Climate-Aquatics Blog #22: Climate change effects on sediment delivery to channels

Climate Affects Everything, Even The Way a Stream Looks

Hi Everyone,
So last time out we wrapped up the hydrology module and we'll eventually transition into the next formal module on biological effects, but before starting that, I'm going to work through a few miscellaneous topics & new research on previous topics that bear on the issue of climate and streams. Typically, when we think about climate change effects on streams we think temperature and hydrology first but that's only part of the story. Drainage network structure, stream channel morphology, and the array of fish habitats like pools, riffles, and runs are the way they are because streams have adjusted their form to efficiently transport sediment yielded by a landscape downstream to the sea. Anything that shifts the historical balance between this sediment load and a stream's hydrograph will cause the stream to adjust its form so that its work is continued efficiently.

A simple conceptual tool for thinking about how stream channels may adjust to changes in sediment & flow regimes is Lane's Balance (graphic 1). Probably all the fluvial geomorphologists in the crowd are cringing at this point regarding the crudeness of this tool, but it's about as deeply as us fish people want to think about dirt. Basically, Lane's Balance predicts whether a channel will either aggrade (accumulate sediment) or degrade (export sediment) through time as a function of the sediment load, hydrologic regime, stream slope, and sediment size. Lots of moving parts there but the biggies are sediment and hydrology. We've previously discussed climate-induced hydrologic changes (blogs 16 – 21), with the annual high flows most important for transporting sediment increasing in some areas and decreasing in others (blog 17), but we haven't yet brought sediment into the equation. As it is the brick and mortar of fish habitat, it is important to think about how climate change will affect the left side of this fluvial balance.

So this week, we're highlighting two recent papers that begin to address this topic. The first is by Sue Cannon and colleagues and describes the probability and volume of postfire debris flow sediment deposition into stream channels (graphic 2). The basic story is that if a wildfire happens in steep terrain, then a high-intensity precipitation event like a thunderstorm drops a lot of water on there in the next few years, a big chunk of sediment may succumb to gravity and find its way into the channel network. If you're a fish living in the path of such a debris flow, your best days are behind you as the slug of sediment scours and transports your entire world somewhere else further downstream. Once that slug of sediment enters a larger channel and/or where the valley slope decreases below a critical threshold, the ride & your life are over. But if you're a fish living in that downstream depositional channel, you only give passing notice to the demise of your relative and spend more time enjoying all the great new spawning gravels and other diverse habitats that a fresh slug of sediment often provides.

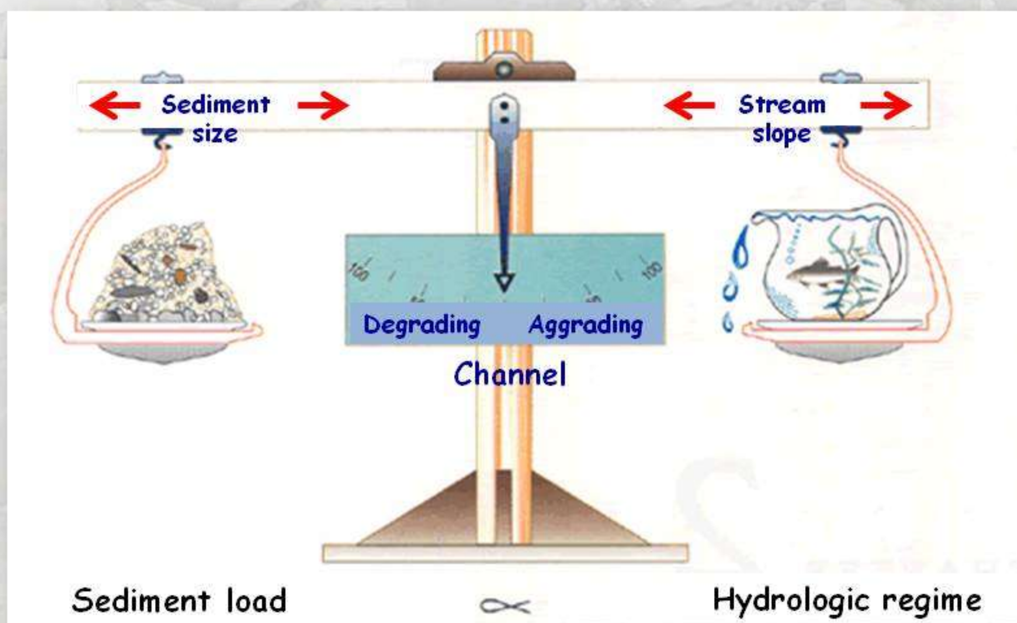
To think more broadly about how this influx of fire-related sediment may affect the fish housing market and what the government can do to bail them out (credit for this analogy to J. Goode), Goode et al (2012) synthesized all available sediment delivery data from central Idaho to assess the potential climate drivers (top figure in graphic 3) of sediment yields in fire-influenced landscapes. The potential changes were framed in the context of implications for infrastructure and habitat management and the question was, “what can be done to offset the increased sediment from fires?” In a warmer and drier climate, vegetation disturbance from wildfires, insect/pathogen outbreaks, and drought induced die off (graphic 4) are likely to promote to hillslope instability and lead to a general increase in sediment delivery.

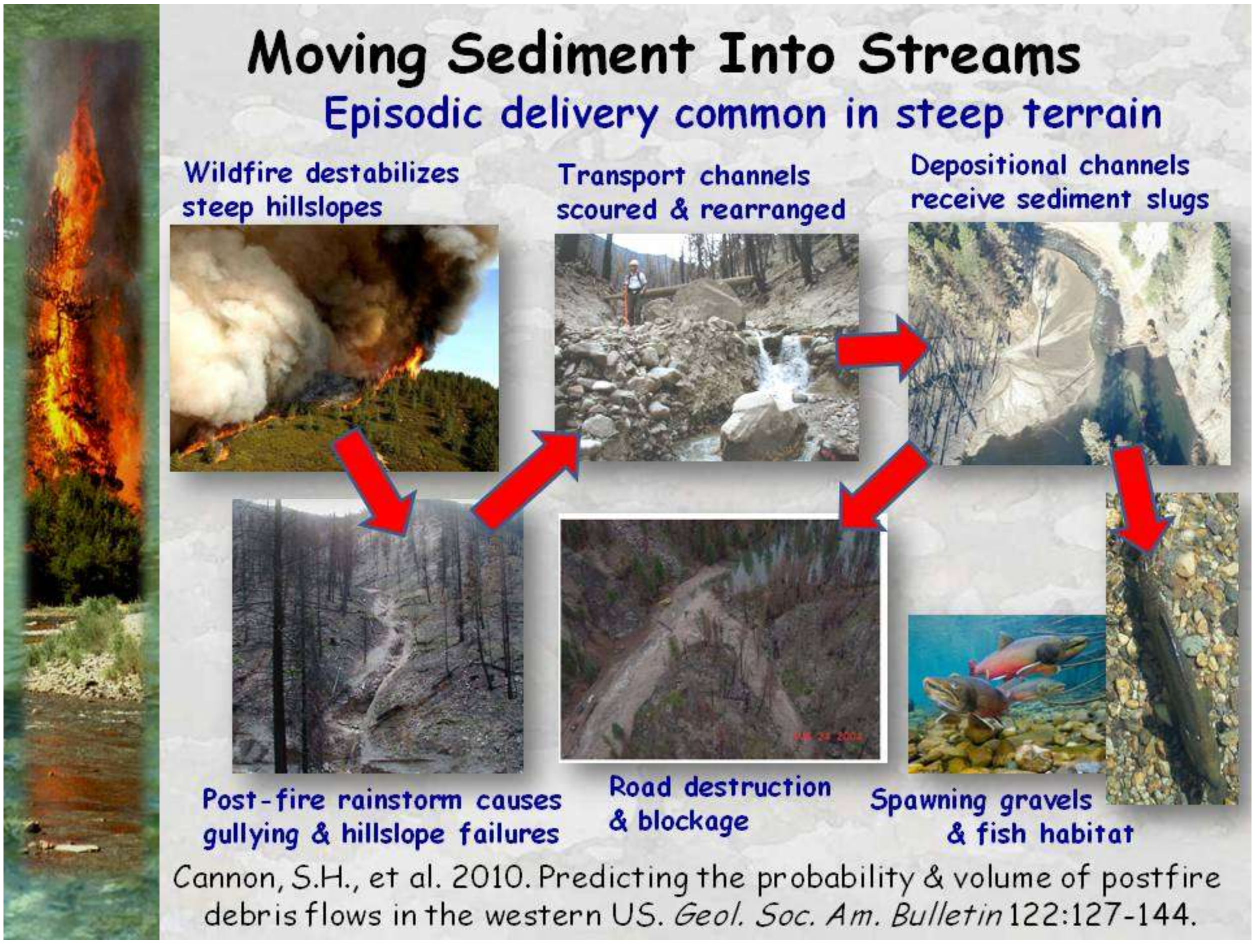
Although the magnitude of sediment delivery from fires far surpasses that from anthropogenic sediment sources (grazing, mining, timbering, and roading; lower figure in graphic 3), fish in fire-prone landscapes across the northern Rockies have evolved with wildfires & debris flows often provide fresh spawning gravels and nutrients from hillslope soils that are needed to maintain diverse and productive habitats. More problematic to fishes and infrastructure are the fine-sediments that may smother fish eggs and interstitial spaces between substrates where aquatic insects live. Wildfires provide these fine-sediments periodically, but these background levels are greatly enhanced by chronic delivery from anthropogenic sources & especially roads. Moreover, it is these fine sediments that are of greatest concern for the maintenance of downstream infrastructure (dams and levees) because they are easily transported downstream by relatively steep mountain rivers. A sensible approach for mitigating climate-wildfire-sediment effects on fish populations and infrastructure, therefore, is not through fire suppression activities, but by minimizing anthropogenic sources of sediment.

So if the general prediction holds in semi-arid areas that there will be fewer forests and other vegetative types with deep root systems to keep sediment on hillslopes as climate change progresses this century (graphic 4; blog 15), we’d expect more sediment to be finding it’s way into streams. What that ultimately translates to for stream channel morphology and fish habitats depends on the interaction with the evolving hydrologic regime in that same place. In streams where peak flows are declining and sediment rates are increasing, aggradation may be expected over the long-term. In areas where peak flows are increasing and sediment rates increasing, perhaps no big changes occur (graphic 5). It all depends on where the stream fits in the relation between sediment supply and transport capacity. So again, and as we’ve seen several times previously, even though everything’s changing in response to climate forcing, the details of those responses depends on the local context.

Until next time, best regards.
Dan

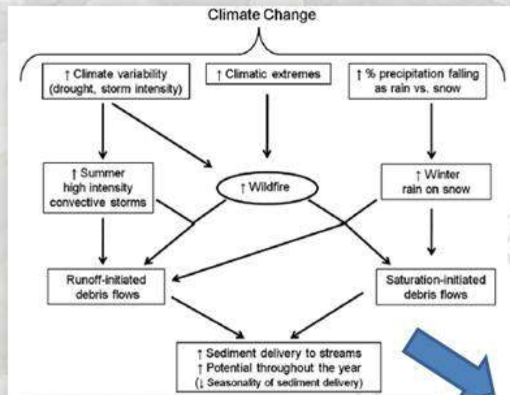
Lane's Balance, A Conceptual Tool for Understanding Channel Responses



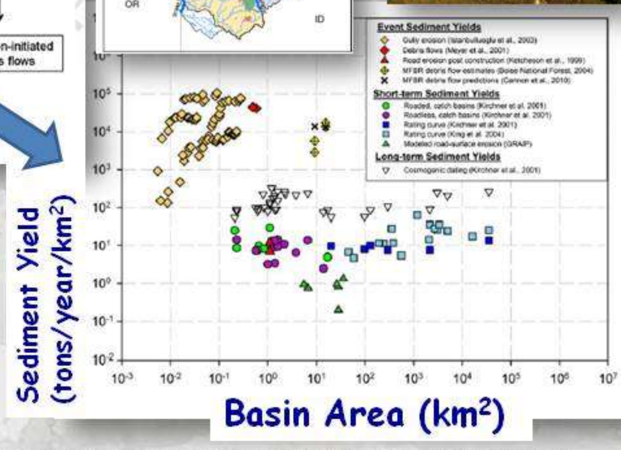


Moving Sediment Into Streams
Episodic delivery common in steep terrain
Wildfire destabilizes steep hillslopes
Transport channels scoured & rearranged
Depositional channels receive sediment slugs
Post-fire rainstorm causes gullying & hillslope failures
Road destruction & blockage
Spawning gravels & fish habitat
Cannon, S.H., et al. 2010. Predicting the probability & volume of postfire debris flows in the western US. *Geol. Soc. Am. Bulletin* 122:127-144.

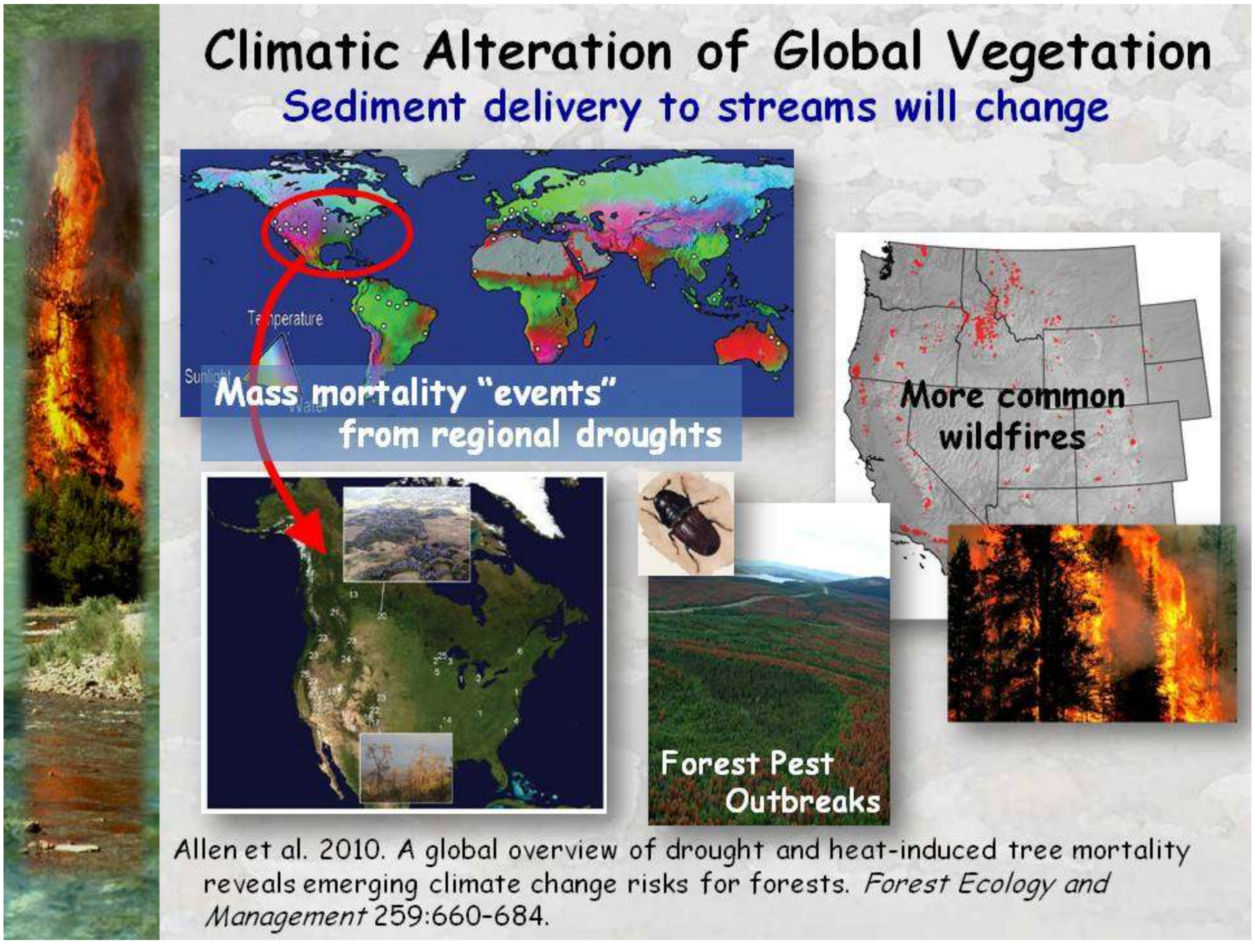
Climate Effects on Sediment Loads to Stream Channels

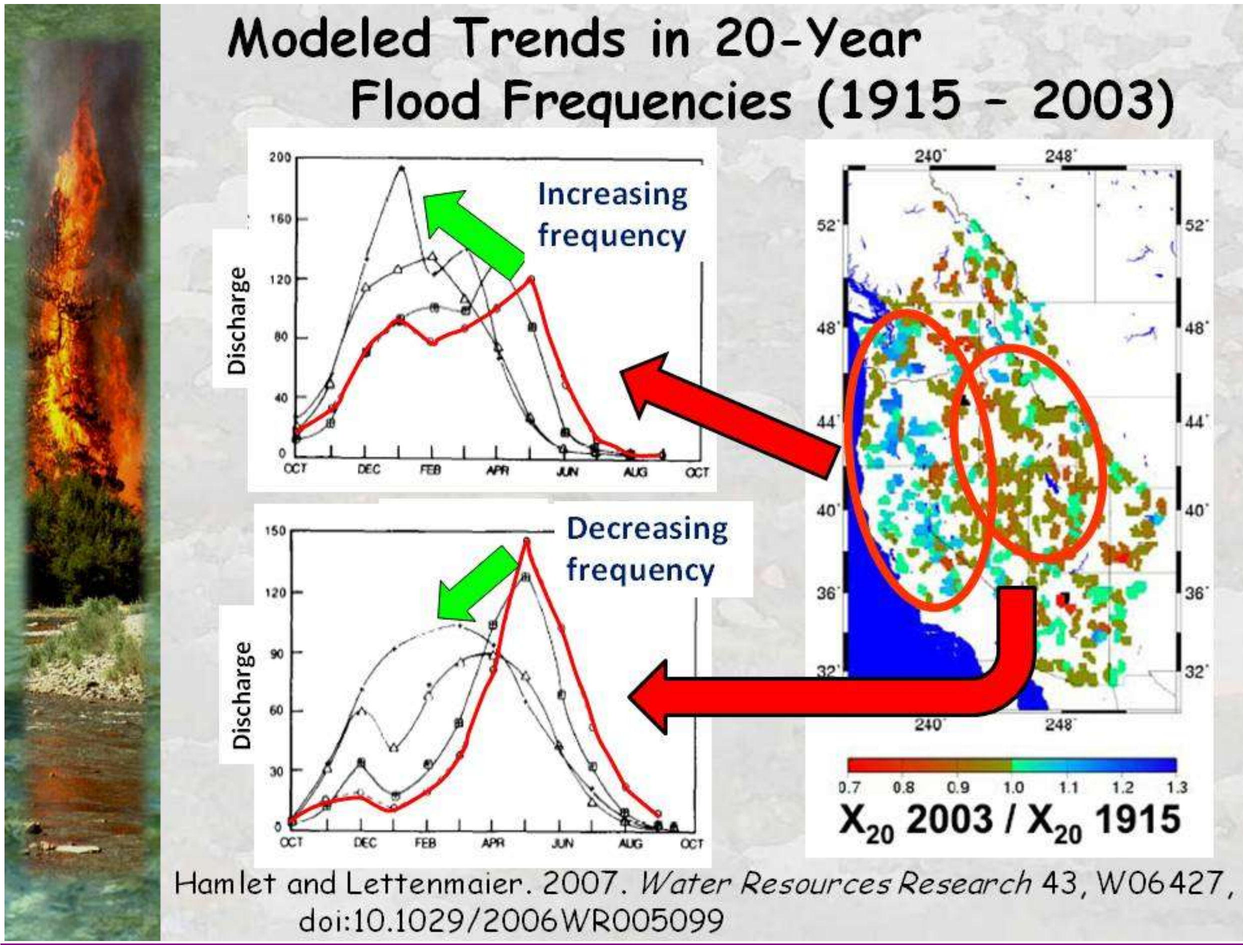


Example Based on Wildfires in Central Idaho



Goode et al. 2011. Enhanced sediment delivery in a changing climate in semi-arid mountain basins: Implications for water resource management and aquatic habitat in the northern Rocky Mountains. *Geomorphology* 139/140:1-15.


Climatic Alteration of Global Vegetation
Sediment delivery to streams will change
Mass mortality "events"
from regional droughts
More common
wildfires
Forest Pest
Outbreaks
Allen et al. 2010. A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests. *Forest Ecology and Management* 259:660-684.



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 3,448 (& 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