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Climate Change, Crowd-Sourcing, and Conserving Aquatic Biotas in the Rocky Mountains This Century

The cold and relatively pristine rivers and streams of the Rocky Mountains and Pacific Northwest are known for being productive trout and salmon fisheries, respectively. The landscapes in which these fish thrive are often stunning and iconic of the western U.S. However, increasing river temperatures may make for less suitable fish habitat.

SUMMARY

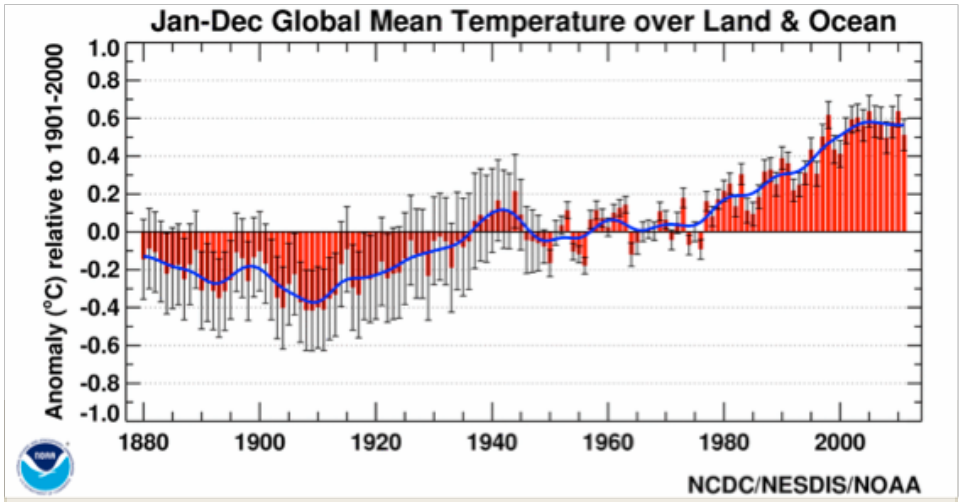
Climate change is causing rapid changes to stream habitats across the Rocky Mountains and Pacific Northwest as warmer air temperatures and changes in precipitation increase stream temperatures, alter stream hydrology, and increase the extent and magnitude of natural disturbances related to droughts and wildfires. These changes are affecting trout, salmon, and other fish populations, many of which are already subject to substantial non-climate stressors. Fish habitats at lower elevations—near the downstream edges of species distributions—are particularly vulnerable. However, three Rocky Mountain Research scientists are conducting research and developing applied management tools that harness the power of crowd-sourcing to generate information and create opportunities for collaboration and resource allocation decisions that may help to conserve some of the aquatic biotas currently at risk. This is enabling adaptation to move forward at a scale and pace more appropriate to the challenges posed by climate change.

The cold and relatively pristine rivers and streams of the Rocky Mountains and Pacific Northwest are known for iconic trout and salmon species. These species are foundational to the surrounding ecosystems, possessing ecological, cultural, recreational, and commercial significance. The landscapes in which these fish thrive are quite often stunning—rivers running through lush riparian areas, gorgeous canyons, or set against the backdrop of towering mountains. For many, the aesthetic appeal of these landscapes is deeply rooted in notions of escape, relaxation, or wilderness.

Trout and salmon play a critical role in local food webs, and salmon have been suggested as a keystone ecological species due to the role they play in transporting nutrients from the marine environment to freshwater and terrestrial ecosystems when they spawn. Both trout and salmon are consumed by terrestrial vertebrates who subsequently deposit nutrients—in the form of urine, feces, and fish carcasses—from aquatic into terrestrial ecosystems.

Many of these fishes are also culturally significant to Native American tribes and recreationally significant to a substantial segment of the American public. The Greater Yellowstone Ecosystem, for example, sustained 250,000 angler days annually from 1975-2000[1], a testament to the popularity of the region's iconic rivers and streams. The economic implications are also significant: According to research by the Natural Resources Defense Council and the Defenders of Wildlife, the direct economic value of river and stream fisheries in the US ranges from $1.5-14 billion annually, while the US Environmental Protection Agency estimates that "about 33 million anglers spend $41.8 billion annually on trips, equipment, licenses, and other items to support their fishing activities."[2]

Despite the significance and economic value of fisheries, trout and salmon have not always been prioritized for conservation. Their habitats have been degraded by numerous land uses throughout the past century and a half, related to logging, urban growth and housing development, dams and diversions, and pollution. Climate change is adding substantial new stressors to the already-existent suite. Research efforts by a trio of Rocky Mountain Research Station research scientists—fish biologists Dan Isaak and Mike Young, and hydrologist Charlie Luce—are not only enhancing our understanding of the changes, stressors, and potential outcomes that may result, but are catalyzing the creation of a suite of high-resolution tools and databases that have the potential to significantly improve conservation efforts. More information on the tools will be given later in the Bulletin, but first, let's understand the stressors.



Global mean temperature data from 1880 to present demonstrates a trend toward increasing average temperatures. Increasing air temperatures contribute to increasing river and stream temperatures. (Image credit: NCDC / NESDIS / NOAA)

MERCURY RISING ON THE ECTOTHERMS

Research being led by hydrologist Charlie Luce and others is illuminating some of the ways that climate change is causing substantial changes in aquatic habitats across the Rocky Mountains, as warmer air temperatures and changes in precipitation increase stream temperature, alter stream hydrology, and contribute to the increased extent and magnitude of droughts and wildfires.

General Circulation Model (GCM) projections for changes in total annual precipitation in the Rocky Mountains and Pacific Northwest are very uncertain, with anywhere from a 10% decline to a 21% increase predicted by different models. Luce's research on historical trends, however, has documented an overall decrease in Pacific Northwest streamflow from 1948 to 2006, with flows decreasing as much as 20–50% in the driest years. More recently, Luce and others have linked this decrease in streamflow to a decrease in winter westerly winds across the Pacific Northwest, which has reduced precipitation in Pacific Northwest mountains. These changes in mountain precipitation were previously unrecognized and the wind mechanism suggests that future mountain precipitation may stay in this relatively low state as the climate warms. In addition, rising air temperatures are causing earlier snowmelt and runoff, which affect the overall availability of that precipitation to downstream communities and ecosystems in summer months. Reduced snowpack and precipitation is decreasing the amount of cold groundwater flowing into streams and slowing the velocity at which streams flow, thereby increasing temperatures.

[1] Kerkvliet et al, 2012.
[2] http://water.epa.gov/type/rsl/streams.cfm

Spawning migrations like this one by Kokanee salmon in Idaho could become increasingly difficult if climate-related summer flow declines continue. (Image credit: Clayton Nalder)

Fish biologist Dan Isaak notes, "In general, [stream] temperature increases may be more relevant in the northern Rocky Mountains.... In the southern Rocky Mountains, decreasing summer flows and disturbances like extreme droughts and wildfires may be greater risk factors..."

In addition, more extensive wildfires driven by the combination of decreased precipitation and earlier snowmelt may decrease the amount of shade by opening riparian canopies. Finally, increasing air temperatures simply result in the transfer of more energy from the atmosphere into streams, thereby further enhancing stream temperature increases.

All of this has a substantial effect on the trout and salmon that have historically thrived in the river and stream ecosystems of the Rocky Mountains and Pacific Northwest. Trout and salmon, like most aquatic organisms, are ectotherms—their body temperatures are controlled by the temperature of the environment. As such, they are dependent on specific thermal niches for metabolic regulation, growth, and development. For example, most cold-water fish require summer stream temperatures ranging from 45 to 65 degrees Fahrenheit and different species have relatively narrow ranges for optimal growth and survival. Because of the broad range of elevations and climatic conditions in Rocky Mountain streams, the downstream limits of many species are dictated by warm temperatures. These boundaries are expected to shift upstream as temperatures increase so many fish populations already confined to headwater areas may experience shrinking habitats.

Native fish populations are also susceptible to more than just rising stream temperatures. For example, warming waters may allow nonnative invasive species, which are typically constrained by cold temperatures, to expand upstream and outcompete native species. Air temperature increases may lead to more frequent winter rain and a greater risk for winter flooding. This could result in channel scour while eggs are in the streambed and poor reproduction for fall-spawning native species, such as the bull trout, which is currently listed as a threatened species. Research by fish biologist Dan Isaak suggests that the vulnerability of populations to climate change will depend strongly on local context. "In general, [stream] temperature increases may be more relevant in the northern Rocky Mountains where species' population boundaries, angling opportunities, and zones of competitive overlap are often mediated by temperatures. In the southern Rocky Mountains, decreasing summer flows and disturbances like extreme droughts and wildfires may be greater risk factors because populations are heavily fragmented and confined to small headwater streams," notes Isaak.

While native trout and salmon populations can adjust to some degree of environmental change by adjusting life history timing or by shifting spatial distributions, the magnitude and velocity of change in some streams is likely to

Native westslope cutthroat trout (bottom fish) are often displaced from streams by non-native species like brook trout (top fish) where the invasive species is introduced. (Image credit: Mike Young) overwhelm some populations and could result in local extirpations. “Depending on the species and location within the historic range, bioclimatic model projections suggest 20-90% of currently suitable habitat for popular trout species could disappear in the Rocky Mountains by the end of the 21st century,” says Isaak.

A CLIMATE AND CONSERVATION CONUNDRUM

In an era of dwindling budgets and resources, climate change challenges managers to allocate conservation resources efficiently so they are most beneficial to native fishes in the long run. We are at a crucial moment in time and Isaak notes that “wise and proactive management decisions in the next decade could substantially affect how many native fish populations there are in Rocky Mountain streams 100 years from now.” Knowing when and where to allocate limited conservation resources, however, is anything but straightforward.

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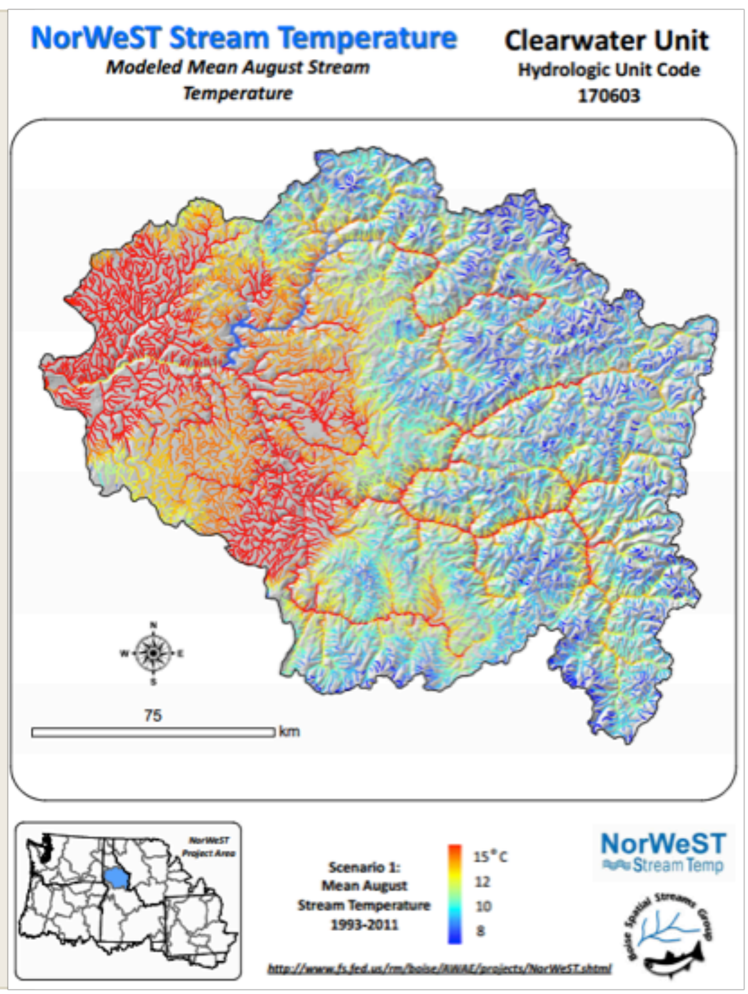
Aquatic environments in these ecosystems are complex: “Interactions between climate and topography have profoundly influenced the evolution of native fishes and current patterns of biodiversity across the Rocky Mountains,” says fish biologist Mike Young. The conservation and research communities still do not fully appreciate the spatial patterns of diversity in well-studied species like salmon and trout, let alone many nondescript native species such as sculpin. In fact, Young and colleagues have recently discovered

Climate change will reduce summer flows and contribute to more frequent or extreme droughts and wildfires. These factors will most impact fish communities that are heavily fragmented and confined to small headwater streams. Local extirpations and reductions in native biodiversity may result. (Image credit: US Forest Service)



Outputs from the NorWeST project are modeled stream temperature scenario maps and accompanying GIS data for river networks like the Clearwater River shown above, in northern Idaho. NorWeST stream temperature scenarios are developed at a 1-kilometer resolution using spatial statistical stream network models to provide managers with sufficient resolution for decision making.

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a new species of sculpin from northern Idaho, and the data suggest there may be several more within that region. "Across the Rocky Mountain west there may be dozens of undiscovered species and considerable genetic diversity within existing species that we have yet to appreciate," says Young. And it is the suite of conservation units of these species, and diversity hotspots that might constitute native fish conservation areas, which form the biodiversity portfolio that managers will be balancing in the future.

The rich biological diversity in aquatic ecosystems across the Rocky Mountains is a reflection of a diverse environment. Factors such as past climates, topography, geomorphic history, and glaciation all affect habitat and biological patterns to create local diversity. Understanding this can help one understand why planning for conservation strategies in an era of climate change is so difficult. "Past generations of global climate models and species distribution models have not had enough resolution to adequately describe this diversity. Better information is needed at the landscape scales to empower local decision makers and make proactive, efficient management a reality," says Isaak.

Genetics research by fisheries biologist Mike Young has led to the discovery of a new species of sculpin, the Cedar sculpin (Cottus schitsuumsh). (Image credit: Zachary Randall)

CROWD-SOURCED SCIENCE FOR COST-EFFECTIVE INFORMATION CREATION

Understanding more about local diversity helps us understand why finer-scale tools are critical for successful conservation in an era of climate change. Fortunately, inexpensive data collection protocols now exist for many of the variables—such as stream discharge, temperature, and species distribution, abundance, and diversity—that are needed to develop high-resolution status maps and climate scenarios for streams, rivers, and ecosystems. If collaborating agencies can be engaged in using similar data protocols and the data are archived in shared, open-access databases, powerful synergies emerge. Below are two examples of how Isaak, Luce, Young, and others are harnessing the potential of crowd-sourcing in the information age to create powerful tools for conservation.

EXAMPLE ONE: THE NORWEST STREAM TEMPERATURE DATABASE, MODEL, AND CLIMATE SCENARIOS

The NorWeST Project is developing a regional stream temperature data archive from contributions by hundreds of individual biologists and hydrologists that work for more than 70 state, federal, tribal, and non-governmental organizations in the northwest U.S. The NorWeST database may be the largest of its kind in the world, consisting of more than 50 million hourly temperature recordings at over 15,000 unique stream sites. The project is made possible by the technical expertise of professional support

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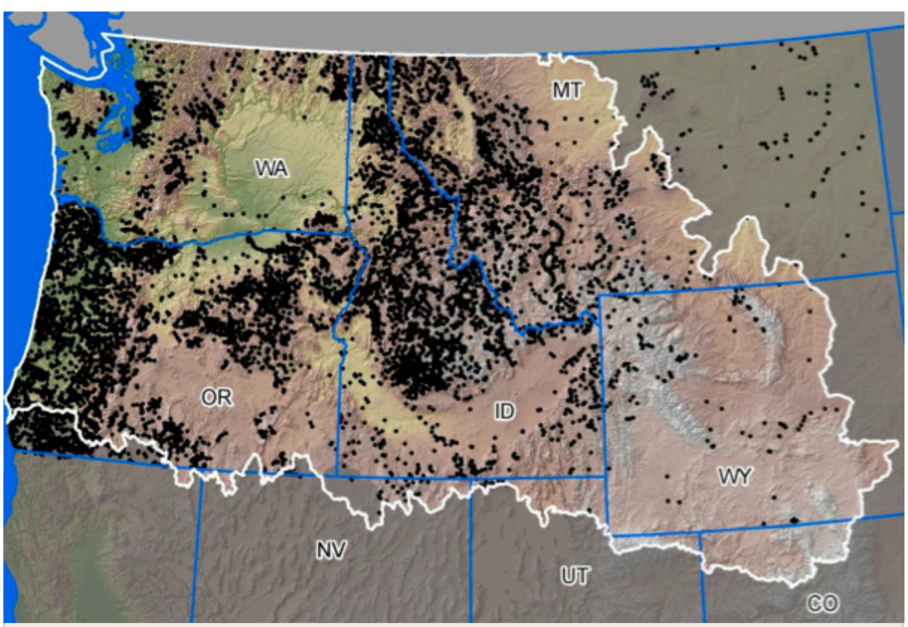
staff at the Boise Aquatic Sciences lab and funding and partnerships with the US Forest Service, the Great Northern and North Pacific Landscape Conservation Cooperatives (LCCs), NOAA, USGS, Trout Unlimited, CSIRO, and many others. When complete, the project will have created high-resolution stream temperature climate scenarios for 500,000 km of streams and 50 National Forests. As the scenarios are completed within each river basin, the information is posted to the project website in several geospatial data formats and local land managers are notified of its availability. Because the scenarios are very accurate, provided in a user-friendly format, and were developed from data contributed by the local management community, the information is rapidly adopted in decision making and prioritization of limited resources for restoration projects. Equally important, the raw temperature database underpinning the NorWeST model scenarios is also distributed through the website so that it's easier for other researchers to study stream temperatures and develop other types of models and information. Besides providing the kind of information that land managers need, the NorWeST project is "kicking open the barn door" on creating opportunities for collaboration and decisions around resource allocation and adaptation to move forward at a scale and pace appropriate to the magnitude of the challenges posed by climate change.



Map showing the observed temperature locations for the NorWeST Stream Temperature Database and Model. The model will ultimately develop high-resolution stream climate scenarios from the 45 million hourly temperature recordings at the 15,000 unique sites shown on the map.

EXAMPLE TWO: FIN-CLIPPING FISH FOR DESCRIBING BIODIVERSITY

Analyzing the spatial pattern of biodiversity is a critical element that can serve as a benchmark for identifying ecological change and informing conservation priorities. This biodiversity is generally represented by conservation or management units of species—that is, genetically recognizable units unique to certain river basins or geographic areas. Fisheries biologist Mike Young is combining crowd-sourced field sampling with genetic analyses to identify and map conservation units of known species and to discover new ones throughout the western U.S. Biologists from every western state are contributing pieces of fin or whole specimens of different species of fishes that not only make broad-scale biodiversity analyses possible, but represent an irreplaceable tissue archive for monitoring species trends.

In addition, once these conservation units are identified, it may be possible to detect their presence without actually seeing or capturing an individual. Young and his colleagues are developing tools to detect environmental DNA (eDNA) in samples of stream water. Environmental DNA is the genetic material that fish (and other organisms) leave behind in their urine, feces, and sloughed skin cells. It can be detected in aquatic environments by careful but relatively inexpensive sampling and analysis yet is species-specific and extraordinarily sensitive. This approach may revolutionize biological sampling, making possible the cost-effective assessment and monitoring of widely distributed species across their entire range.

Collectively, these advanced genetic techniques paired with the newly developed stream temperature and climate models will allow scientists and managers to identify and prioritize what to conserve—at-risk and valued conservation units of species—and where to conserve it in climate refuge areas resistant to thermal changes.

STRONGER SOCIAL NETWORKS FOR CONSERVATION

While crowd-sourcing can produce good information inexpensively, Isaak notes that "its most important contribution may simply be the better communication, collaboration, and relationships that develop among researchers and managers as we go through the process together." The team notes the following four examples of how crowd-sourcing adds value:

1. Helping management: Without crowd-sourcing, the NorWeST Stream Temperature Model would be only a fraction of its current size and scope. The model's vast amount of crowd-sourced data over such a sprawling and complex topography allows managers to see how temperatures are changing at much finer scales. This can inform vulnerability assessments and adaptation actions, allowing managers to direct finite funding toward the wisest and most durable management actions—whether that involves assisted migration, removing barriers to fish passage, or restoring riparian areas and habitat.

Crowd sourcing's "most important contribution may simply be the better communication, collaboration, and relationships that develop among researchers and managers as we go through the process together…" says Isaak.

2. Helping science: Creating open access to large amounts of raw data unleashes the potential for creativity and innovation. The bioclimatic models being created by Isaak and colleagues from the NorWeST model data are just one example of high-value outputs that can result.

3. Creating efficiencies: By standardizing data collection and archiving, these projects provide transparency, reduce redundancies across agencies, and create the potential for more efficient monitoring while reducing "random acts of monitoring." With the NorWeST model, for example, individuals can check to see which streams already have temperature data and can target new data collections on streams that currently have no temperature data.

4. Fostering collaboration: Using temperature data from hundreds of individuals across more than 70 organizations engages them in a collaborative process for monitoring and conservation. Better interagency communication and cooperation are stimulated through the use of shared databases as each agency attempts to grapple with the challenges of climate change. In addition, the spatially continuous information about stream temperature conditions should help facilitate collaboration between managers of aquatic and terrestrial ecosystems, as our understanding of the dynamic relationship between these two ecosystem types continues to grow.

BENEFITING IN-STREAM OUTCOMES

While research continues, the suite of research and tools generated by Isaak, Luce, Young, and others thus far is being used today to benefit fish conservation. "Outputs from our bioclimatic and stream temperature models are mapped to real-world coordinates and provided as GIS data layers that currently encompass more than 300,000 stream kilometers and are being picked up and used as the basis of many climate vulnerability assessments across an ever-growing portion of the Rocky Mountains," notes Isaak. The stream temperature scenarios are used in the Blue Mountains Adaptation Partnership, the Northern Rockies Adaptation Partnership, ongoing forest plan revisions, decision-support tools, studies on the thermal ecology of many aquatic species, and much more. By continuing to work together, scientists and managers are hopeful that we can conserve many of the aquatic biotas and iconic fisheries of the Pacific Northwest and Rocky Mountains in the 21st century.

KEY FINDINGS:

- Climate change is causing rapid changes to stream habitats across the Rocky Mountains and Pacific Northwest as warmer air temperatures and changes in precipitation increase stream temperatures, alter stream hydrology, and increase the extent and magnitude of natural disturbances related to droughts and wildfires.
- Bioclimatic model projections suggest that 20-90% of currently suitable habitat for popular trout species could disappear in the Rocky Mountains by the end of the 21st century. The amount of habitat loss will vary among species, by location within the range of a species, and will be caused by a variety of mechanisms.
- Crowd-sourcing is being used in several important ways to generate information and create opportunities for collaboration, resource allocation decisions, and adaptation to move forward at a scale and pace appropriate to the challenges posed by climate change.
- The NorWeST Stream Temperature model uses crowd-sourcing to gather data that will ultimately be used to create high-resolution stream temperature climate scenarios for 500,000 km of streams and 50 National Forests in the northwest U.S.
- Fin clips for fish biodiversity will tap a crowd-sourced tissue database to describe new species and biodiversity in streams across the western U.S.

MANAGEMENT IMPLICATIONS:

- Outputs from NorWeST-derived bioclimatic and stream temperature models are mapped to real-world coordinates and provided as geospatial data layers for use in GIS to provide managers with consistent and accurate information across significant portions of the Rocky Mountains. These data provide strategic decision support for where to target monitoring activities most efficiently or where to focus habitat restoration efforts.
- Outputs from these models also provide spatially continuous information regarding stream conditions, thereby facilitating collaborative efforts between managers of terrestrial and aquatic ecosystems.
- Wise and proactive management decisions in the next decade could significantly affect the amount of native fish biodiversity that exists in Rocky Mountain streams 100 years from now.

WRITER'S PROFILE

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FURTHER READING

Stream Hydrology:

Luce, C.H., J.T. Abatzoglou, Z.A. Holden. 2013. The missing mountain water: Slower westerlies decrease orographic enhancement in the Pacific Northwest USA. Science 342: 1360-1364.

Luce, C. H., Holden, Z. A., 2009, Declining annual streamflow distributions in the Pacific Northwest United States, 1948-2006, Geophys. Res. Lett., 36, L16401, doi:10.1029/2009GL039407.

Western U.S. Stream Flow Metrics. Available at: http://www.fs.fed.us/rm/boise/AWAE/projects/modeled_stream_flow_metrics.shtml

Stream Temperature:

Isaak, D. J., Luce, C. H., Rieman, B. E., Nagel, D., Peterson, E., Horan, D., Parkes, S., Chandler, G., 2010, Effects of climate change and wildfire on stream temperatures and salmonid thermal habitat in a mountain river network, Ecological Applications, 20, 1350-1371, doi: 10.1890/09-0822.1

Isaak, D.J., and B.E. Rieman. 2013. Stream isotherm shifts from climate change and implications for distributions of ectothermic organisms. Global Change Biology 19:742-751.

Luce, C., Staab, B., Kramer, M., Wenger, S., Isaak, D., McConnell, C., 2014, Sensitivity of Summer Stream Temperatures to Climate Variability in the Pacific Northwest, Water Resources Research DOI:10.1002/2013WR014329.

The NorWest Stream Temperature Database & Model. Available at: http://www.fs.fed.us/rm/boise/AWAE/projects/NorWeST.html

Stream Climate Syntheses:

Isaak, D.J., C.C. Muhlfeld, A.S. Todd, R. Al-Chokhachy, J. Roberts, J.L. Kershner, K.D. Fausch, S.W. Hostetler. 2012. The past as prelude to the future for understanding 21st-Century climate effects on Rocky Mountain trout. Fisheries 37:542-556.

Luce, C., P. Morgan, K. Dwire, D. Isaak, Z. Holden, and B. Rieman. 2012. Climate change, forests, fire, water, and fish: building resilient landscapes, streams, and managers. Joint Fire Sciences Program, U.S. Forest Service, Rocky Mountain Research Station, GTR-RMRS-290, Fort Collins, CO.

Peterson, D.P., S.J. Wenger, B.E. Rieman, and D.J. Isaak. 2013. Linking climate change and fish conservation efforts using spatially explicit decision support models. Fisheries 38: 112-127.

Rieman, B., and D. Isaak. 2010. Climate change, aquatic ecosystems and fishes in the Rocky Mountain West: implications and alternatives for management. USDA Forest Service, Rocky Mountain Research Station, GTR-RMRS-250, Fort Collins, CO. Climate Aquatics Blog. Archived online at: http://www.fs.fed.us/rm/boise/AWAE/projects/stream_temp/stream_temperature_climate_aquatics_blog.html

Climate and Aquatic Biodiversity:

Rieman, B.E., D.J. Isaak, S. Adams, D. Horan, D. Nagel, C. Luce, and D. Myers. 2007. Anticipated climate warming effects on bull trout habitats and populations across the Interior Columbia River Basin. Transactions of the American Fisheries Society 136:1552-1565.

Wenger, S.J., D.J. Isaak, C.H. Luce, H.M. Neville, K.D. Fausch, J.B. Dunham, D.C. Dauwalter, M.K. Young, M.M. Elsner, B.E. Rieman, A.F. Hamlet, and J.E. Williams. 2011. Flow regime, temperature, and biotic interactions drive differential declines of Rocky Mountain trout species under climate change. Proceedings of the National Academy of Sciences 108:14175-14180.

Young, Michael K.; McKelvey, Kevin S.; Pilgrim, Kristine L.; Schwartz, Michael K. 2013. DNA barcoding at riverscape scales: Assessing biodiversity among fishes of the genus Cottus (Teleostei) in northern Rocky Mountain streams. Molecular Ecology. doi: 10.1111/1755-0998.12091

LEMOINE, M., YOUNG, M. K., MCKELVEY, K. S., EBY, L., PILGRIM, K. L., & SCHWARTZ, M. K. (2014). Cottus schitsuumsh, a new species of sculpin (Scorpaeniformes: Cottidae) in the Columbia River basin, Idaho-Montana, USA. Zootaxa, 3755(3), 241-258.

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The following scientists were instrumental in the creation of this Bulletin:

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CHARLES LUCE is a research hydrologist with the Rocky Mountain Research Station in Boise, ID. His current research focuses on the effects of climate change and wildfire on streamflows and forest and aquatic ecology. Charlie has an MS in forest hydrology from the University of Washington, and a Ph.D. in civil engineering from Utah State University.

MICHAEL K. YOUNG is a research fisheries biologist with the Rocky Mountain Research Station in Missoula, MT. His current research focuses on the ecology, sampling, and assessment of native and nonnative aquatic vertebrates in streams in the Rocky Mountains and intermountain basins. Mike received his MS in wildlife biology from the University of Montana and Ph.D. in zoology from the University of Wyoming.

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