Climate-Aquatics Blog #26: Mapping Thermal Heterogeneity & Climate in Riverine Environments

Pictures really are worth a thousand words, which is why maps are powerful tools…

Hi Everyone,
I'm not talking about just any old map, mind you, because in this day & age, given the ubiquity of spatial data & the ease with which lots of pretty pictures can be made, it's all too easy to do "GIS tricks" & call it science. No, I'm talking about smart maps built from lots of data & the outputs of appropriate analytical procedures that accurately show the locations and values of the things we care about and are attempting to manage. Though it's the 21st Century, I'd argue that in many regards we're still trying to catch up to where Lewis & Clarke were 200 years ago in terms of having maps that show the current status of stream resources (graphic 1). And if we can't make maps that accurately describe status now, it's going to be really difficult to describe how things look in the future, let alone understand what is lost along the way or be able to adapt our management intelligently to minimize those losses.

So this time out, I thought I'd highlight one of the best tools available for making maps of thermal conditions in rivers; the airborne thermal infrared (TIR) system that Torgersen and colleagues pioneered development of more than a decade ago. The attached paper has the details, but the system essentially consists of a special type of camera mounted to a plane or helicopter that is flown along a section of river. The camera records long-wave infrared radiation emitted from the water surface, which is calibrated against temperature measurements taken contemporaneously along the river at various points. After some post-processing of the remotely sensed imagery, detailed maps can be generated that show thermal heterogeneity within the river channel and along the longitudinal profile (graphic 2).

Although the technology has been around for a while, it's a fundamentally important tool for assessing thermal conditions in larger rivers & streams. Moreover, in streams like some of those we have in the Northwest where temperatures are already pushing the limits of what salmon and trout can tolerate, we're going to need these inventories to understand where important thermal refugia exist (& hopefully persist) as temperatures continue to increase. And that brings us to the second piece of work highlighted in this blog, which is a recent report commissioned by the EPA to help management agencies implement temperature water quality standards. The report by Torgersen, Ebersole, and Keenan is a primer on ways to identify thermal refugia using a variety of sensor technologies from complex systems like TIR to simple hand-held temperature probes (graphic 3). Apparently, this area of research has rapidly expanded rapidly in the last decade and the report is too large to send as an attachment (18 MB) but it can be downloaded from a webpage here http://fresc.usgs.gov/research/StudyDetail.asp?Study_ID=540.

More broadly, then, as we continue generating lots of stream and river temperature data using various sensor technologies, the challenge will be to integrate & use this data to develop smart maps that show the current thermal diversity & patterns of climate in streams. The process of developing those smart maps is often tedious and labor intensive but these efforts are required to have the necessary foundation for understanding thermal patterns & accurately translating various climate change scenarios to stream ecosystems. With accurate maps, it will be possible to examine differences between historic and future conditions to see where changes occur and how those changes relate to important biological entities (e.g., fish population) or water quality parameters (e.g., a TMDL standard). Where future changes appear likely to push past important thresholds, we then have to ask ourselves whether management interventions could make a difference (e.g., degraded stream) or not (e.g., pristine wilderness stream)? In the former case, the area becomes a logical candidate for consideration when choosing where to target limited resources for habitat and population conservation efforts. The more precisely we can identify these key areas, the more aquatic biodiversity we'll be able to bring with us through this transitional century. There are, of course, lots of other complicating factors to consider, but at its core, the essence of the problem is simply picking the smartest things to do in the smartest places.

So it's pretty straightforward to see how a tool like TIR could be used to inventory the most important rivers within a region and derive accurate maps of current conditions. Perhaps such inventories could even be repeated in warm years and cold years to describe how temperatures differ across contrasting climatic conditions to provide an analogue for future climate change. Yes, that's all well and good but it won't work on smaller streams where the water's surface is obscured by riparian vegetation & the costs would be prohibitive if we tried to do it across the 100,000's of kilometers that comprise regional river networks.

To develop smart maps for entire river networks, we need to adopt a different approach. As we saw in the last blog regarding the NorWeST database (#25), an informal temperature monitoring network has already been implemented by hundreds of biologists and hydrologists from dozens of agencies across the Northwest over the last 20 years. Some 45,000 summers of temperature measurements at more than 15,000 unique stream sites are represented in that database. Each of those temperature sites contains some information about the spatial patterns in stream temperature across the region. All we need is an analytical technique that allows us to interpolate information between those sites correctly and then it would be possible to start making accurate predictions at unsampled locations & to generate smart maps for all streams at river network and larger scales. The analytical techniques for doing this sort of interpolation by valid means on networks have only recently been developed and next time out we'll start a mini-module that steps through some of their inherent advantages for modeling stream temperatures across networks.

Until next time, best regards.

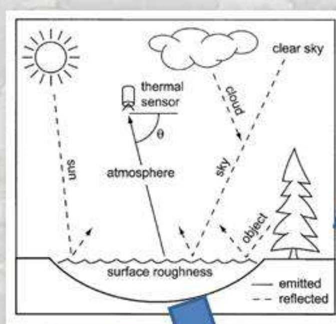
Dan

Catching up to Lewis & Clarke

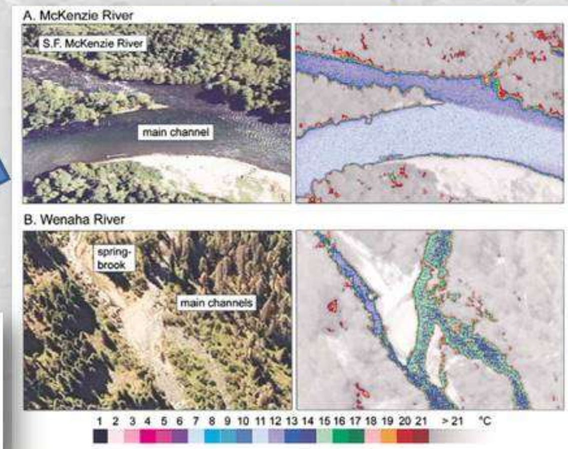
Building "smart maps" to represent stream resources

Maps built from the best available data & analytical techniques are needed to summarize the current (& possible future) status of the stream resources we want to manage and conserve.

Airborne thermal infrared (TIR) system



Thermal heterogeneity within…



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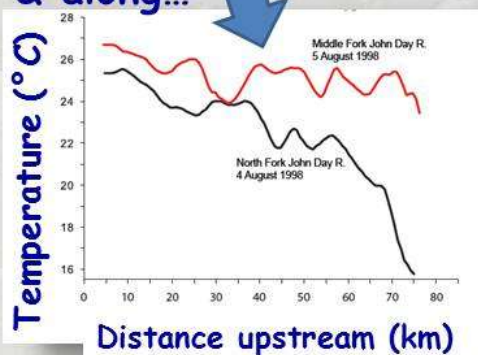
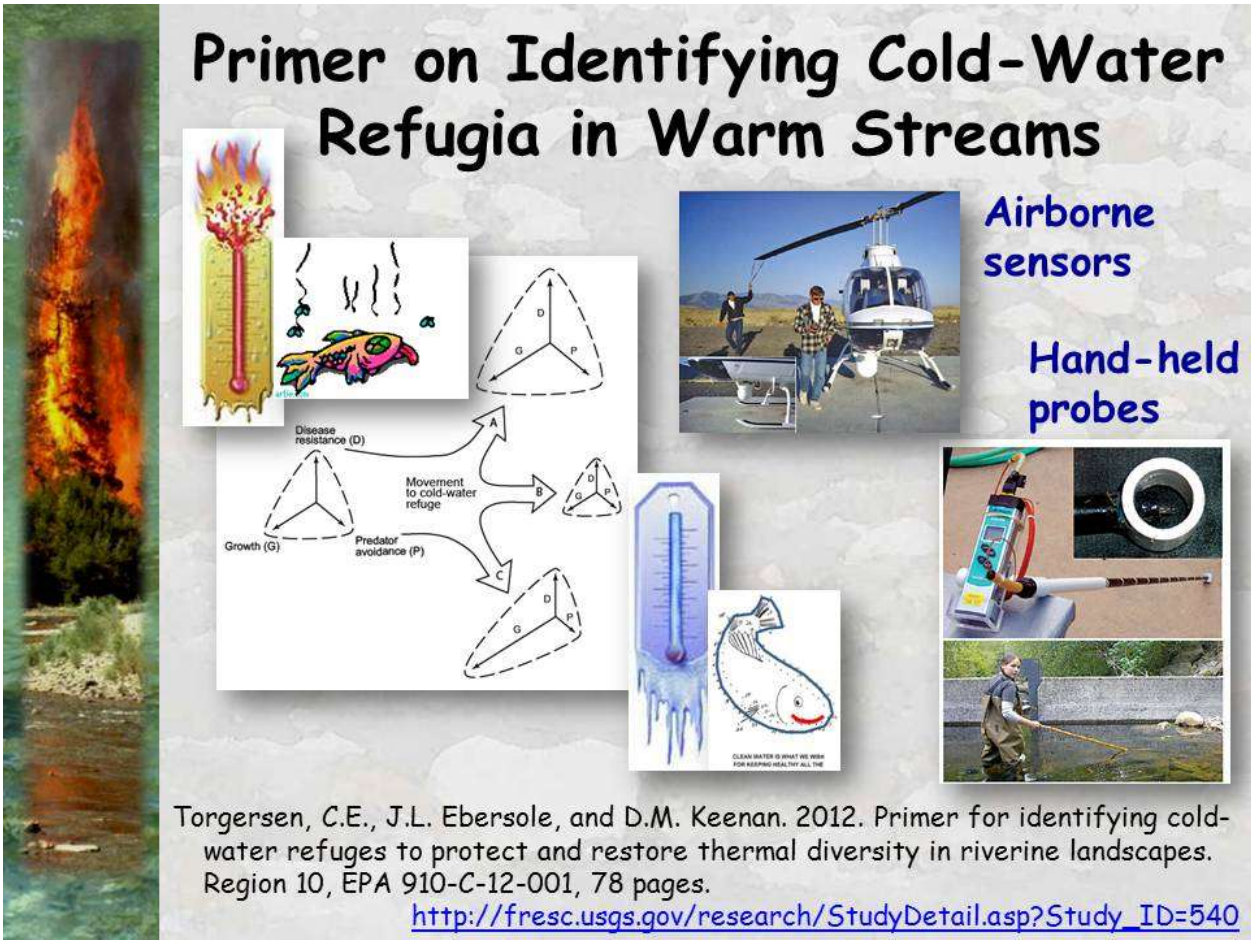


Torgersen, C.E., R.N. Faux, B.A. McIntosh, N.J. Poage, and D.J. Norton. 2001. Airborne thermal remote sensing of water temperature assessment in rivers and streams. Remote Sensing of Environment 76:386-398.



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 3,952 (& 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 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

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

Future topics…

Climate-Aquatics Biology Module

Climate-Aquatics Management Module
Climate-Aquatics Cool Stuff Module