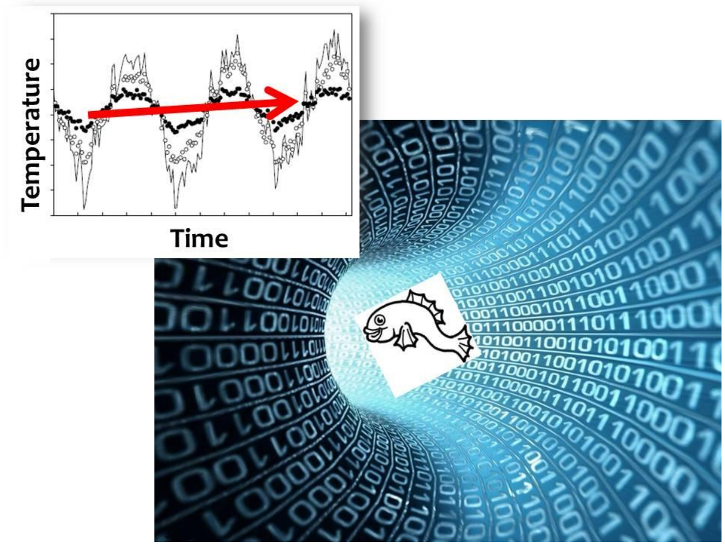
Climate-Aquatics Blog #39:

Part 3, Monitoring to detect climate effects on fish distributions: BIG DATA regional resurveys



Extracting the signal from the noise…

Hi Everyone,
So as we saw last time, there are ways to do the time travel necessary for understanding how climate change is affecting fish distributions, and to develop that understanding in the next few years. Streams with good historical transects are out there & will be important sources of information, but they are also relatively rare against the backdrop of 100,000's of stream kilometers in regional networks. Scattered across those same networks, however, are hundreds, sometimes even many thousands, of fish survey sites our "army in the woods" has been busily sampling in previous decades (graphic 1). If we could somehow tap into that wealth of data to extract information regarding the climate signal, then we'd really be in business.

Well, we can. And all it requires is doing what the Beever did with the pika. That is, doing what Eric Beever & colleagues did via broad regional resurveys of pika populations across the Great Basin in the western US (graphic 2; paper attached). They simply revisited habitats where pika populations had been documented in previous decades, determined whether populations still existed, and then examined the frequency of extirpations relative to local climatic conditions. To get accurate measures of local climatic conditions, they deployed temperature sensors within the pika habitats (e.g., blog #9) and reconstructed long-term trends through linkages to nearby weather stations (e.g., blog #14). What they found was that 9 of 25 historical populations had been extirpated and that measures of local climate (i.e., average summer temperature, # days exceeding threshold temperatures, etc.) were good indicators of pika persistence. In particular, those pika populations that were already near important thermal thresholds during historic surveys proved to be most vulnerable to recent extirpations.

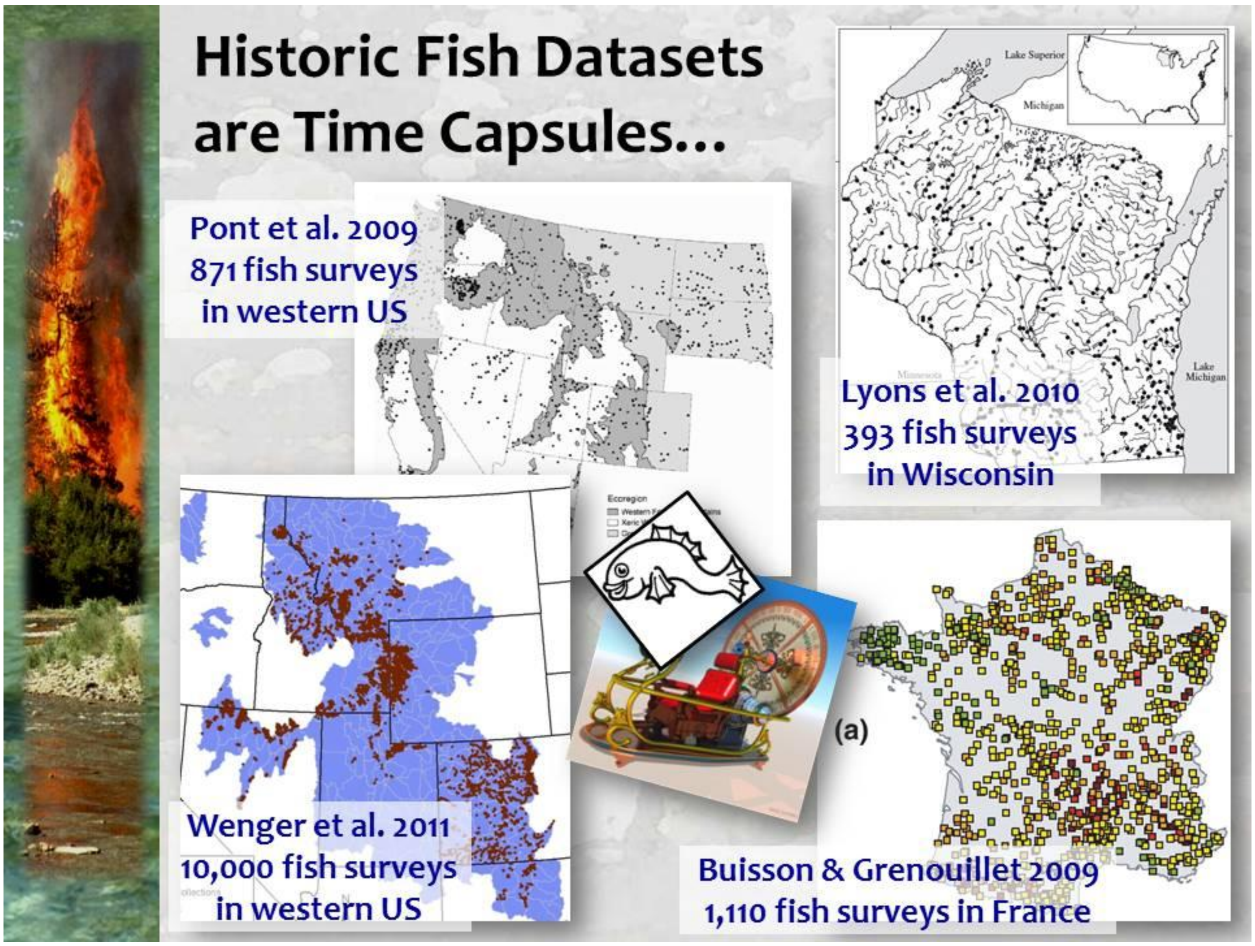
So as you've probably noted by now, pika are not fish but rather small, adorable, rabbit-like mammals that live on the side of mountains rather than in streams. Warm and fuzzy yes, but nowhere near as cool and slimy as our favorite animals, so modifications of Beever's pika study are needed for aquatic applications. First, we generally have poorer historical documentation and distinct population boundaries to work with for stream fishes than is the case for pika. Where we do have those things and extirpations have occurred, the complex of contributing factors generally has more to do with species invasions, excessive harvest, and habitat degradation than recent climate change. So it's tough to do something as clean-cut climate-wise as Beaver's pika study. But we do have those masses of fish surveys from previous decades to play with. And if per the general predictions from the bioclimatic models are right (blog #33), we'd expect that as it gets warmer, and species distributions shift to track thermally suitable areas, then there should be a disproportionate number of extirpations at sites that have been historically warm for some species (graphic 3). Similarly, we'd expect a disproportionate number of colonizations at new sites that had previously been too cold for some species.

These will be subtle patterns that take decades to manifest given the incremental shifts of isotherms shifts relative to short-term variability (blog #'s 36 and 37), and as we saw last time with transect resurveys (blog #38), there will be other factors such as invasive species & habitat degradation to confound the climate signal. But a BIG DATA approach that resampled hundreds of sites strategically placed along the margins of thermally mediated boundaries would allow the signal to be extracted from the noise using appropriate statistical techniques. In my view, getting good estimates of the rates at which fish population boundaries are shifting due to climate change is presently *the* most important question in the climate-aquatics world. Doesn't matter whether we get those estimates through a BIG DATA regional resurvey, or transect resurveys, or yet some other means, as long as we get them. That being the case, today we're initiating a global contest, much like the X prize, to see who can provide the first conclusive estimates of these shift rates (graphic 4; fine print disclaimer: unlike the X prize, there is no monetary compensation for this prize, only the eternal esteem & recognition by your colleagues as one famous fishy person).

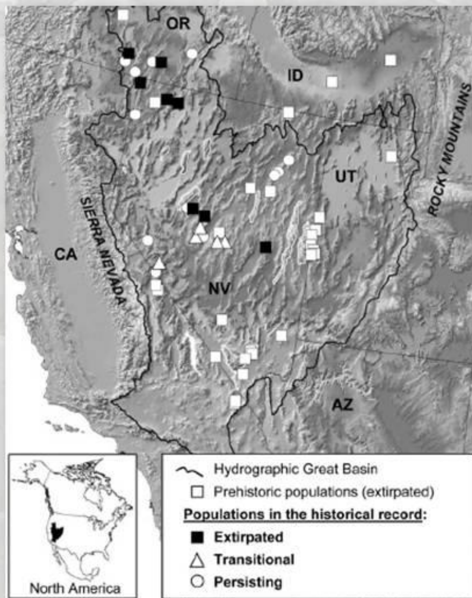
One challenge with the BIG DATA approach is targeting the site resurveys as precisely as possible. Brute force resampling of all historical sites, which could run into the thousands, would be too expensive in most cases so criteria to guide sampling efforts efficiently are needed. Focusing on older sites (e.g., original surveys > 15 years ago) with faster climate velocities (i.e., lower stream slopes) would be a good start as these areas are most likely to show changes. Also importantly, however, we'd want sites meeting those criteria to be located near thermally mediated species boundaries because we wouldn't expect distribution shifts to occur where temperature hasn't been a limiting factor. Identifying thermally limiting sites requires some means of inference about local temperatures at all the candidate sites. Crude surrogates like elevation could be used, or one could take Beever's approach and deploy sensors within the fish sites. But the former is very imprecise and doing the latter for hundreds of sites across a large area is a logistical nightmare because of the multiple trips it requires to each site (1: install sensors, 2: sample fish populations, 3: retrieve sensors) and it wouldn't provide the temperature information at the study outset for planning purposes.

No, the best option would be having a consistent set of stream temperature "maps" (blog # 26) derived from accurate models against which all historic fish survey sites could be referenced. Simple plots of species occurrence relative to a consistent temperature baseline would immediately reveal sites near thermal boundaries (graphic 5), while also providing the significant side benefit of describing realized thermal niches for various species (which are critical for assessing climate vulnerability and making projections). Unfortunately, regional stream temperature models capable of providing the necessary historic climate scenarios don't yet exist in most places. But efforts to develop such models are underway and next time out, we'll highlight how something called "crowd-sourcing" is being used to develop a BIG DATA stream temperature model in the Northwest US that can facilitate regional fish resurveys, among a good many other things…

Until then, best regards,
Dan



Pika & Climate Mediated Extirpations



time$_1$ *time*$_2$

1 → 0

Site extirpation

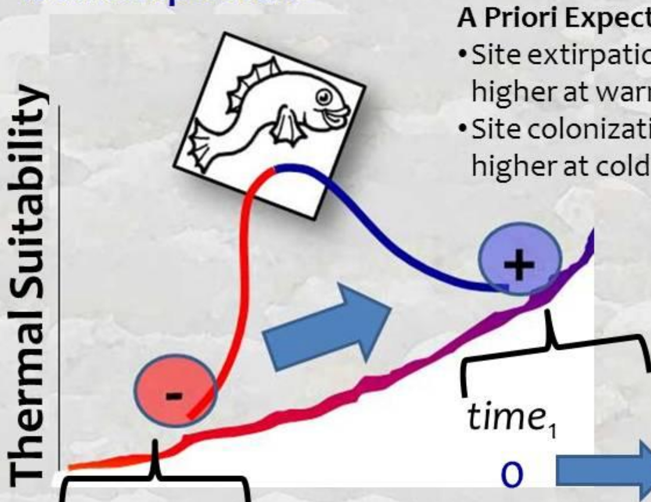
Beever et al. 2010. Testing alternative models of climate-mediated extirpations. *Ecol. Apps.* **20**:164-178.

Broad Fish Distributional Resurveys

Examine site extirpation/colonization rates relative to local temperature

A Priori Expectations…

- Site extirpation rates should be higher at warm thermal boundaries
- Site colonization rates should be higher at cold thermal boundaries



time$_1$ *time*$_2$

0 → 1

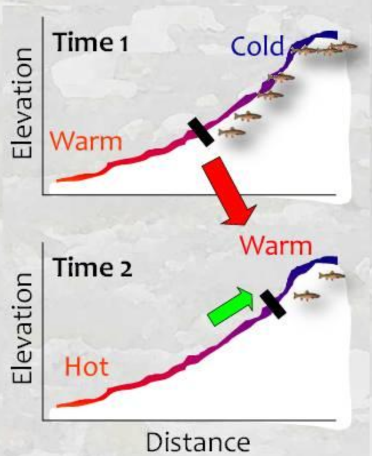
Site colonization

time$_1$ *time*$_2$

1 → 0

Site extirpation

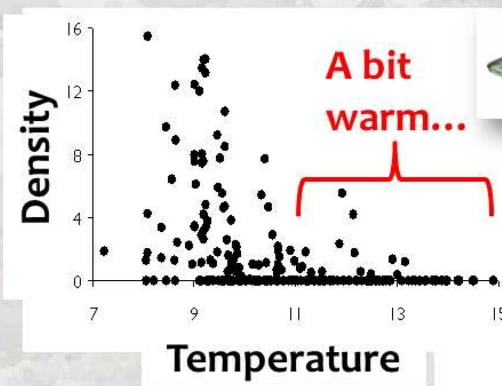
Who Will Provide Conclusive Estimates of Fish Distribution Shift Rates Caused by Global Warming?



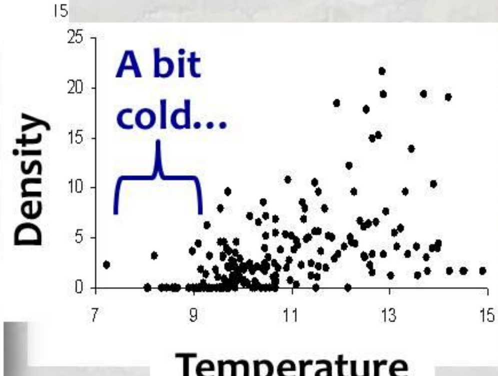
How far?

How fast?

Where are Thermally Limiting Sites?



Bull Trout



Rainbow Trout

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 4,538 (& 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 most 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 and their names can be added to the mailing list for notification regarding additional science products on this topic. If you do not want to be contacted regarding future such notifications, please reply to that effect and you will be removed from this mailing list.

Previous Posts

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

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

Future topics…
Climate-Aquatics Management Module