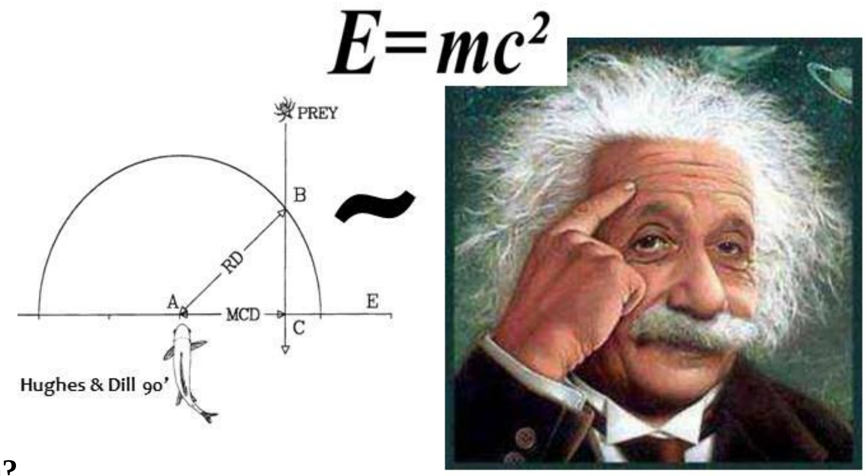
Climate-Aquatics Blog #48:
Part 7, Mechanisms of change in fish populations: Changing food resources



Did he really mean fish?

Hi Everyone,
The first law of thermodynamics isn't quite the same thing as Einstein's famous mass–energy equivalence equation but it tells us some useful things about how fish populations will have to respond to climate change. The first law states that the total energy of a system is constant; it can be transformed from one form to another, but cannot be created or destroyed. In our stream world, therefore, a fish eating a bug is simply one way that food energy is transformed (some fly fishermen would say "blessed") as it moves through the system. If the energy available from those food resources changes, fish populations will have to adjust accordingly (typically through adjustments in size, growth, & density; blog #44). The attached paper by Railsback & Rose does a nice job of describing bioenergetics in trout populations (graphic 1) & calibrating a model to rainbow trout population growth at several stream sites.

Fish bioenergetics has its complexities to be sure, but in the grand scheme of things, is relatively well understood given that many key parameters can be directly measured in the laboratory and/or small scale field studies. The bigger challenge, at least for an ignorant fish guy like me, is understanding and being able to predict how climate change will affect fish food in streams across a range of spatial and temporal scales relevant to research and management. There are a variety of tools, datasets, and models out there now to do this for hydrology (blogs #20 and #21), stream temperature (blogs #7 and #25), stream geomorphology (i.e., slope, size, elevation) and landuse/land cover (e.g., NHDPlus (http://www.horizon-systems.com/nhdplus/), but nothing tells me how much food is moving through river networks, now, or in the future. Granted, it is a complex process that involves many linkages between streams and terrestrial environments across multiple levels of biological organization (individual, population, community) and every part of the system is being affected by the environmental trends associated with climate change (Blogs 10, 11, 13, 15, 16, 17, 18, 22, 23), which propagate through foodwebs (graphic 2; good review by Woodward & colleagues hyperlinked here: http://izt.ciens.ucv.ve/ecologia/Archivos/ECO_POB%202010/ECOPO7_2010/Woodward%20et%20al%202010_II.pdf)….BUT…there have to be key indicators that can be measured efficiently to provide information about food resources in streams. As the seminal paper by

Vannote & colleagues on the River Continuum Concept (hyperlinked here: www.limnoreferences.missouristate.edu/assets/limnoreferences/Vannote_et_al_1980_RCC.pdf) & the more recent paper by Wipfli & Baxter (.pdf attached) make apparent, the necessary conceptual foundation has been built. That foundation needs to be parameterized with data at high resolutions across large enough scales that it's useful for real world applications (graphic 3; good review Naiman & colleagues hyperlinked here: www.researchgate.net/publication/233794482_Developing_a_broader_scientific_foundation_for_river_restoration_Columbia_River_food_webs/file/9fcfd50b8f106afed0.pdf).

So my (admittedly naïve) proposal and/or sets of questions are these… What are the core set of parameters that convey the most relevant information about food resources? Do empirical datasets already exist that could be used to start getting a more precise handle on spatial patterns in food resources throughout at least some river networks? Do standardized techniques exist that make it easy to process measurements of key parameters on-site? If so, could intensive field campaigns be conducted to target interesting landscapes and/or ecoregions as a means of developing relatively dense datasets in some areas? Are any of the key parameters water quality attributes, or could these attributes be used as surrogate measures for key parameters? One attractive feature of many water quality attributes is that they're cheap to measure and standardized protocols already exist. Moreover, as the recent paper by Olsen & Hawkins (attached) illustrates, large databases exist in some areas that might be compiled & mined to make initial maps and/or guide additional sampling surveys.

Once we have many samples of key parameters throughout river networks, it should be straightforward to use current geospatial technologies (e.g., remote sensing, GIS) and/or the spatial statistical network models (blogs #27, #28, #29) to interpolate among measurements and develop "smart maps" like those now being done routinely for stream temperatures at broad scales & high resolutions (blogs #26 and #40). Yes, some key food resource parameters will be too labor intensive or expensive to measure at very many sites (which is why we need surrogates), and yes, we'll have to revisit a subset of sites to understand temporal variation in spatial patterns, but it all seems eminently doable.

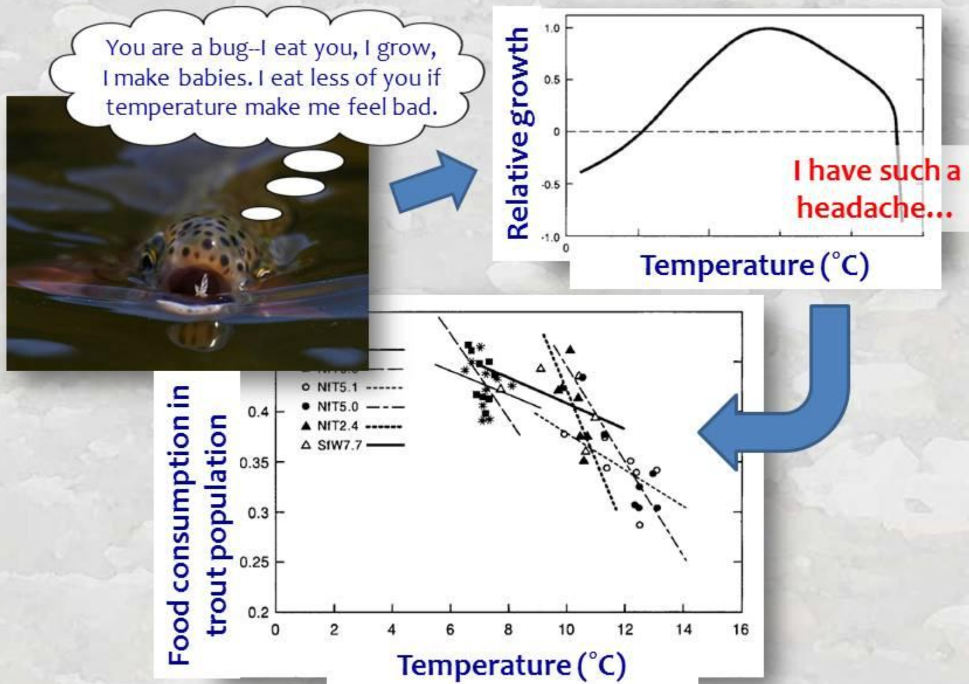
Good stream fish food maps would not only provide important information for understanding the distribution & abundance of many fish species but would also create a bridge to the terrestrial realm. Continuous food maps would enable cross-referencing stream patterns with those in the surrounding environment so these linkages could be studied at a variety of spatial scales & proximities (e.g., riparian zone vs full watershed) to the channel network. Knowing these linkages intimately would yield a deeper understanding of how streams reflect their watersheds, which would ultimately enable better diagnosis and treatment of the ills that climate change may visit upon fish.

Until next time, best regards,

Dan

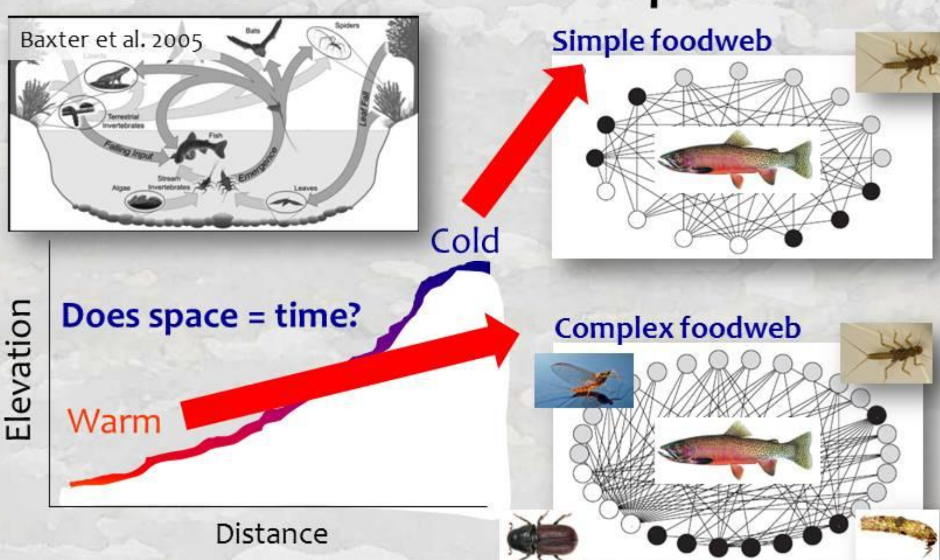
Now Tweeting at Dan Isaak@DanIsaak

Fish Bioenergetics is Not Complicated



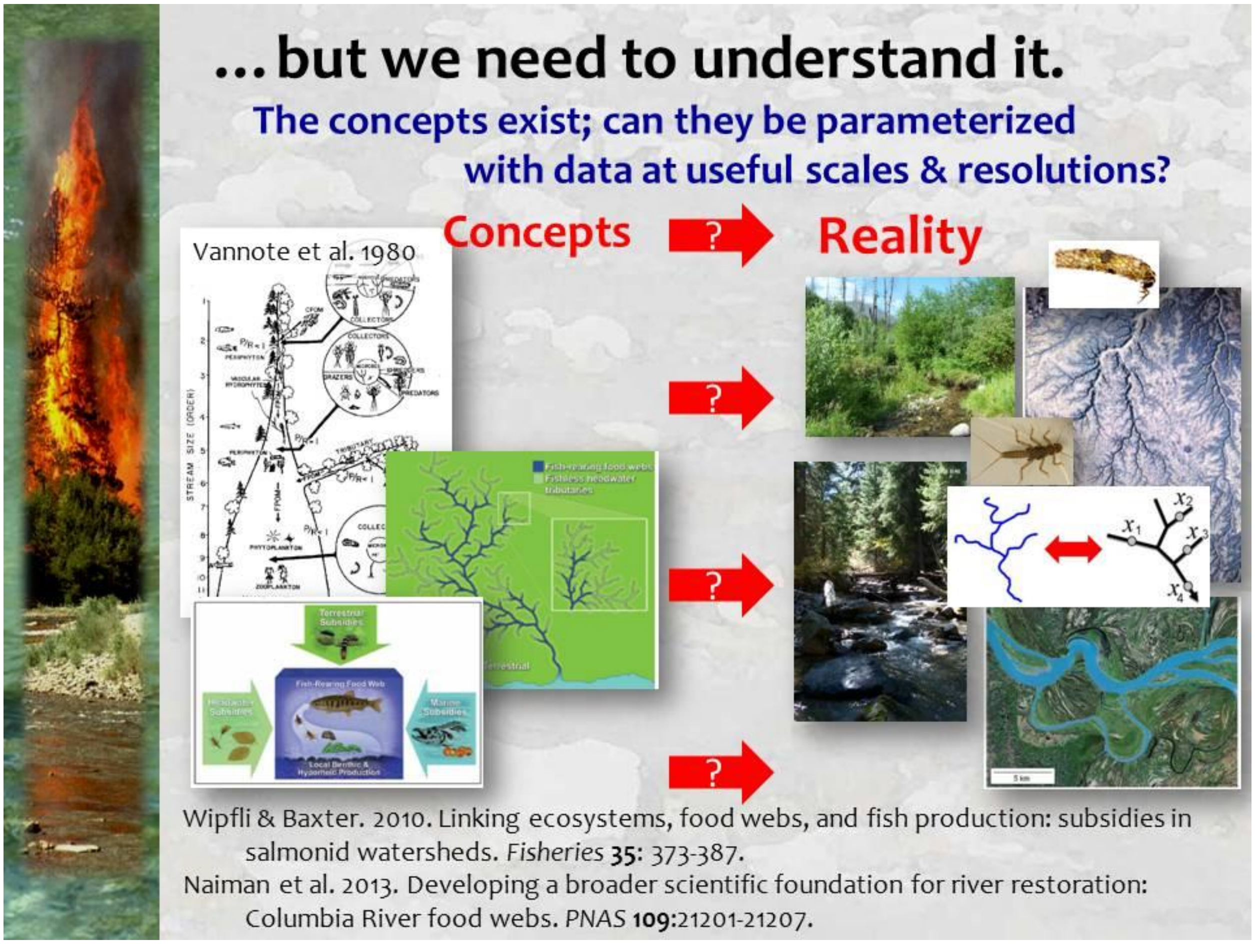
Railsback & Rose. 1999. Bioenergetics modeling of stream trout growth: temperature and food consumption effects. *Transactions of the American Fisheries Society* **128**: 241-256.

Understanding Where Fish Food Comes from is More Complicated…



(& climate is changing how it happens)

Woodward et al. 2010. Climate change and freshwater ecosystems: impacts across multiple levels of organization. *Philosophical Transactions of the Royal Society B: Biological Sciences* **365**: 2093-2106.



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 5,452 (& 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 #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

Future topics…
Climate-Aquatics Management Module

Climate-Aquatics End Game