Regional Stream Temperature Model – GNLCC Proposal

Project Title: NorWeST: An Interagency Stream Temperature Database and Model for the Northwest United States

Project Category: Landscape connectivity of thermal habitats for salmon, steelhead, cutthroat trout, and bull trout in all rivers and headwater streams across the GNLCC and Northwest U.S.

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Partial List of Supporting Partners*:
U.S. Bureau of Land Management (Idaho, Montana, Oregon, Wyoming Offices)[1,2], Kalispel Tribe[1], U.S. Forest Service (Regions 1, 2, 4, and 6, PIBO, AREMP)[1,2], U.S. Geological Survey (NWIS, FRESC, NOROCK)[1,2], Greater Yellowstone Coalition[1,2], Wyoming Game and Fish Department[1,2], Idaho Fish and Game, Montana Game, Fish, and Parks[1], Clarke Fork Coalition[1], U.S. Fish and Wildlife Service[1,2], Clearwater Resource Council[2], The Wilderness Society[2], Idaho Rivers United[2], Trout Unlimited[1], Idaho Power[1,2], Kootenai Tribe[1], Nez Perce Tribe[1], Idaho Department of Environmental Quality[1], Montana Department of Environmental Quality[1], Washington Department of Environmental Quality[1], Oregon Department of Environmental Quality[1], NOAA Fisheries[1], Henry's Fork Foundation[1,2], U.S. Bureau of Reclamation[1], U.S. Army Corp of Engineers[1], National Park Service (North Cascades Park)[1], Shoshone-Bannock Tribe[1], Oregon Department of Fish and Wildlife[1], Colville Tribe[1], King County[1]
  *Support consists of either: [1]a contribution of temperature data to this project or [2]verbal confirmation by an agency representative that the database and research products from this project will be used. A list of agency representatives is available upon request.

Project Summary: Stream temperature data have been compiled from more than 60 federal, state, tribal, and private sources to develop a comprehensive regional database. Spatial statistical models for river networks are being applied to these data to develop a consistent set of climate scenarios for all streams after the data are organized and formatted within individual river basins. The amount of stream temperature data across the region is much larger than earlier estimates, which has extended project timelines. This 3rd year proposal seeks additional funds ($31,558) to maintain the database team that organizes temperature records for scenario modeling. The status of NorWeST is updated regularly at the project website where geospatial products are posted upon completion (http://www.fs.fed.us/rm/boise/AWAE/projects/NorWeST.html).

Need: Stream temperature is a primary control on the distribution and abundance of aquatic organisms because most are ectothermic (i.e., cold-blooded; Pörtner and Farrell 2008) and many sensitive coldwater species and fisheries in the northwest U.S. are already significantly fragmented warm temperatures (Rieman et al. 2007; Williams et al. 2009; Wenger et al. 2011a). Moreover, evidence exists that environmental trends associated with climate change have been warming streams in the region for several decades and future projections suggest that warming will continue for the foreseeable future (Peterson and Kitchell 2001; Isaak et al. 2010; Mantua et al. 2010; Isaak et al. 2012). Managers of aquatic ecosystems throughout the GNLCC need to consider the effects of climate change in addition to traditional stressors, but broad-scale planning efforts are, at present, only possible by using crude climate surrogates like air temperature or elevation (e.g., Rieman et al. 2007; Williams et al. 2009; Haak et al. 2010; Wenger et al. 2011a; Wenger et al. 2011b). These surrogates are often weakly correlated with stream temperatures and introduce considerable uncertainty to vulnerability assessments (Figure 1).

Discussions originating from several climate-related planning groups and workshops, as well as interactions with regional biologists and hydrologists, have identified a clear need and broad support for a regional stream temperature database and model to provide an accurate and consistent means of downscaling climate effects to all streams. The temperature modeling infrastructure developed in this proposal provides a science-based tool for enhancing coordinated stakeholder management of aquatic resources. Moreover, this tool is built by integrating data from numerous existing agency temperature monitoring efforts across the GNLCC to provide a common modeling framework and set of reference scenarios that would overcome inconsistencies otherwise arising from basin-by-basin approaches. Corollary outcomes will include reduced (and quantified) uncertainty when planning for climate change and easier communication with the public and among agencies about climate change because of the availability of credible scientific information at spatial scales relevant for planning. Spatially continuous maps of stream temperature derived from a regional temperature model would significantly reduce the amount of uncertainty associated with climate change effects on stream ecosystems by quantifying the total amount and locations of thermally suitable habitat for different species under different climate scenarios. This information can be directly used to represent the climate vulnerability of salmon, bull trout, cutthroat trout, and other sensitive species across the GNLCC, is already being used in several climate vulnerability projects (e.g., range-wide bull trout climate assessment, J. Dunham, personal communication), decision support tools (e.g., Peterson et al. 2013), and enables a suite of applications related to traditional assessments of thermal conditions in streams (e.g., cumulative effects, regulatory standards).

Objective: The primary objective of this project is an accurate assessment and description of historical and future stream temperatures and thermal habitat distributions for sensitive aquatic species so that planning efforts can be undertaken more efficiently and with greater confidence across the GNLCC. *Our objective is not to make recommendations regarding specific management activities in different locales, only to provide accurate information that is fundamental to an informed discussion about prioritizing those activities.* Specific tasks include: 1) developing a comprehensive, interagency stream temperature database, 2) developing a regional stream temperature model that incorporates important climate drivers, riparian conditions, and geomorphic factors; 3) using the model to predict historic and future patterns in stream temperatures for all fish-bearing streams; and 4) translating stream temperatures to thermal habitats for assessing potential species distribution shifts across the GNLCC.

Methods and Progress: This project encompasses approximately 250,000 km of fish-bearing streams and rivers across the U.S. portion of the GNLCC and spans significant portions of Idaho, Montana, Oregon, Washington, and Wyoming. A comprehensive stream temperature database compiled from hundreds of biologists working for more than 60 resource agencies has been assembled across this area. More than 45,000,000 hourly temperature records at more than 15,000 unique stream sites are contained in this database. Database technicians are hired and, with assistance from professional support staff at USGS and USFS labs, organizing the data within river basins so that it can be modeled. Spatial statistical stream network models developed by collaborators on this project are being used with the temperature database (Ver Hoef et al. 2006; Ver Hoef and Peterson 2010; more information at the SSN/STARS website: http://www.fs.fed.us/rm/boise/AWAE/projects/SpatialStreamNetworks.shtml). The spatial models accommodate non-randomness among observations on stream networks and are well suited to applications involving databases aggregated from multiple agencies. The spatial models provide unbiased parameter estimates and good predictive accuracy, typically accounting for ~90% of the variability in stream temperatures with average prediction errors < 1.0 ˚C (Figures 1 and 2). Isaak et al. (2010) provides a published example that uses the spatial statistical models with an interagency temperature database and Figure 3 shows the types of map outputs for describing climate scenarios and thermal habitats that are being developed for all streams in the GNLCC. Calibration of the stream temperature model to data within a river basin and derivation of model outputs (see Deliverables) is following procedures developed in earlier projects for sub-domains within the GNLCC (Isaak et al. 2010; Wenger et al. 2011a; Wenger et al. 2011b; Figure 2) and extensive metadata and modeling descriptions are archived at the NorWeST website (http://www.fs.fed.us/rm/boise/AWAE/projects/NorWeST.html). As an additional benefit, the GIS and spatial model infrastructure already completed in the initial phase of the regional stream temperature project have equal utility for developing more accurate fish distribution and abundance models in the future. Use of this infrastructure and the spatial models for these biological attributes would only require assembly of large, georeferenced fish databases, which often exist in similar or greater densities than do stream temperature data (e.g., Wenger et al. 2011a, 2011b).

Deliverables: Numerous deliverables are produced from this project, including: a) a comprehensive regional temperature database, b) spatially continuous maps and descriptive summaries of stream temperatures for historic and future climatic conditions, c) thermal habitat maps and descriptive summaries (e.g., total amount of habitat, temporal trends in habitat, fragmentation of habitat) for aquatic species of concern under historic and future climate conditions, and d) spatially continuous maps showing the precision of temperature model outputs (Figure 3). This information is being presented at scientific conferences and workshops and will be the subject of numerous peer-reviewed science manuscripts. The temperature database, digital maps, and model outputs for individual river basins are posted to the NorWeST website upon completion (http://www.fs.fed.us/rm/boise/AWAE/projects/NorWeST.html). At present, these outputs have been completed for the Salmon and Clearwater river basins in central Idaho and are nearing completion for the remainder of northern Idaho and northwest Montana. Initial feedback from the local management community in the Salmon/Clearwater basins indicates rapid adoption and use of NorWeST products to improve the efficiency of temperature monitoring and facilitate species vulnerability assessments.

Statement of compliance: The project coordinator and principal investigator have read the GNLCC Information Management, Delivery, and Sharing Standards and agree to comply with these standards. A Data Management Plan has been completed and submitted to the GNLCC.

Schedule: Full project completion will require three years but deliverables are posted to the NorWeST website as they are completed for individual river basins. See table for additional timeline details.

Task*	End 2011	Mid 2012	End 2012	End 2013
1. Regional stream temperature data assembled	X	X		
2. Data checked for errors, summarized, and georeferenced to stream hydrography layer	X	X	X	X
3. GIS procedures completed to prepare stream hydrography layer for use with spatial model	X	X		
4. Preliminary models fit to temperature data and procedures established	X	X		
5. Final spatial temperature model fits and temperatures predicted			X	X
6. Digital maps and result summaries described in the deliverables section are produced from the final temperature model			X	X
7. Progress reports (written reports or oral presentations at GNLCC or other regional meetings of relevance)	X	X	X	X
8. Final project report in the form of multiple peer-reviewed science manuscripts and reports delivered				X
9. Digital maps (GIS layers), stream temperature data, and metadata served over websites for access by agency partners as described in the GNLCC Information Management and Sharing Standards			X	X

*Project initiation occurred in mid-2011 after budgetary spending authority was obtained and a database technician was hired. The temperature database is larger than initial estimates and consist of more than 45,000,000 hourly recordings at more than 15,000 unique stream sites. Status maps showing stream locations where data have been received can be viewed at the GNLCC temperature project website (http://greatnorthernlcc.org/technical/stream-temp).

Key references for related projects previously undertaken by PIs (others available upon request)

Isaak, D.J., C. Luce, B.E. Rieman, D. Nagel, E. Peterson, D. Horan, S. Parkes, and G. Chandler. 2010. Effects of climate change and recent wildfires on stream temperature and thermal habitats for two salmonids in a mountain river network. *Ecological Applications* **20**:1350-1371.

Isaak, D.J., S. Wollrab, D.L. Horan, and G. Chandler. 2012. Climate change effects on stream and river temperatures across the Northwest U.S. from 1980 – 2009 and implications for salmonid fishes. *Climatic Change* **113**:499-524.

Peterson, D., S. Wenger, B. Rieman, and D. Isaak. 2013. Linking climate change and fish conservation efforts using spatially explicit decision support models. *Fisheries* **38**(3):xxx.

Rieman, B. E., D. Isaak, S. Adams, D. Horan, D., Nagel, and C. Luce. 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.

Ver Hoef, J.M., and E.E. Peterson. 2010. A moving average approach for spatial statistical models of stream networks. *J. American Statistical Association* **105**:6-18.

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

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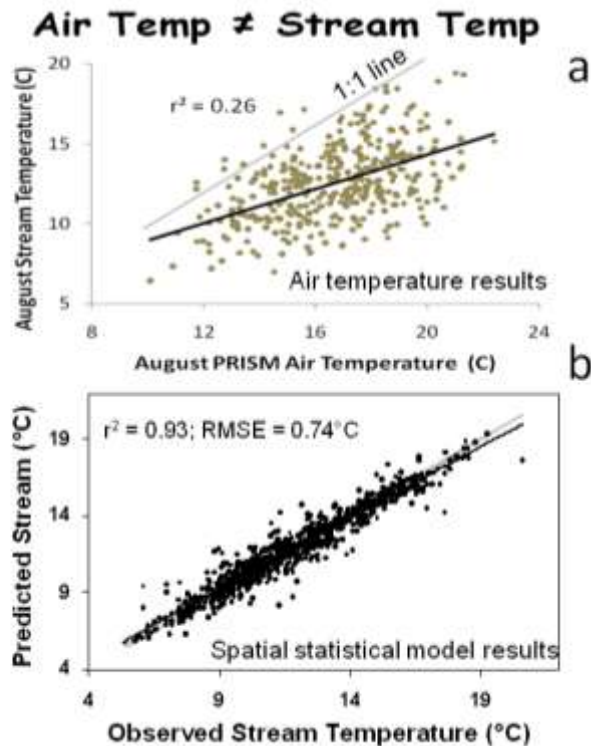
Figure 1. Scatterplot showing the relationship between air temperature and stream temperature in the northwest U.S. (panel a). Air temperatures are often used as a surrogate for stream temperatures in bioclimatic assessments for coldwater fish but this creates significant uncertainties. Lower panel (b) shows the results of a spatial statistical model applied to a stream temperature database (n = 780) in the Boise River (from Isaak et al. 2010).
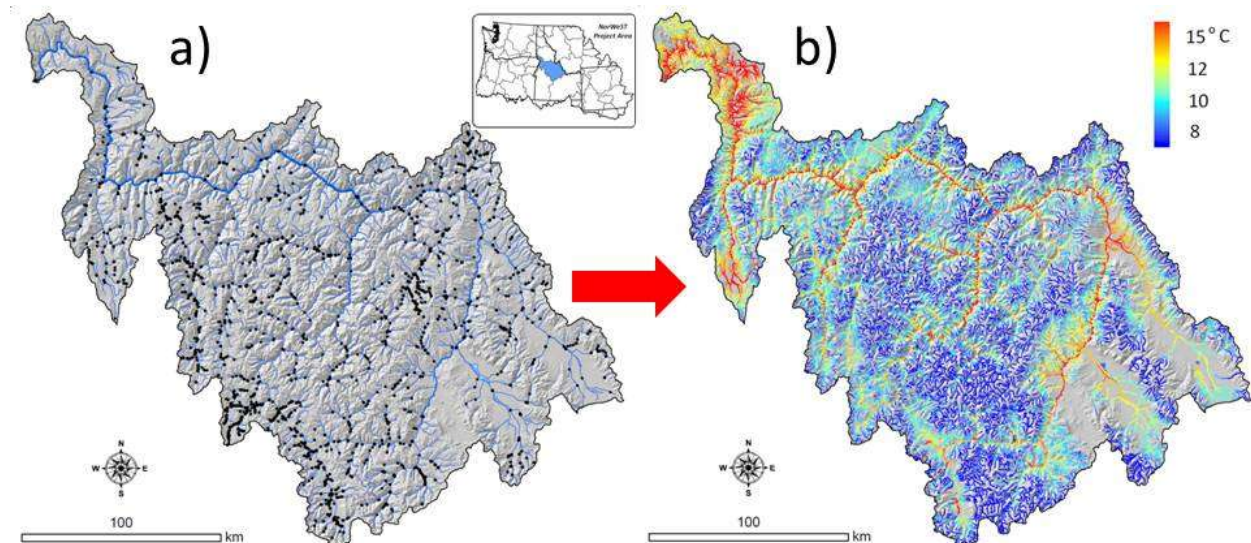

Figure 2. Example of final NorWeST stream temperature database (panel a; n = 4,401) and historic climate scenario map for the 21,000 kilometer Salmon River network in central Idaho (panel b). These stream temperature products are available as geospatial data for download through the NorWeST website and similar products will exist for all streams in the GNLCC at the end of this project.
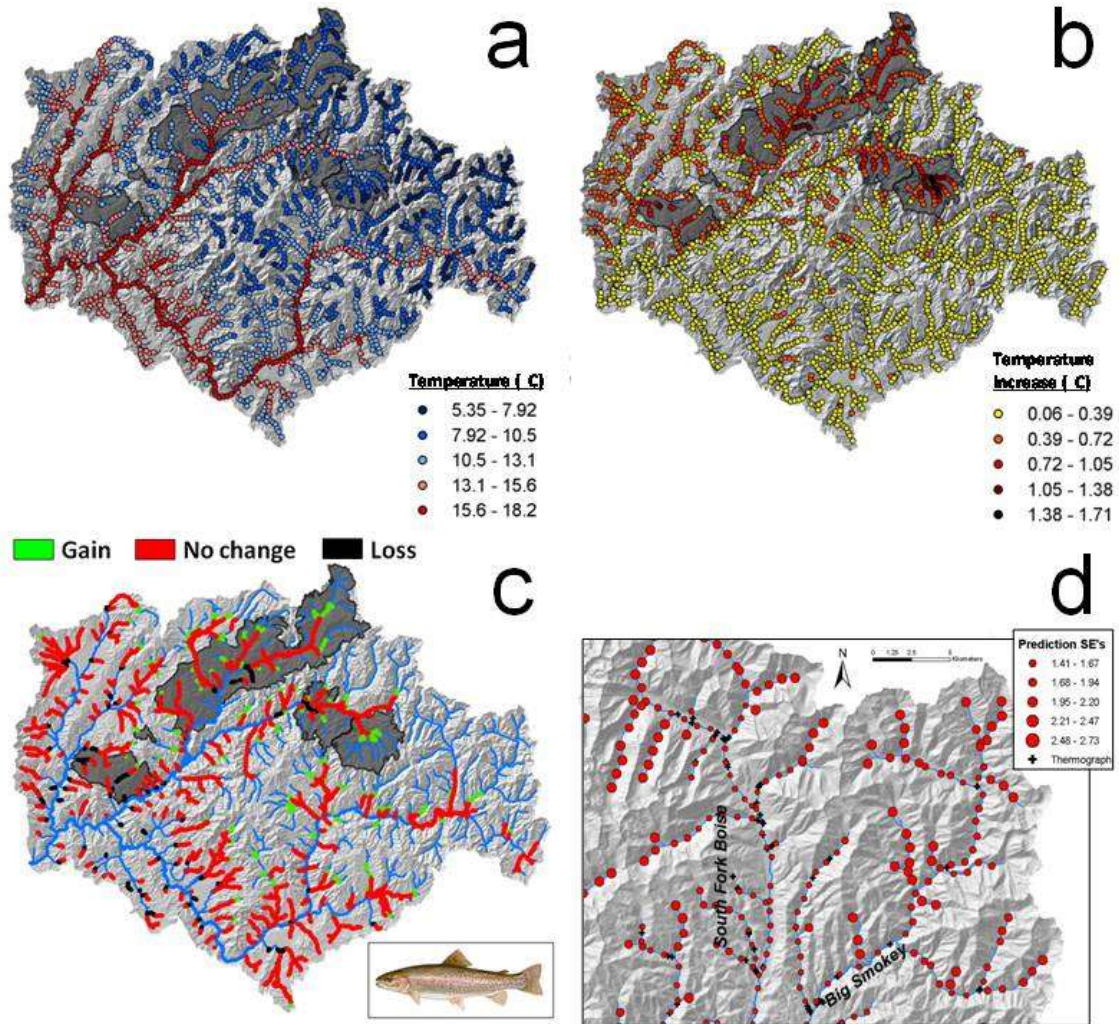
Figure 3. Example outputs from the NorWeST stream temperature model produced as part of an aquatic vulnerability assessment for all streams across the GNLCC: a) spatially continuous maps of stream temperature, b) maps of temperature changes associated with climatic change trends, c) thermal habitat maps for fish species like rainbow trout, and d) spatially-explicit representations of model precision (from Isaak et al. 2010).