperatures in central Wisconsin. *North American Journal of Fisheries Management* **33:** 682-692.

Cooler Streams May also Inhibit Expansion of Non-native Predators Upstream



Lawrence et al. 2014. The interactive effects of climate change, riparian management, and a nonnative predator on stream-rearing salmon. *Ecological Applications* **24**: 895-912.

Riparian Shade & Cooling Effect is Larger on Smaller Streams…



Cristea and Burges. 2010. Assessment of the current and future thermal regimes of three streams located in the Wenatchee River basin, Washington State: some implications for regional river basin systems. *Climatic Change* **102**:*493–520.*

New, obscure, prominent, & sometimes relevant stream temperature studies…

Arismendi, et al. 2013. Descriptors of natural thermal regimes in streams and their responsiveness to change in the Pacific Northwest of North America. *Freshwater Biology* **58**:880-894. http://onlinelibrary.wiley.com/doi/10.1111/fwb.12094/full

Garner et al. 2014. Inter-annual variability in the effects of riparian woodland on micro-climate, energy exchanges and water temperature of an upland Scottish stream. *Hydrological Processes*. (detailed heat budgets in contrasting streams across years) http://onlinelibrary.wiley.com/doi/10.1002/hyp.10223/pdf

Hilderbrand et al. 2014. Regional and local scale modeling of stream temperatures and spatio-temporal variation in thermal sensitivities. *Environmental management* **54**: 14-22. (local and regional modeling of stream temperatures to examine air temperature and discharge effects across multiple time and space scales) http://link.springer.com/article/10.1007/s00267-014-0272-4

Jurgelėnaitė et al. 2012. Spatial and temporal variation in the water temperature of Lithuanian rivers. *Baltica* **25**:65-76. (trends in longterm Lithuanian stream temperature records…who knew?) http://opalas.geo.lt/geo/fileadmin/Failai/Baltica_25_1_/06_Jurgelenaite-et-al.pdf

Kelleher et al. 2012. Investigating controls on the thermal sensitivity of Pennsylvania streams. *Hydrological Processes* **26**: 771-785. (examines changes in stream temperatures based on *within* year changes and relates those to stream context) http://www.mcglynnlab.com/uploads/1/0/6/4/10645747/kelleher_et_al_investigating_controls_on_the_thermal_sensitivity_of_pennsylvania_streams_hp_2012.pdf

Lammers et al. 2007. Variability in river temperature, discharge, and energy flux from the Russian pan-Arctic landmass. *Journal of Geophysical Research* **112**, G04S59, doi:10.1029/2006JG000370. (Russia has many cold streams…) http://onlinelibrary.wiley.com/doi/10.1029/2006JG000370/abstract

Luce et al. 2014. Sensitivity of summer stream temperatures to climate variability in the Pacific Northwest. *Water Resources Research* **50**:3428-3443. (examines changes in stream temperatures relative to *across* year changes in air temperature & discharge to provide more accurate assessment of how streams will respond to future climate change) http://www.fs.fed.us/rm/pubs_other/rmrs_2014_luce_c001.pdf

Mayer, T. D. 2012. Controls of summer stream temperature in the Pacific Northwest. Journal of Hydrology, 475, 323-335. http://www.sciencedirect.com/science/article/pii/S0022169412008864

New, obscure, prominent, & sometimes relevant stream temperature studies…

Moore et al. 2013. Empirical modelling of maximum weekly average stream temperature in British Columbia, Canada, to support assessment of fish habitat suitability. Canadian Water Resources Journal 38:135-147. (spatial regression model with predictor variables representative of heat budget factors) http://www.tandfonline.com/doi/abs/10.1080/07011784.2013.794992#.U8bjJrGa_yw

Moore et al. 2005. Riparian microclimate and stream temperature response to forest harvesting: a review. *Journal of the American Water Resources Association* **41**: 813-834. (comprehensive review) http://www.sierraforestlegacy.org/Resources/Conservation/FireForestEcology/ThreatenedHabitats/Riparian/AquaticRiparina-Moore05.pdf)

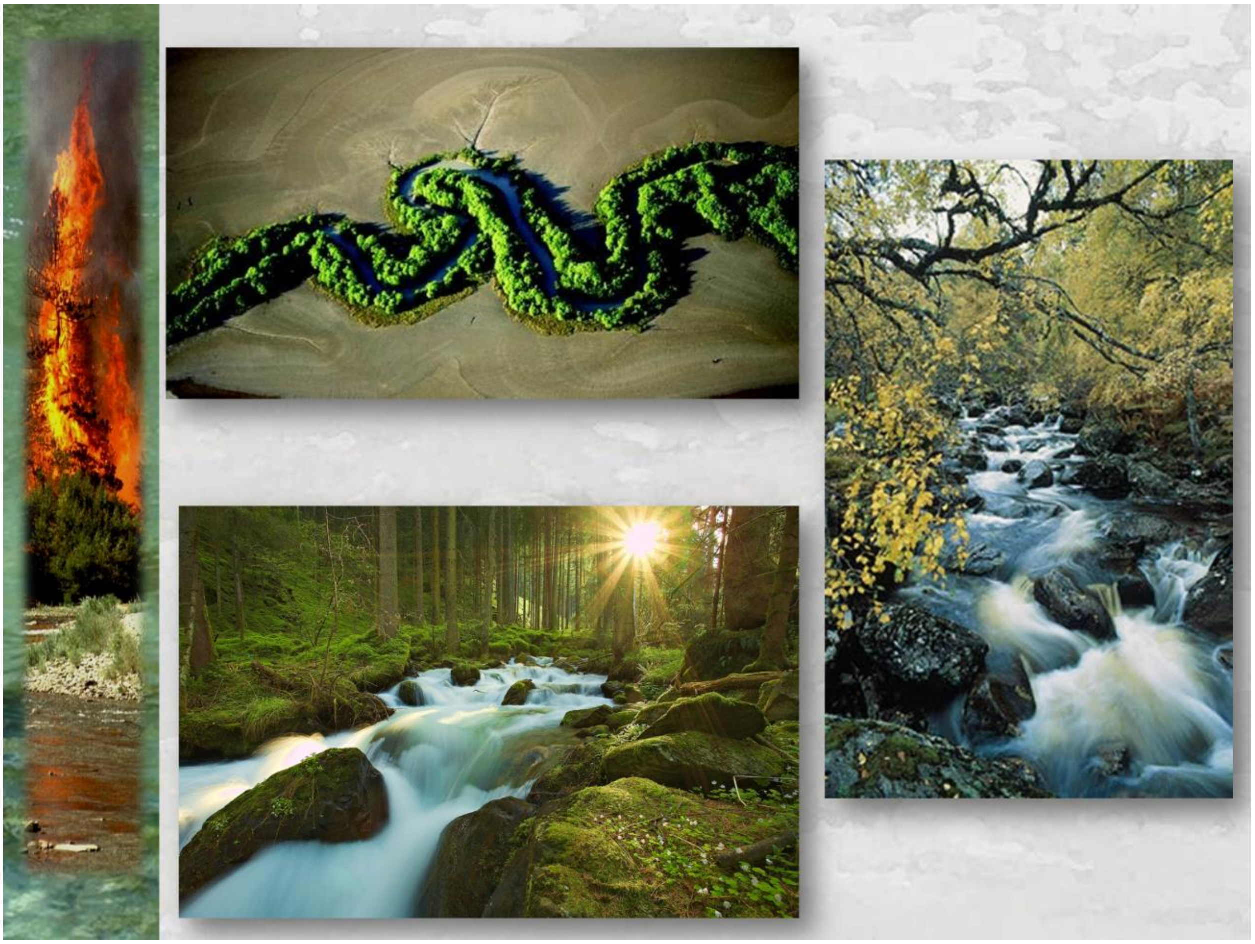
Pilgrim, Fang, and Stefan. 1998. Stream temperature correlations with air temperatures in Minnesota: implications for climate warming. *Journal of the American Water Resources Association*. **34**:1109-1121. (looked at correlations between air & stream temps across multiple timesteps & using air data from remote climate stations. We've been reinventing wheels ever since…) http://onlinelibrary.wiley.com/doi/10.1111/j.1752-1688.1998.tb04158.x/abstract

Rivers-Moore et al. 2013. Towards setting environmental water temperature guidelines: A South African example. *Journal of environmental management* **128**:380-392. (cogent example of multi-metric thermal regime description and setting water temperature criteria) http://www.sciencedirect.com/science/article/pii/S0301479713003125#

Van Vliet et al. 2011. Global river temperatures and sensitivity to atmospheric warming and changes in river flow. *Water Resources Research* **47.2** (incorporated discharge into the basic Mohseni air-stream regression approach to improve at a station predictions) http://onlinelibrary.wiley.com/doi/10.1029/2010WR009198/abstract

Webb et al. 2003. Water–air temperature relationships in a Devon river system and the role of flow. *Hydrological Processes* **17**:3069-3084. (incorporated discharge and to basic Mohseni air-stream regression and looked at correlations across multiple timesteps) http://onlinelibrary.wiley.com/doi/10.1002/hyp.1280/abstract

Webb et al. 2008. Recent advances in stream and river temperature research. *Hydrological Processes* **22**: 902-918. (comprehensive review) http://neef.ca/uploads/library/8440_WebbHannaMoore.etal_2008_hydrologytemperature.pdf



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 8,035 (& 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
Blog #56: New studies provide additional evidence for climate-induced fish distribution shifts
Blog #57: Identifying & protecting climate refuge lakes for coldwater fishes

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