Climate-Aquatics Blog #30: Recording & Mapping Earth's stream biodiversity from genetic samples of critters

Justifying stream fish electricity rodeos…

Hi Everyone,
So just a quick follow-up after that last blog wrapping up the stream statistical module. I think it's useful to re-emphasize the fact that many of the things we care about and manage for in streams—water quality attributes, fish abundance, presence of certain species—are often sampled in ways that provide reach-averaged, point values of these attributes scattered across stream networks. As such, most of these attributes might be modeled using the spatial models if the data are organized and maintained in georeferenced databases (Blogs #27 and #28). Moreover, it's going to be important to work collectively to build these databases and make smart maps of these things because there's no other way the information will exist otherwise. It's not going to be possible to remotely sense these attributes any time soon, so it's going to require people physically mucking around in streams and to direct measure these things. Once that's been done in enough places, it becomes possible to make models linking the things we care about to the physical attributes of streams and networks that can be remotely sensed or otherwise accurately described from existing spatial data layers and then smart maps based on data and model predictions become possible.

That said, it's often rather enjoyable to muck around in streams and one of the more exciting forms of mucking sometimes involves fish electricity rodeos. We fish biologists often make these rodeos sound more official by calling them, "standardized electrofishing surveys for estimating species composition and abundance" but it's mainly a ploy to be in the woods and chase partially stunned fish with nets through steep streams whilst jumping over the occasional large rock. As strange as it may seem to the uninitiated, there's quite a bit of this business that goes on. In a few river basins where we've pulled together georeferenced database of both fish surveys and stream temperature measurements, there seem to be 2 – 3 times as many fish survey sites as there are temperature sites. If that rule of thumb holds more generally, the numbers would dwarf the number of temperature sites in the NorWeST database (Blog #25) and there might be somewhere around 50,000 unique stream sites that have been sampled for fish across the Northwest U.S. Moreover, there are 1000s of additional sites sampled each year by biologists from dozens of resource agencies and 10,000s of fish being handled.

At these sites, it's traditionally been the case that we're most interested in describing whether or not the species that angers like to catch (e.g., trout, bass, catfish) occur and how abundant they are, but give limited consideration to those less sexy aquatic denizens—the small, nondescript fishes, salamanders, toads, and aquatic insects that live in those same places and often constitute the majority of the overall aquatic community. That's a shame, because I would guess that 100 years from now, one of the things a 22nd-Century fish biologist will care about most is knowing what biodiversity once occurred at specific stream sites. I suspect they'd very much like to be able to compare a map of what's there in the year 2112 to what was here now to understand how things changed as we passed through this transitional century (just think if we had a map like that from the year 1900 for comparison!). But even now, with all the fish sampling that's going on in some places, we're a long ways from having good status assessments, spatial inventories, and archived databases for the majority of aquatic species in the majority of the Earth's streams that could serve as useful time-capsules for future biologists. And lacking that basic information, how are we going to design effective strategies for conserving this biodiversity?

One impediment to doing more comprehensive biodiversity surveys is simply the traditional goals we've had when sampling fish populations. When the goal is to develop abundance estimates for a few target species at a site, it's quite possible to do, but also a labor- and time-intensive procedure. Often it involves using block nets to close off a section of stream and then making several electrofishing passes through that section to mark, capture and remove individuals of the target species in ways that meet the statistical assumptions of the abundance estimator. As such, we tend to spend a lot of time at a few sites and on a few species and sometimes ignore large portions of river networks and the majority of species. Biodiversity surveys, in contrast, simply require catching individuals from the various species that occur at a site and sampling enough stream habitat to ensure a minimum level of species detection. For this too, there are standardized sampling protocols to apply, but typically this sort of survey can be done more rapidly than an abundance estimate.

With critters in hand, the standard sets of length, weight, and age measurements may be taken, but a sample that contains a vast amount of biological information about a populations at that site—but is often overlooked—is a piece of tissue. The genes in that tissue are the record of a species' evolutionary history over the course of the preceding 100s – 1,000,000s of years. That set of biological information dwarfs by many orders of magnitude the tiny bits of information traditionally obtained regarding the size and number of a few of the critters. Moreover, genetic information can be described very accurately with modern instruments, so once the tissues are analyzed, the results can be digitized to a computer's memory and archived indefinitely. Twenty, 50, or 100 years from now, a biologist of the future will have an unambiguous description of the aquatic biodiversity that occurred at that site in one of Earth's streams.

Other impediments to biodiversity/genetic sampling in the past have been the cost and inconvenience of collecting and processing tissue samples. Costs are constantly coming down and for some species that have had single nucleotide polymorphism (SNP) markers developed, it now costs as a few dollars per fish or amphibian to run the analysis. SNPs still need to be developed for many species but as the digital/information revolution marches on it will eventually happen. Between now and then, useful tissue archives could be compiled essentially for free during the course of routine monitoring and fish sampling efforts. It might require a bit more time at a site to take tissue samples from non-target species but that cost is trivial relative to the potential biological information gains and the costs of hiring crews and sending them to and from sampling sites. The last issue is simply one of convenience because preserving/storing tissue samples has traditionally meant having to deal with small alcohol vials that were prone to breakage or leaking. A more efficient protocol was recently developed by LaHood and colleagues (graphic 1; attached paper) that simply involves placing fin tissue on chromatography paper. One hundred samples can easily be stored on an individual piece of paper and archiving the tissues (if there's no immediate plan for analysis) simply involves stacking them for storage somewhere in the office or lab that's dry and protected from insects and heat.

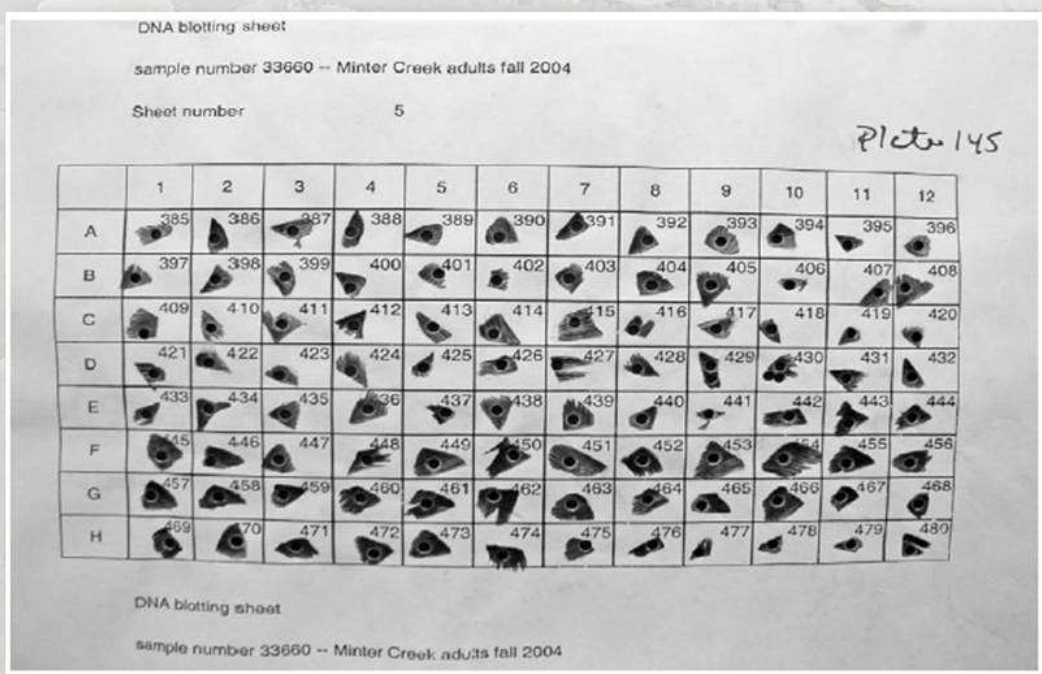
It may take a few years, but if the collection of tissue samples became a standard part of stream surveys, significant archives of Earth's aquatic biodiversity would be accumulated. As sample sizes grew, the data might be used in some instances with the spatial models to literally "map" genetic diversity on top of geomorphic and climatic attributes of stream networks to study and better understand these relationships. But there's also a large and growing list of applications for genetic data in this rapidly advancing field. The attached paper by Schwartz and colleagues describes a few of these, including: DNA-based abundance monitoring, estimation of demographic rates like survival and recruitment, and detection of pathogens to name a few. Another application is presented in the attached paper by Whiteley and colleagues, for estimating effective population size in headwater trout populations. Quite familiar to many biologists is the use of genetic testing to reveal levels of hybridization, but these same tests permit the real possibility, even in this day and age in a place as densely sampled as the Northwest U.S., of discovering and describing new species as researchers in the Northern Rockies are currently doing (Mike Young, USFS, personal communication). And in the not-too-distant future, it may also be possible to extract DNA from stream water samples to assess and monitor biodiversity (Kevin McKelvey, USFS, personal communication), which would have the unfortunate consequence of rendering some fish rodeos obsolete.

OK, so we've been at this Climate-Aquatics Blog now about 1.5 years; far longer than I'd originally envisioned, and I'm guessing we're about ½ done. Sorry it's been a bit of a rambling, disjointed journey but there's an information revolution going on in parallel to the climate change thing that warrants some mention because it holds the promise of fundamentally better information about stream ecosystems that could make all our efforts far more efficient as we grapple with the global phenomenon of climate change. So when we come back next time, we'll get serious about the biology module and understanding the consequences of climate change this century for what we care about most, FISH! (& perhaps a few other aquatic critters). Before engaging on that wide ranging topic, however, I've got a few busy months ahead of me personally so the blog is going to be suspended until mid-fall sometime. Hope everyone has a productive and safe field season if you have a chance to partake in one of the perks our profession provides.

Until next time, best regards.

Dan

Fin Tissues Preserved on Chromatagraphy Paper



DNA blotting sheet

sample number 33660 -- Minter Creek adults fall 2004

Sheet number 5

Plate 145

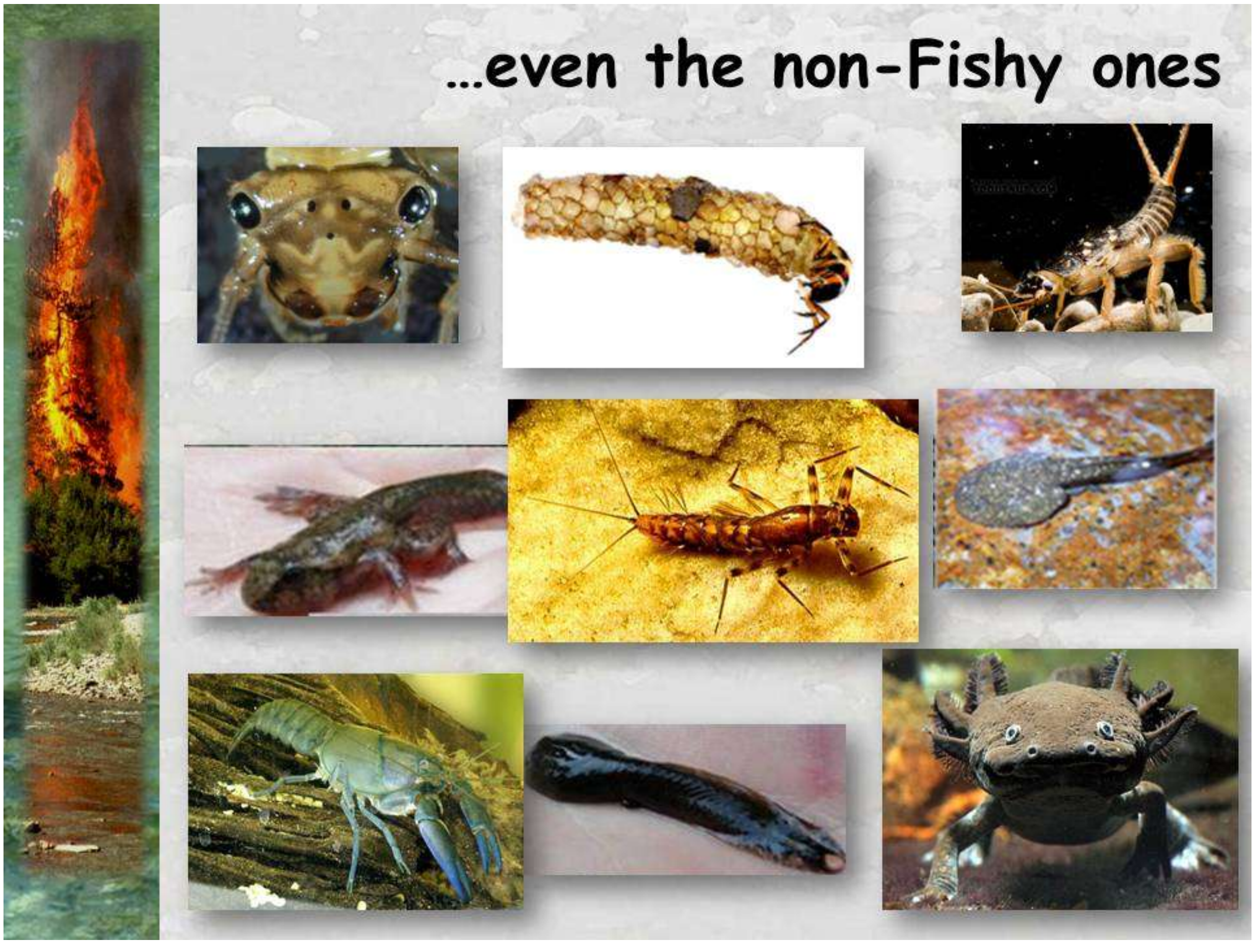
	1	2	3	4	5	6	7	8	9	10	11	12
A	385	386	387	388	389	390	391	392	393	394	395	396
B	397	398	399	400	401	402	403	404	405	406	407	408
C	409	410	411	412	413	414	415	416	417	418	419	420
D	421	422	423	424	425	426	427	428	429	430	431	432
E	433	434	435	436	437	438	439	440	441	442	443	444
F	445	446	447	448	449	450	451	452	453	[illegible]	455	456
G	457	458	459	460	461	462	463	464	465	466	467	468
H	469	470	471	472	473	474	475	476	477	478	479	480

DNA blotting sheet

sample number 33660 -- Minter Creek adults fall 2004

LaHood et al. 2008. *Trans. American Fisheries Society* 137:1104-1107.


Stream Critters are Cool...



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 4,320 (& 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 future 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

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 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

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

Future topics…
Climate-Aquatics Biology Module
Climate-Aquatics Management Module