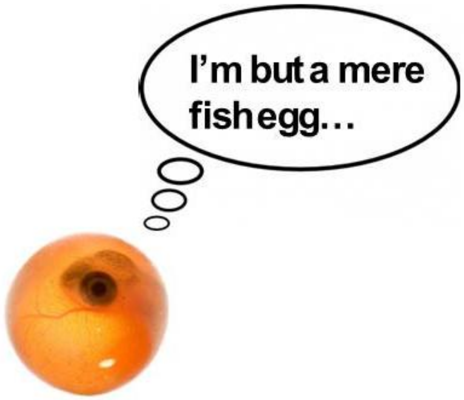
Climate-Aquatics Blog #43:
Part 2, Mechanisms of change in fish populations: Floods and streambed scour during incubation & emergence



Hi Everyone,
So picking up again with Part 2 of the new module on "Mechanisms of change…" wherein we delve more into the various means by which climate change may affect local habitats and population dynamics…Recall that earlier we put these local considerations within the context of the BIDE processes (Birth/Immigration/Death/Emigration; Blog #41) and discussed how the temporal variability of habitat conditions at a site needs to mesh with species biology & life cycle requirements for things to work. One of the big things determining that temporal variation is the annual flow regime as manifest by the amount & timing of water moving through a stream channel. As Leroy Poff and his collaborators have amply demonstrated in previous decades, populations of fish and other aquatic critters are often strongly adapted to what are the historical norms regarding flow conditions (graphic 1; this hyperlink takes you to the paper: http://rydberg.biology.colostate.edu/~poff/Public/poffpubs/Lytle%26Poff2004(TREE_natflow).pdf). Fish breed, their eggs incubate, and juveniles hatch and grow at certain times of year that are synched up with the flow regime. In a similar sense, the structure of the stream channel itself (i.e., sediment size distribution, distribution of pools/riffles/runs) is also adapted to the flow regime and represents a quasi-equilibrium among the flux of water, sediment, and wood through a river network (Blog #22). It's reasonable to assume, then, that as climate change alters temperature, precipitation, and runoff regimes (blogs 13, 16, and 17), conditions within channels have to adjust & will cause concomitant adjustments to the habitats that streams offer their biological denizens.

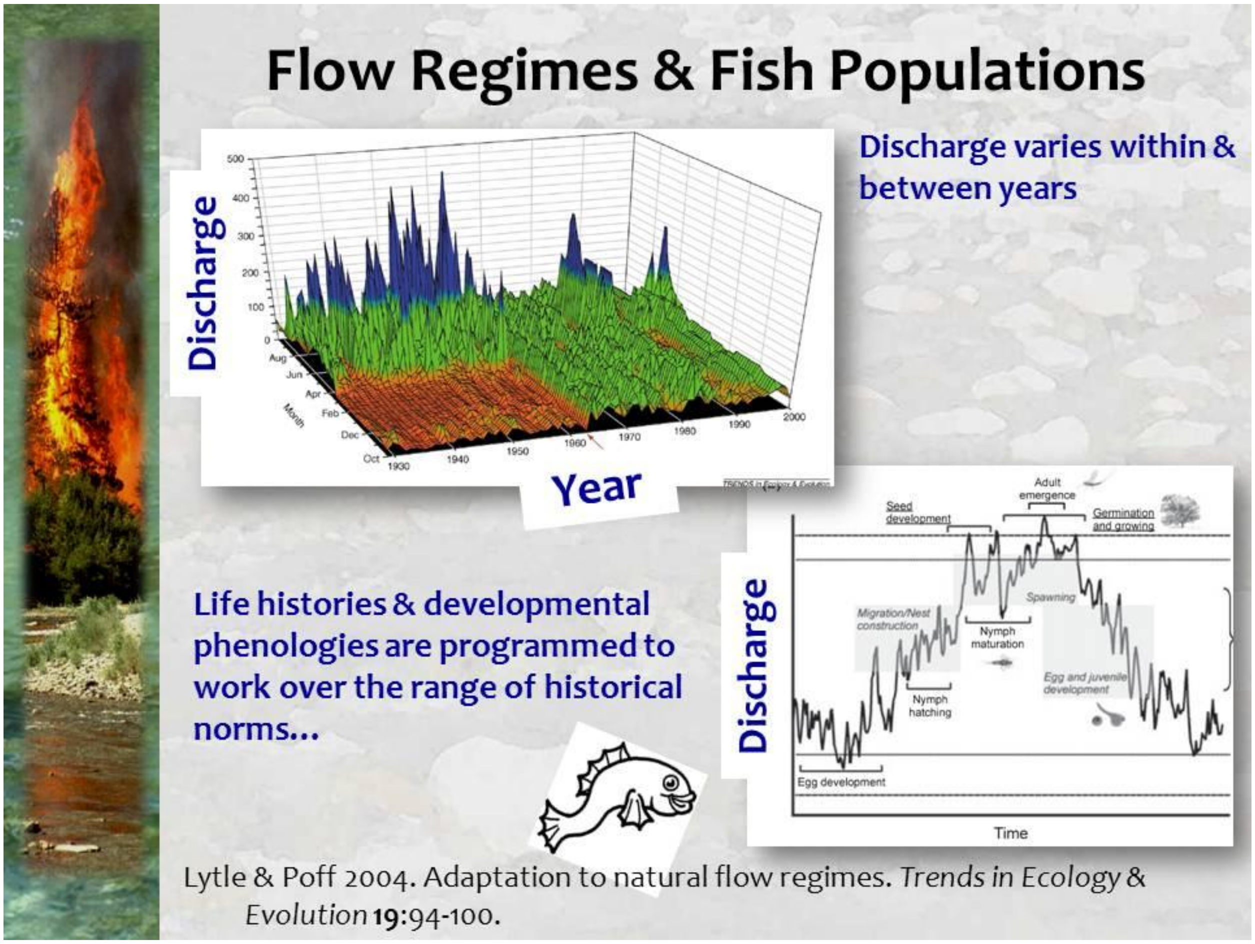
Sometimes these adjustments will be gradual, occur over many decades, and not necessarily be that disruptive. But other parts of the adjustment process will be relatively dramatic & rapid (from a fish's perspective) and could negatively affect some of the BIDE processes. One thing often discussed for streams draining watersheds with substantial seasonal snowpacks is increased risk of channel scour from rain-on-snow events. When rain falls on snow, heat is transferred to the snow, the snow melts rapidly and dramatic runoff events sometimes occur (graphic 2). As temperatures slowly warm & isotherms creep upwards (Blog #36), snowpacks at higher elevations in mountains that were previously too cold to experience rain will slowly begin to do so. Stream channels and fish populations that were unaccustomed to big floods at certain times of year will have to adjust and if you're an egg incubating in the streambed or newly emerged fry developing along the stream's margin, adjustment may not be an option. For these little guys, Martin Short's quote, "I'm not a real strong swimmer" from his classic Saturday Night Live skit on men's Olympic synchronized swimming comes to mind (the YouTube video helps if this reference is too obscure http://www.youtube.com/watch?v=A2AU2xu3CeQ). In these situations, the D in BIDE may spike for small fish as their calm marginal habitats become chaos and previously protective streambed substrates turn into fish blenders.

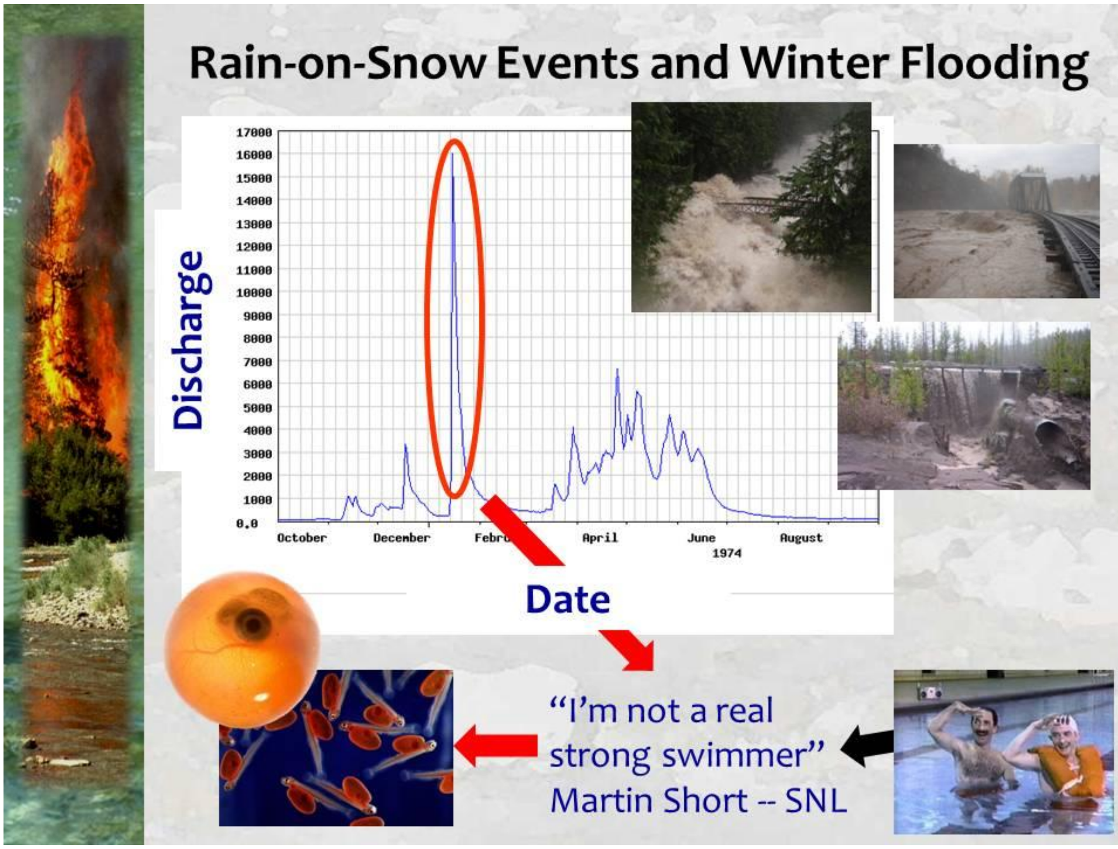
Fortunately, not all stream channels, even in areas with snowmelt dominated hydrologies, are going to be susceptible to these types of disruptive flow events. And our papers this time focus on sorting out the factors that govern spatial differences in susceptibility to channel scour. Goode and colleagues linked global climate model outputs to a hydrologic model to predict changes in the frequency of channel forming (flows with approximately a 2-year return interval) & larger floods across a mountain river network. Flood levels were then linked to reach-averaged shear stress equations to predict the depth & likelihood of bed scour for individual stream reaches and this information was cross-referenced to those times and places when the eggs of different salmon & trout species would be incubating in the gravel (graphic 3; this hyperlink takes you to the paper: http://www.treesearch.fs.fed.us/pubs/43353 ; as an aside, this paper appearred in a recent special issue in Hydrological Processes (Volume 27, Issue 5) entitled "Catchments in the future North: interdisciplinary science for sustainable management in the 21st Century" that has lots of related studies on similar topics). Goode and colleagues found that susceptibility to scour events varies depending on position within the river network (high vs low elevation), reach morphology (pool-riffle, planebed, step-pool), species life history (spring spawners vs fall spawners, the latter of which are generally more vulnerable because their eggs incubate in the substrate all fall and winter), and body size (larger species bury eggs deeper, which makes them less vulnerable to scour). For some species in some parts of the network, the future looks less promising as scour frequencies & depths are predicted to increase to harmful levels. But for other species in that same part of the network or nearby, it may not matter.

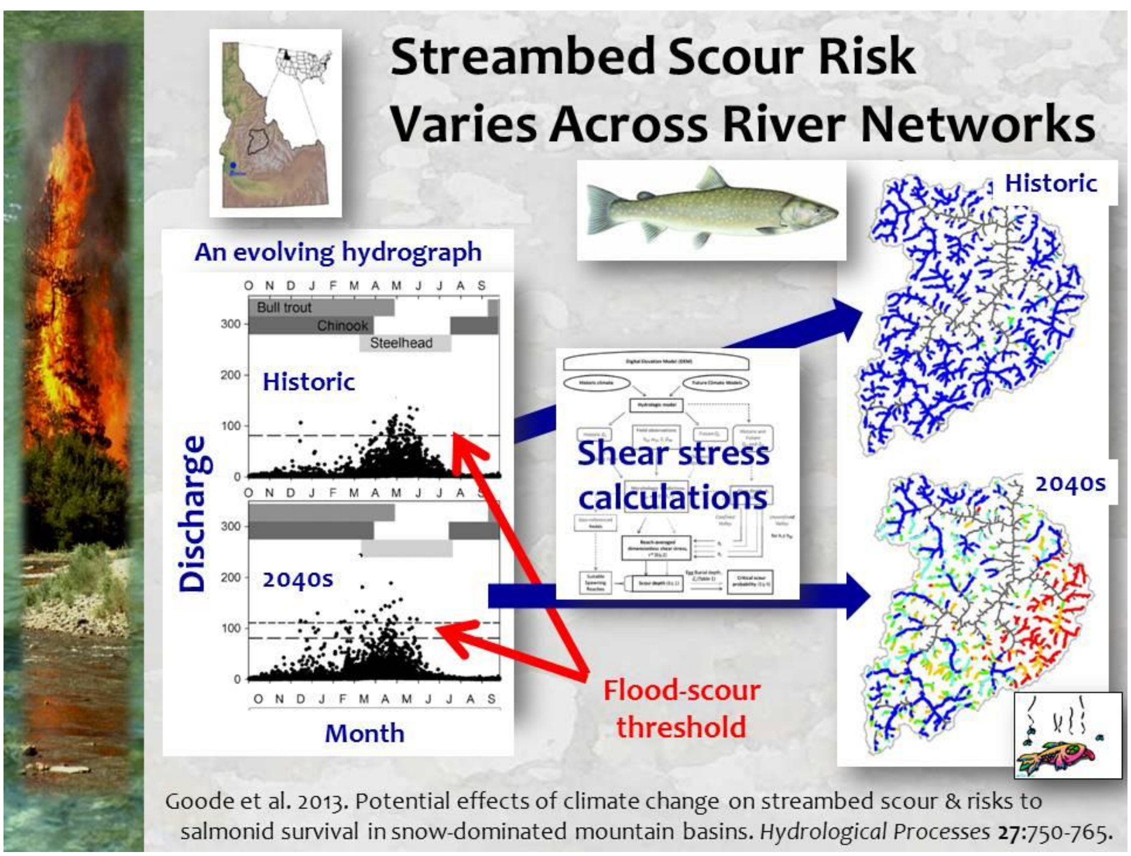
The second study by Shellberg and colleagues addresses this topic in more detail through an empirical approach (this hyperlink takes you to the paper: http://gis.ess.washington.edu/grg/publications/pdfs/Shellberg_etal_Scour_CharSpawning_Washington.pdf). Scour chains were used to measure the depth of streambed scour along elevational transects during several years of monitoring (graphic 4). These depths were compared to depths that fall-spawning bull trout are reported to bury their eggs when building a nest. Shellberg and colleagues found that scour depth at a site varied across years with the magnitude of the flood, by channel type (pool-riffle, planebed, step-pool), and microhabitat location within a channel. Notably, some microhabitats in diverse channels experienced relatively little scour (sometimes even aggradation) even when in close proximity to those that did. One of the paper's conclusions, therefore, was that structural channel diversity might provide population resilience by ensuring that some spawning fish would consistently find areas where eggs incubated successfully.

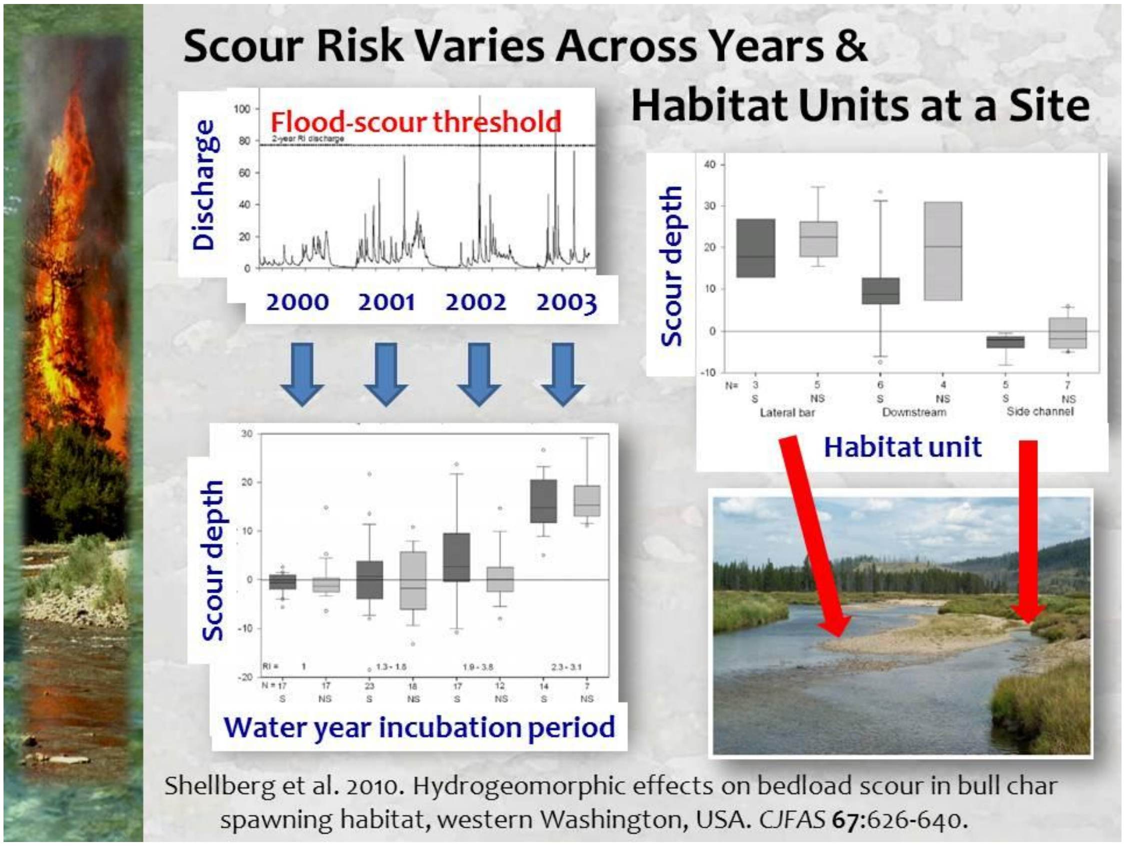
These studies make it apparent that there are many complexities involved with understanding vulnerability of even a single life stage to a single type of habitat alteration that could occur from climate change. As such, we need to continue validating and refining our models and thinking by comparison of empirical data against model predictions and one can see how studies of this sort could be used in complimentary fashion to do so. Also important is doing the biological validation to confirm that the predicted effects on fish populations are a reality. One possibility might be using a modeling approach like Goode and colleagues to reconstruct the temporal variation in scour events (or other relevant flow characteristics) at sites with long-term biological monitoring (Blog #41) and to look at the biological variation relative to flow variation. It's a sort of sensitivity analysis, but a post-hoc version that could be done relatively quickly to leverage information from existing biological datasets. That's it for now; next time we'll think about the other side of the flow spectrum and how too little (rather than too much) water might affect fish populations.

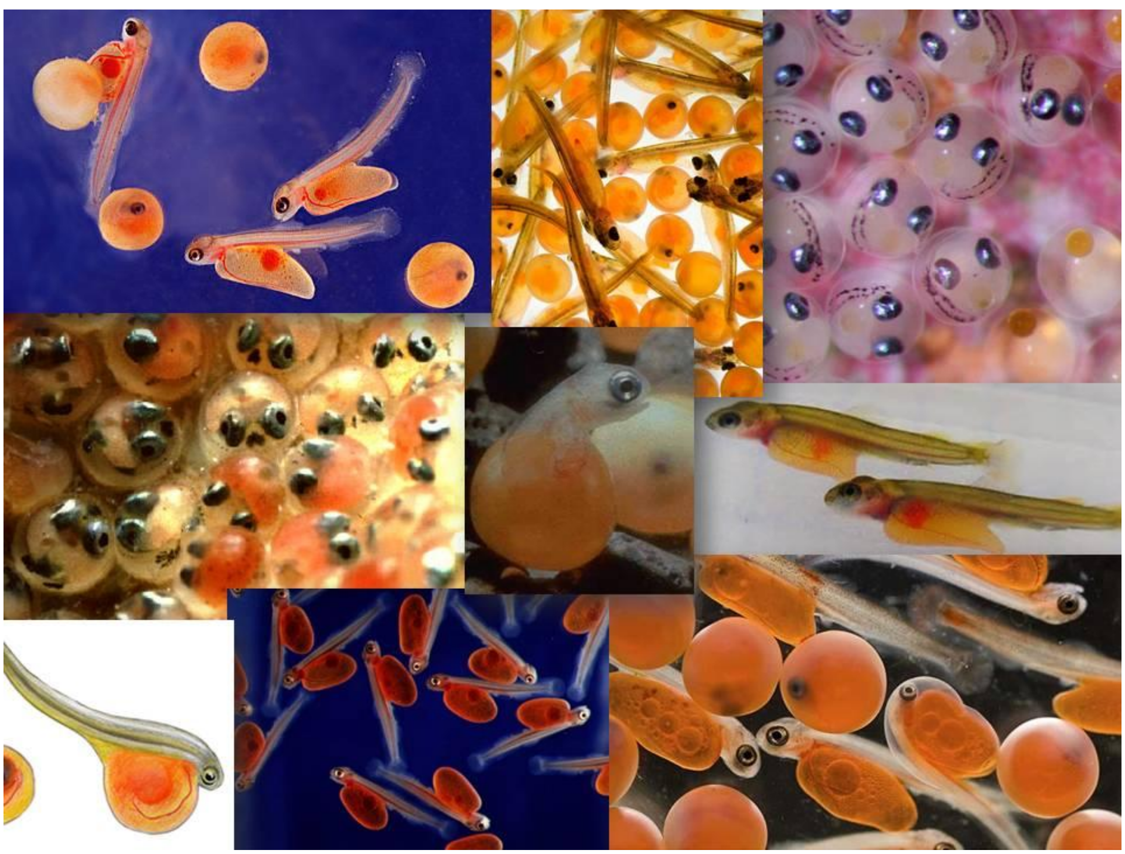
Until then, best regards
Dan




Rain-on-Snow Events and Winter Flooding
Discharge
17000
16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0.0
October
December
April
June
1974
August
Date
"I'm not a real
strong swimmer"
Martin Short -- SNL


Streambed Scour Risk
Varies Across River Networks
An evolving hydrograph
O N D J F M A M J J A S
Bull trout
Chinook
Steelhead
Historic
2040s
Discharge
300
200
100
0
Month
Shear stress
calculations
Historic
2040s
Flood-scour
threshold
Goode et al. 2013. Potential effects of climate change on streambed scour & risks to salmonid survival in snow-dominated mountain basins. *Hydrological Processes* **27**:750-765.


Scour Risk Varies Across Years &
Habitat Units at a Site
Discharge
Flood-scour threshold
2000
2001
2002
2003
Scour depth
Water year incubation period
Scour depth
Lateral bar
Downstream
Side channel
Habitat unit
Shellberg et al. 2010. Hydrogeomorphic effects on bedload scour in bull char spawning habitat, western Washington, USA. CJFAS 67:626-640.



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 5,373 (& 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 #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

Future topics…
Climate-Aquatics Management Module