Stream Temperature Database and NorWeST Scenarios – NPLCC Proposal

Project Title: Developing a comprehensive interagency stream temperature database and high-resolution NorWeST climate scenarios for the North Pacific LCC

Funding Announcement #1

Project Coordinator: Daniel J. Isaak (disaak@fs.fed.us), 208.373.4385; U.S. Forest Service, Air, Water, and Aquatics Program, Rocky Mountain Research Station, Boise, ID.

DUNS#: 929332484; SAMS registration: current

Project PI(s): Daniel J. Isaak, Seth J. Wenger (swenger@tu.org)[1], Erin E. Peterson (Erin.Peterson@csiro.au)[2], Jay Ver Hoef (Jay.Verhoef@noaa.gov)[3], Jason B. Dunham (jdunham@usgs.gov)[4], Steve Hostetler (swhostet@usgs.gov)[5], Charles H. Luce (cluce@fs.fed.us), Jeff Kershner (jkershner@usgs.gov)[6], Brett B. Roper (broper@fs.fed.us)[7], and Dave Nagel

U.S. Forest Service, Air, Water, and Aquatics Program, Rocky Mountain Research Station, Boise, ID.
[1]Trout Unlimited, Boise, ID.
[2]CSIRO Division of Mathematics, Informatics, and Statistics, Dutton Park, Queensland, Australia.
[3]NOAA National Marine Mammal Laboratory, University of Alaska Fairbanks, Fairbanks, AK.
[4]U.S. Geological Survey Forest and Rangeland Ecosystem Science Center, Corvallis, OR.
[5]U.S. Geological Survey, NRP, Water Resources Center, Corvallis, OR.
[6]U.S. Geological Survey, Northern Rocky Mountain Science Center, Bozeman, MT.
[7]U.S. Forest Service, Fish and Aquatic Ecology Unit, Logan, UT.

Partial List of Supporting Partners*:
Quinault Indian Nation[1,2], Confederated Tribes Warm Springs[1,2], Quileute Tribe[1], Washington Department of Ecology[1,2], Oregon Department of Environmental Quality[1], Oregon Department of Fish and Wildlife[1], Hood River Watershed Group[1,2], PacifiCorp[1,2], Pierce County, WA[1,2], Skagit County,WA[1,2], Snohomish County, WA[1,2], King County, WA[1,2], Columbia Riverkeepers[1,2], U.S. Bureau of Land Management (Roseburg and Medford offices)[1,2], U.S. Forest Service (Regions 5 and 6, AREMP monitoring program)[1,2], U.S. Geological Survey (NWIS, FRESC)[1,2], U.S. Fish and Wildlife Service[1,2], The Wilderness Society[2], Trout Unlimited[2], NOAA Fisheries[1], U.S. Bureau of Reclamation[1], National Park Service[1], EPA (Region 10)[1,2]

*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 and several formal letters of support are also included with this proposal.

Project Summary: Stream temperature data will be compiled from all tribal, federal, state, and private sources to develop a comprehensive database for those portions of the NPLCC within Oregon, Washington, and California. Spatial statistical models for river networks will be used with these data to develop a consistent set of high-resolution climate scenarios for all streams and reaches within streams. This proposal would extend the geographic domain of the NorWeST regional temperature project currently funded by the Great Northern LCC to the NPLCC. The temperature database and climate scenarios will be distributed as ArcMap geospatial products through the NorWeST project website (http://www.fs.fed.us/rm/boise/AWAE/projects/NorWeST.html) to facilitate planning and vulnerability assessments for all aquatic species.

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 by 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 NPLCC 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 NPLCC 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: 1) reduced and quantified uncertainty when planning for climate change and 2) easier communication with the public and among agencies about climate change because of the availability of credible scientific information at spatial scales and resolutions relevant for planning. Spatially continuous maps of stream temperature derived from a regional temperature model 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 used to accurately describe current and future distributions of thermally suitable habitats for non-salmonid anadromous fishes like eulachon or lamprey, as well as salmon, bull trout, cutthroat trout, and other species of concern across the NPLCC. In parts of Idaho and Montana where similar stream temperature climate scenarios have been developed from the NorWeST project funded by the Great Northern LCC, the scenarios are being used to facilitate a regional climate vulnerability assessment for bull trout (J. Dunham, USGS), to develop decision support tools (e.g., Peterson et al. 2013), and enable a suite of applications related to traditional assessments of thermal conditions and monitoring efforts in streams (e.g., cumulative effects, TMDL regulatory standards). The accuracy of the NorWeST stream temperature climate scenarios (r^2 ~ 90%; average prediction errors < 1.0 ˚C), their ease of use within a GIS environment, and development from data collected by those working within the local landscape translates to rapid adoption and use in decision making.

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 like eulachon or lamprey so that planning efforts can be undertaken more efficiently and with greater confidence across the NPLCC. *The 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 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 habitat maps for assessing species distributions and climate relationships across the NPLCC.

Methods: This project would encompass approximately 100,000 km of fish-bearing streams and rivers across portions of Washington, Oregon, and northern California within the NPLCC. Significant amounts of stream temperature data have already been compiled from agency sources within this area and these data would be further supplemented with data from Tribal and other partners. These data would be combined with the 45,000,000 hourly temperature records at more than 15,000 unique stream sites already contributed to the NorWeST database by 60+ resource agencies. Database technicians would be hired and, with assistance from professional support staff at the Boise Aquatic Sciences Lab, organize temperature data into a relational Oracle database so that it can be efficiently queried and summarized for modeling. Spatial statistical stream network models developed by project collaborators would be used to model patterns in stream temperature data and develop accurate, high-resolution climate scenario maps (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 and are well suited to applications involving databases aggregated from multiple agencies. Previous applications to stream temperature databases suggest 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 currently being developed for streams across the GNLCC immediately to the east of the NPLCC. Calibration of the stream temperature model to data within river basins and derivation of model outputs (see Deliverables) follows procedures developed earlier and extensively documented at the NorWeST website (http://www.fs.fed.us/rm/boise/AWAE/projects/NorWeST.html).

Geographic Extent: The project area would consist of approximately 100,000 stream kilometers within the Washington, Oregon, and California portions of the NPLCC. Stream temperature patterns will be interpolated between temperature sensor measurements to provide high resolution, continuous maps of thermal conditions for all streams. These climate scenarios will be similar to those currently under development for GNLCC stream further east and will facilitate accurate and consistent comparisons.

Products and Outcomes: Numerous deliverables will be 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 like eulachon and lamprey under historic and future climate conditions, and d) spatially continuous maps showing the precision of temperature model outputs (Figure 3). This information will be presented at scientific conferences and workshops and will be the subject of multiple 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). Responses from local management

communities in Idaho and Montana where NorWeST outputs have been developed are overwhelmingly positive and the temperature products and climate scenarios are rapidly adopted in planning efforts for many species.

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

Task*	End 2013	Mid 2014	End 2014
1. Stream temperature data assembled	X		
2. Data checked for errors, summarized, and georeferenced to stream hydrography layer	X	X	
3. Models fit to temperature data and scenarios generated		X	X
4. Periodic status assessments via oral presentations at NPLCC or other regional meetings of relevance		X	X
5. Project reports in the form of multiple peer-reviewed science manuscripts and reports		X	X
6. Final digital maps (GIS layers), stream temperature data, and metadata distributed through NorWeST website		X	X

Data sharing disclaimer: The final stream temperature database that is distributed through the NorWeST website is filtered to withhold data that project contributors do not want distributed. Past experience in Idaho and Montana suggests that the large majority of contributors will give permission to distribute their data (~95% of data contributed to NorWeST are ultimately shared). Stream temperature model scenarios and associated geospatial information derived from the data will all be distributed through the website with no restrictions.

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**:112-127.

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.

Ver Hoef, J.M., E.E. Peterson, and D. Theobald. 2006. Spatial statistical models that use flow and stream distance. *Environmental and Ecological Statistics* **13**:449-464.

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.

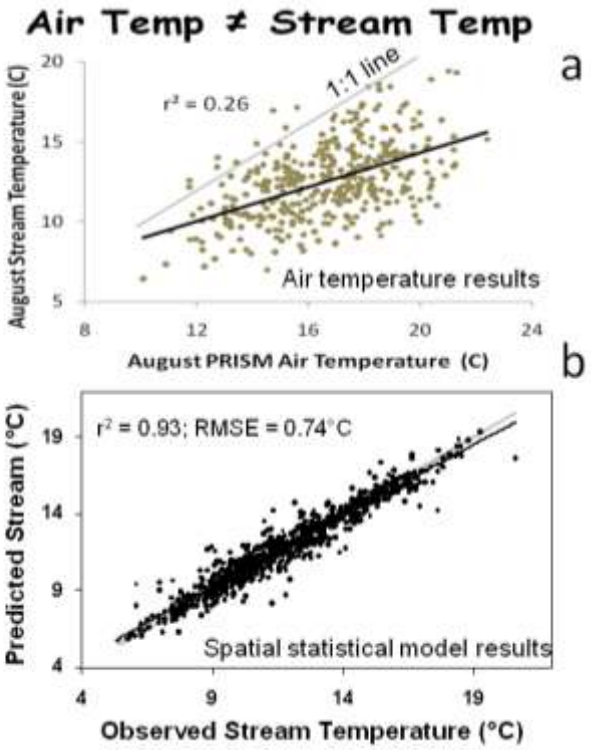

Figure 1. Scatterplot showing the relationship between air temperature and stream temperature in the northwest U.S. (panel a). Air temperatures are often used as a surrogate for stream temperatures in bioclimatic assessments for coldwater fish but this creates significant uncertainties. Lower panel (b) 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).

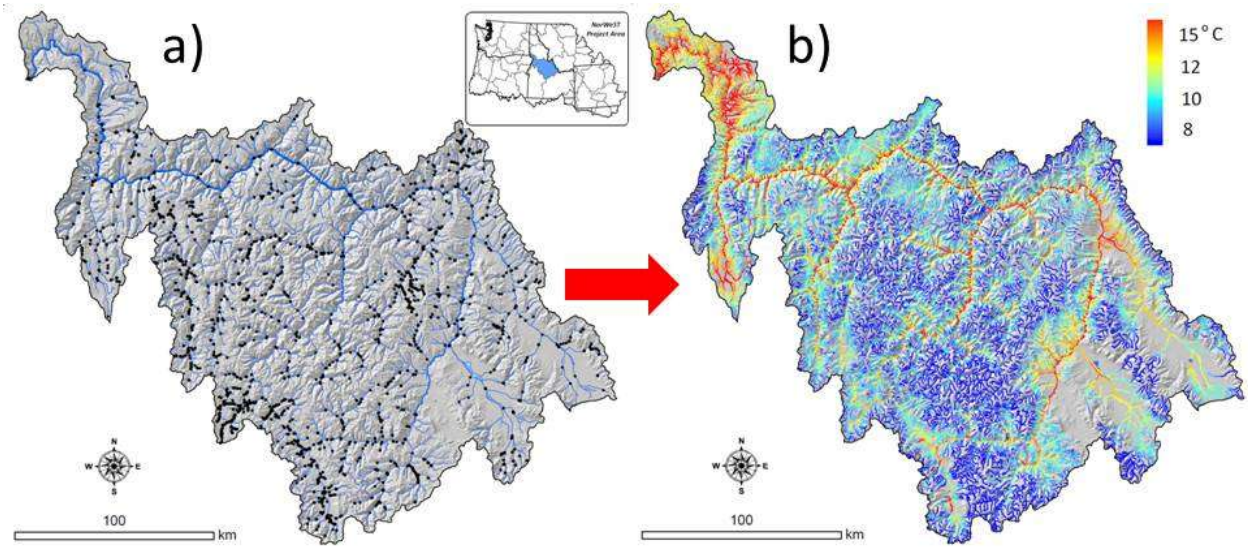

Figure 2. Example of final NorWeST stream temperature database (panel a; n = 4,401) and historic climate scenario map for the 21,000 kilometer Salmon River network in central Idaho (panel b). These stream temperature products are available as geospatial data for download through the NorWeST website and similar products will exist for all streams at the end of this project.

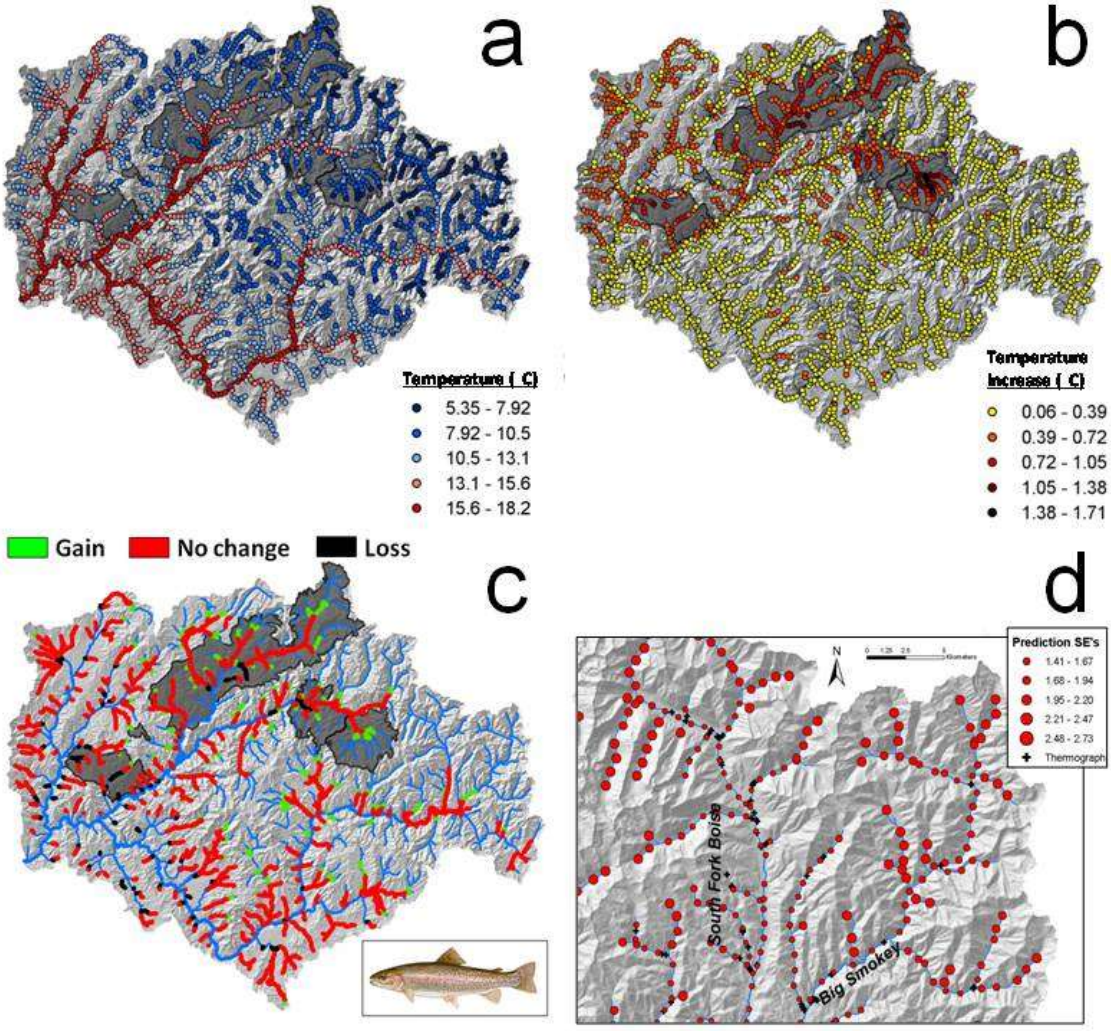

Figure 3. Example outputs from the NorWeST stream temperature project that will be available for all streams within the project area: a) spatially continuous maps of stream temperature, b) maps of temperature changes associated with climate trends, c) thermal habitat maps for fish species like rainbow trout, and d) spatially-explicit representations of model prediction precision (from Isaak et al. 2010).

Budget to develop stream temperature database and NorWeST climate scenarios for the North Pacific LCC.

Budget Category		**2013**	**2014**	**Comments**
Salary	Database technician I	$15,700	$15,700	Hired for 12 months (6 months each year) at GS-5
	Fringe (30%)	$4,710	$4,710	
		$14,000		Hired for 6 months at GS-4
		$4,200		
Travel	Dan Isaak		$4,000	Presentations at regional meetings to provide updates and technology transfer for NorWeST scenarios within NPLCC
Equipment	Workstation computer	$3200		
	GIS/database software	$400		
	Backup hard-drives	$400		
	Total:	$42,610	$24,410	
	USFS overhead rate (7%)	$2,983	$1,709	
	Yearly total:	$45,593	$26,119	
	Project total request:		**$71,712**	
Match/In-kind				
	Office space	$9,000	$4,500	Technician space at USFS Aquatic Sciences Lab
	GIS/database support	$22,500	$22,500	Fifteen payperiods among 5 research lab personnel
	Project administration	$7,500	$7,500	Three payperiods for Dan Isaak
	Scientific writing	$20,000	$20,000	One payperiod from each PI
	Temperature data	$1,500,000		Assumes 15,000 summer temperature observations are compiled
	Yearly in-kind	$1,559,000	$54,500	&each observation costs $100 (conservative estimate)
	Total in-kind		$1,613,500	

Letters of Support

Oregon

John A. Kitzhaber, MD, Governor

Department of Environmental Quality
Water Quality Division
811 SW Sixth Avenue
Portland, OR 97204-1390
(503) 229-5696
FAX (503) 229-6977
TTY 711

North Pacific LCC
c/o Dan Isaak - Fisheries Research Scientist
Rocky Mountain Research Station; U.S. Forest Service
322 E. Front St., Suite 401; Boise, ID 83702

May 6, 2013

Dear NPLCC,

I am writing on behalf of the Oregon Department of Environmental Quality (DEQ) to support the proposal to the North Pacific Landscape Conservation Cooperative (NPLCC) entitled, "Developing a comprehensive interagency stream temperature database and high-resolution NorWeST climate scenarios for the North Pacific LCC." The project would yield significant benefits to DEQ by providing a standardized and consistent temperature database across all state, federal, tribal, and private organizations. It would significantly reduce the redundancies in monitoring efforts within, and among, agencies and enable efficient coordination of future temperature monitoring.

The stream temperature model and climate scenarios developed from these data are also valuable assets because they provide valid interpolations of information between monitoring locations to show the status of stream temperatures at high-resolution across full river networks. Having these scenario maps would be valuable for better understanding the current distribution of thermal conditions across the state of Oregon or as a planning tool when addressing climate change. We believe this effort will compliment our current efforts to address temperature issues in the state of Oregon.

Previous work by this research team demonstrates their capacity to execute the components of this project as they have already compiled stream temperature data from thousands of sites and dozens of agencies across the interior Northwest and developed climate scenarios for streams across the states of Idaho and Montana. The DEQ strongly supports continuation and extension of this work to the NPLCC so that western Oregon streams will have consistent temperature information with those in other parts of the state and region.

Sincerely,

Gene Foster, Ph.D.
Manager, Watershed Management Section
Oregon Department of Environmental Quality
811 SW 6th Avenue
Portland, OR 97204

United States Department of Agriculture **Forest Service** **Pacific Northwest Region**

333 SW First Avenue (97204)
PO Box 3623
Portland, OR 97208-3623
503-808-2468

File Code: 2020
Date: May 7, 2013

North Pacific Landscape Conservation Cooperative
c/o Dan Isaak - Fisheries Research Scientist
U.S. Forest Service, Rocky Mountain Research Station
322 E. Front Street, Suite 401
Boise, ID 83702

Dear Sir or Madam:

I am writing to express my strong support for the proposal to the North Pacific Landscape Conservation Cooperative (NPLCC) entitled, *"Developing a comprehensive interagency stream temperature database and high-resolution NorWeST climate scenarios for the North Pacific LCC."* This project would yield significant benefits to our agency by providing a standardized and consistent temperature database across all state, federal, tribal, and private organizations. It would significantly reduce the redundancies in monitoring efforts within, and among, agencies and enable efficient coordination of future temperature monitoring. The stream temperature model and climate scenarios developed from these data are also valuable assets because they provide valid interpolations of information between monitoring locations to show the status of stream temperatures at high-resolution across full river networks. Having these scenario maps would be valuable for better understanding the current distribution of thermal conditions across the states of Oregon and Washington and as a planning tool when addressing climate change.

Previous work by this research team demonstrates their capacity to execute the components of this project, as they have already compiled stream temperature data from thousands of sites and dozens of agencies across the interior Northwest and developed climate scenarios for streams across the states of Idaho and Montana. The Forest Service strongly supports continuation and extension of this work to the NPLCC, so that western Oregon and Washington streams will have consistent temperature information with those in other parts of the state and region. Our support is evidenced by the fact that, in the past several years, we have made substantial investments in improving the quantity, quality, and accessibility of our significant stream temperature dataset (10,000s of surveys from several 1,000 sites) to support this and related efforts.

If you have any questions or comments, please contact Brian Staab, Regional Hydrologist at (503) 808-2694 or Becky Gravenmeier, Regional Climate Change Coordinator at (503) 808-2851.

Sincerely,

/s/ Jeff Walter (for):
KENT P. CONNAUGHTON
Regional Forester

cc: Brian Staab, Becky Gravenmier, Tracy B Beck

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
NATIONAL HEALTH AND ENVIRONMENTAL EFFECTS
RESEARCH LABORATORY
WESTERN ECOLOGY DIVISION
200 S.W. 35TH STREET, CORVALLIS, OR. 97333

OFFICE OF
RESEARCH AND DEVELOPMENT

May 2, 2013

Mary Mahaffy and John Mankowski
North Pacific Landscape Conservation Cooperative
510 Desmond Dr. SE, Suite 102
Lacey, WA 98503

Re: NorWeSt Stream Temperature Scenarios – NPLCC Proposal – U.S. Forest Service

Dear Mary and John:

This proposal extends the NorWeST geographic domain to those portions of the NPLCC within Oregon, Washington and California. The EPA has collaborated with the U.S. Forest Service (Dan Isaak et al.) for the last two years on the EPA Region 10 Climate Change and TMDL Pilot. The EPA Pilot is focused on a temperature impaired subwatershed (South Fork) of the Nooksack River in Northwest Washington. We had originally intended to use the NorWeST Stream Temperature Model for this pilot. However, the development schedule for NorWeST did not permit its use for the EPA Pilot and we developed an alternative regression method.

The NorWeST Stream Temperature Model represents a robust, comprehensive and long-term regional solution (Pacific Northwest) to estimate steam temperature for Climate Change Vulnerability Assessments and Adaptation Planning. The use of historical stream temperature data and spatial statistical models for river networks has demonstrated a reliable and accurate (r^2 = 0.90) method. Also, the ongoing capacity to update this model in the future with actual stream temperature monitoring data will prove invaluable for adaptive management under climate change.

We understand that the U.S. Forest Service (Dan Isaak et al.) is submitting a proposal to the North Pacific Landscape Conservation Cooperative in response to USFWS/NPLCC Funding Announcement #1. We support the proposed project and think it provides a common framework (tool) to help mainstream Climate Change Vulnerability Assessments and Adaptation Planning in the Pacific Northwest.

Should you have any questions, please do not hesitate to contact me.

Sincerely,

Thomas Fontaine, PhD
Division Director
Western Ecology Division

Cc: Paul Mayer, Steve Klein

STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
PO Box 47600 • Olympia, WA 98504-7600 • 360-407-6000
TTY 711 or 800-833-6388 (for the speech or hearing impaired)

May 8, 2013

North Pacific Landscape Conservation Cooperative
c/o Dan Isaak, Fisheries Research Scientist
Rocky Mountain Research Station; U.S. Forest Service
322 E. Front Street, Suite 401
Boise, Idaho 83702

Dear Dan:

I am writing on behalf of the Washington State Department of Ecology (Ecology) to support the proposal to the North Pacific Landscape Conservation Cooperative entitled, "Developing a comprehensive interagency stream temperature database and high-resolution NorWeST climate scenarios for the North Pacific LCC."

Ecology faces critical challenges with its agency mission to monitor and regulate water quality. Stream temperature is a critical parameter for our aquatic environment. The results of this project could aid Ecology by:

- Providing a standardized and consistent temperature database across all state, federal, tribal, and private organizations to support environmental monitoring and water quality improvement studies.
- Reducing the redundancies in monitoring efforts within, and among, agencies and enable efficient coordination of future temperature monitoring.
- Providing insight into future conditions when planning restoration actions.
- Identifying vulnerable water bodies and helping to prioritize Ecology's resources.

The stream temperature model and climate scenarios developed from these data are also valuable assets because they provide valid interpolations of information between monitoring locations to show the status of stream temperatures at high-resolution across full river networks. Having these scenario maps would be valuable for better understanding the current distribution of thermal conditions across the state of Washington or as a planning tool when addressing climate change.

Previous work by this research team demonstrates their capacity to execute the components of this project. They have already compiled stream temperature data from thousands of sites and dozens of agencies across the interior Northwest, including data collected by Ecology, and developed climate scenarios for streams across the states of Idaho and Montana.

Ecology strongly supports continuation and extension of this work to the NPLCC so that western Washington streams will have consistent temperature information with those in other parts of the state and region.

Sincerely,

Robert M. Duff, Manager
Environmental Assessment Program
Washington State Department of Ecology

USDA United States Department of Agriculture | Forest Service | Pacific Southwest Region

Regional Office, R5
1323 Club Drive
Vallejo, CA 94592
(707) 562-8737 Voice
(707) 562-9240 Text (TDD)

Date: May 2, 2013

North Pacific LCC
c/o Dan Isaak - Fisheries Research Scientist
Rocky Mountain Research Station; U.S. Forest Service
322 E. Front St., Suite 401; Boise, ID 83702

I am writing on behalf of the Forest Service, Pacific Southwest Region to express our support for the proposal to the North Pacific Landscape Conservation Cooperative entitled, "Developing a comprehensive interagency stream temperature database and high-resolution NorWeST climate scenarios for the North Pacific LCC." The project would yield significant benefits to our aquatic ecosystem conservation program by providing a standardized and consistent temperature database across all state, federal, tribal, and private organizations. It would significantly reduce the redundancies in monitoring efforts within, and among, agencies and enable efficient coordination of future temperature monitoring. The stream temperature model and climate scenarios developed from these data are also valuable assets because they provide valid interpolations of information between monitoring locations to show the status of stream temperatures at a high-resolution scale across full river networks. Development of these high-resolution maps would be valuable for better understanding the current distribution of thermal conditions across national forest lands in the NPLCC of California or as a planning tool when evaluating climate change impacts. Development of climate projections will be invaluable for identifying suitable habitat for our native fish and aquatic invertebrate species and anticipating how a changing climate may influence their distribution and viability.

Previous work by this research team demonstrates their capacity to execute the components of this project as they have already compiled stream temperature data from thousands of sites and dozens of agencies across the interior Northwest and developed climate scenarios for streams across the states of Idaho and Montana. Our staff has also compiled thermographs from hundreds of sites within the project area and we are eager to provide them to support an inner agency database. On behalf of the Pacific Southwest Region of the U.S. Forest Service, we strongly strongly support continuation and extension of this work to the NPLCC so that streams in California will have consistent temperature information with those in other parts of the state and region.

Sincerely,

Joseph Furnish, Ph.D.
Regional Aquatic Ecologist

Michael Kellett
Regional Fisheries Biologist

Principle Investigators

Curriculum Vitae

Daniel J. Isaak (disaak@fs.fed.us; 208.373.4385)

Dan Isaak is a Fisheries Research Scientist with the U.S. Forest Service, Rocky Mountain Research Station Boise Aquatic Sciences Laboratory in Boise, Idaho. He holds a B.S. from South Dakota State University, a M.S. from the University of Idaho, and a Ph.D. from the University of Wyoming. He has worked in native fish conservation and fisheries management and research in the western United States for the past 20 years. His primary research interests include understanding the effects of climate change on stream habitats and fish communities, stream temperature monitoring and modeling, spatiotemporal variation in the distribution and abundance of stream fishes relative to environmental gradients and disturbance, development and application of spatial statistical models for stream networks, and use of digital and social media to connect people, information, and landscapes. Additional details are at the scientist's website (http://www.fs.fed.us/rm/boise/AWAE/scientists/profiles/AWAIsaak.shtml).

Education:

Ph.D., Zoology and Physiology, University of Wyoming, 2001.
M.S., Fisheries Resources, University of Idaho, 1994.
B.S., Wildlife and Fisheries Sciences, South Dakota State University, 1991.

Selected Publications:

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.

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.

Isaak, D.J., S. Wollrab, D. 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.

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 wildfire on stream temperatures and salmonid thermal habitat in a mountain river network. *Ecological Applications* 20:1350-1371.

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* 38:111-125

Rieman, B.E., D.J. Isaak, S. Adams, D. Horan, D. Nagel, C. Luce, and D. Myers. 2007. Spatial variation in anticipated climate change effects on bull trout habitats 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 trout species under climate change. *Proceedings of the National Academy of Sciences* doi:10.1073/1103097108.

Wenger, S.J. D.J. Isaak, J.B. Dunham, K.D. Fausch, C.H. Luce, H.M. Neville, B.E. Rieman, M.K. Young, D.E. Nagel, D.L. Horan, G.L. Chandler. 2011. Role of climate and invasive species in structuring trout distributions in the Interior Columbia Basin. *Canadian Journal of Fisheries and Aquatic Sciences*. 68:988-1008.

Selected Websites:

Stream Temperature Modeling and Monitoring Website (http://www.fs.fed.us/rm/boise/AWAE/projects/stream_temperature.shtml).

SSN/STARS: Tools for Spatial Statistical Modeling on Stream Networks website (http://www.fs.fed.us/rm/boise/AWAE/projects/SpatialStreamNetworks.shtml).

NorWeST website (http://www.fs.fed.us/rm/boise/AWAE/projects/NorWeST.html)

Erin E. Peterson, Ph.D.

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Background

Erin Peterson is a research scientist with the CSIRO Division of Mathematics, Informatics, and Statistics in Brisbane, Australia. Her background and experience allow her to work at the interface of geographic information science, aquatic ecology, landscape ecology, and environmental statistics. This research area provides a rich set of modelling and analysis challenges to work on, related to capturing and quantifying spatio-temporal heterogeneity at multiple scales within a statistical modelling framework. Dr Peterson is also committed to software tool development, which helps to ensure that the methodologies she develops are made accessible to ecologists and natural resource managers. This allows users to implement, modify, and improve on her methods to derive additional information about pattern and process in aquatic and terrestrial landscapes.

Education

- **Ph.D. Earth Resources**, Geosciences Department, Colorado State University, 2005
- **M.S. Forest Sciences**, GIS/Remote Sensing Program, Colorado State University, 2001
- **B.S. Forest Conservation**, Michigan State University, 1995

Relevant Publications

- **Peterson E.E.**, Ver Hoef J.M., Isaak D.J., Falke J.A., Fortin M-J, Jordan C.E., McNyset K., Monestiez P., Ruesch A.S., Sengupta A., Som N., Steel A., Theobald D.M., Torgersen C.E. & Wenger S.J. (2013) Modeling dendritic ecological networks in space: An integrated network perspective. *Ecology Letters*, 16(5): 707-719.
- Ruesch A., Torgersen C., Lawler J., Olden J., **Peterson E.E.**, Volk C., and Lawrence D. (2012) Projected climate-induced habitat loss for salmonids based on a network model of stream temperature. *Conservation Biology*, 26(5): 873-882.
- Isaak D.J., Luce C.H., Rieman B.E., Nagel D.E., **Peterson E.E.,** Horan D.L., Parkes S., and Chandler G.L. (2010) Effects of recent climate and fire on thermal habitats within a mountain stream network: An example with a native Char species, *Ecological Applications*, 20(5):1350-1371.
- **Peterson E.E.** and Ver Hoef J.M. (2010) Capturing multiple patterns in stream ecosystems: A moving-average approach to geostatistical modelling. *Ecology*, 91(3): 644-651.
- Ver Hoef J.M. and **Peterson E.E.** (2010) A moving average approach to spatial statistical models of stream networks, Discussion Paper with Rejoinder, *Journal of the American Statistical Association*, 489: 6-18.
- **Peterson E.E.,** Theobald D.M., and Ver Hoef J.M. (2007) Support for geostatistical modelling on stream networks: Developing valid covariance matrices based on hydrologic distance and stream flow. *Freshwater Biology*. 52, 267-279.
- **Peterson E.E.**, Merton A.A., Theobald D.M., and Urquhart N.S. (2006) Patterns of spatial autocorrelation in stream water chemistry. *Environmental Monitoring and Assessment*. 121, 569-594.
- **Peterson E.E.** and Urquhart N.S. (2006) Predicting water quality impaired stream segments using landscape-scale data and a regional geostatistical model: A case study in Maryland, *Environmental Monitoring and Assessment*. 121, 613-636.
- Ver Hoef J.M., **Peterson, E.E.**, and Theobald, D.M. (2006) Spatial Statistical Models that Use Flow and Stream Distance, *Environmental and Ecological Statistics,* 13, 449-464.

Curriculum Vitae
Jay M. Ver Hoef
(jay.verhoef@noaa.gov)

Jay Ver Hoef is a statistician for a U.S. Government research lab in marine mammals and fisheries (http://sites.google.com/site/jayverhoef/Home/cv). He develops statistical methods and consults on a wide variety of topics related to ecological data in general, and marine mammals in particular. His research interests are in spatial statistics and Bayesian statistics, especially as applied to ecological data. He is a fellow of the American Statistical Association, and an adjunct professor of Statistics with the Mathematics and Statistics Department of the University of Alaska, Fairbanks.

Education:
Ph.D., co-major in Statistics and EEB (Ecology and Evolutionary Biology), Iowa State University, 1985 – 1991.
M.S., Botany, University of Alaska, Fairbanks, 1983 – 1985.
B.S., Botany, Colorado State University, 1976 – 1979.

Employment
2005 – present: Statistician for the National Marine Mammal Lab of the National Oceanic and Atmospheric Association (NOAA), U.S. Dept. of Commerce.
1991 – 2005: Biometrician for the Wildlife Conservation Division of the Alaska Department of Fish and Game.

Selected Publications:
Ver Hoef, J.M. 2012. Who invented the delta method? *The American Statistician* **66**: 124 – 127.
Ver Hoef, J.M. and Peterson, E.E. 2010. A moving average approach for spatial statistical models of stream networks (with discussion). *Journal of the American Statistical Association* **105**: 6 – 18. DOI: 10.1198/jasa.2009.ap08248. Rejoinder pgs. 22 – 24.
Ver Hoef, J.M., London, J.M., and Boveng, P.L. 2010. Fast computing of some generalized linear mixed pseudo-models with temporal autocorrelation. *Computational Statistics* **25**(1): 39 – 55. DOI 10.1007/s00180-009-0160-1.
Cressie, N., Calder, K.A., Clark, J.S., Ver Hoef, J.M., and Wikle, C.K. 2009. Accounting for Uncertainty in Ecological Analysis: The Strengths and Limitations of Hierarchical Statistical Modeling. *Ecological Applications* **19**: 553 – 570.
Garreta, V., Monestiez, P. and Ver Hoef, J.M. 2009. Spatial modeling and prediction on river networks: Up model, down model or both? *Environmetrics*. DOI: 10.1002/env.995
Ver Hoef, J.M. 2008. Spatial methods for plot-based sampling of wildlife populations. *Environmental and Ecological Statistics* **15**: 3 – 13.
Ver Hoef, J.M. and Jansen, J.K. 2007. Space-time zero-inflated count models of harbor seals. *Environmetrics* 18: 697 – 712.
Ver Hoef, J.M. and Boveng, P.L. 2007. Quassi-Poisson vs. negative binomial regression: How should we model overdispersed count data? *Ecology* **88**: 2766 – 2772.
Ver Hoef, J.M., Peterson, E., and Theobald, D. 2006. Spatial statistical models that use flow and stream distance. *Environmental and Ecological Statistics* **13**: 449 – 464.
Ver Hoef, J.M., N. Cressie, and R.P. Barry. 2004. Flexible Spatial Models for kriging and cokriging using moving averages and the Fast Fourier Transform (FFT). *Journal of Computational and Graphical Statistics* **13**: 265 – 282.

SETH J. WENGER - CURRICULUM VITAE

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EDUCATION

PhD Degree in Ecology — 2006
University of Georgia, Athens, GA

MS Degree in Conservation Ecology and Sustainable Development — 1999
University of Georgia, Athens, GA

BS Degree in Environmental Science & BA Degree in English — 1994
Lebanon Valley College, Annville, PA

RECENT PROFESSIONAL EXPERIENCE

Staff Scientist, Trout Unlimited	2010- Present
Post-Doctoral Associate, Trout Unlimited / US Forest Service	2008-2009
Associate Director, University of Georgia River Basin Center	2007-2008
Conservation Ecologist & Policy Analyst, University of Georgia	2005-2007

SELECTED RECENT PUBLICATIONS

Peterson, D.P, S.J. Wenger, B.E. Reiman and D.J. Isaak. 2013. Linking Climate Change and Fish Conservation Efforts Using Spatially Explicit Decision Support Tools. *Fisheries* 38:112-127.

Wenger, S.J. and J.D. Olden. 2012. Assessing transferability of ecological models: an underappreciated aspect of statistical validation. *Methods in Ecology and Evolution* 3: 260-267.

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 trout species under climate change. *Proceedings of the National Academy of Sciences* 108(34): 14175-14180.

Wenger, S.J., D.J. Isaak, B.E. Rieman, J.B. Dunham, M.K. Young, K.D. Fausch, C.H. Luce, H.M. Neville, D.E. Nagel, G.L. Chandler and D.L. Horan. 2011. Role of climate and invasive species in structuring trout distributions in the Interior Columbia Basin. *Canadian Journal of Fisheries and Aquatic Resources* 68: 988-1008.

Dauwalter, D.C., S.J. Wenger, K.R. Gelwicks and K. Fesenmyer. 2011. Land use associations with roundtail chub, flannelmouth sucker and bluehead sucker occurrence in the Upper Colorado River Basin. *Transactions of the American Fisheries Society* 140(3): 646-658.

Wenger, S.J., C.H. Luce, A.F. Hamlet, D.J. Isaak and H.M. Neville. 2010. Macroscale hydrologic modeling of ecologically relevant flow metrics in small streams. *Water Resources Research* 46, W09513, doi: 10.1029/2009WR008839.

Wenger, S.J., and 20 others. 2009. Twenty-six key research questions in urban stream ecology: an assessment of the state of the science. *Journal of the North American Benthological Society* 28: 1080-1098.

Jeffrey L. Kershner

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Phone: (406) 994-5304
Mobile: 406-599-5001
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Education:

B.S. Humboldt State University 1976 - Fisheries
M.S. Humboldt State University 1983 - Natural Resources
PhD University of California, Davis 1991 - Ecology

Employment:

2005-Present USGS - Northern Rocky Mountain Science Center
Position - Director
Affiliate Faculty - Ecology Department, Montana State University
1988-2005 U.S. Forest Service, Washington Office
Position - National Aquatic Ecologist
1991-2005 Research Faculty - Utah State University/Watershed Science Department
Rank - Full Professor
1985-1987 U.S. Forest Service, Eldorado/Tahoe National Forest
Position - Zone fisheries biologist
1979-1985 U.S. Forest Service, Eldorado National Forest
Position - Hydrologist, Fisheries biologist

Professional Societies:

American Fisheries Society – Certified Professional Fisheries Biologist

Courses taught - college level:

Humboldt State University

Introduction to flyfishing - Co-instructor with Bob Kelley (former director of Fenwick schools) 1977-1979

Cosumnes River Junior College

General ecology (1987)
Introduction to flyfishing (1985-86)

Utah State University

Fish/habitat relationships – senior/graduate level
Watershed analysis - graduate level
Graduate seminars - Cumulative effects in watersheds
Adaptation and environment
Ecology and management of regulated rivers
Restoration ecology

Publications:

Jeff has published over 75 scientific articles, book chapters and technical reports on a variety of topics including trout biology, fish habitat, restoration and land use impacts on streams, with students and other colleagues.

Presentations:

Jeff has given over a hundred presentations to professional organizations and public groups.

Co-Investigator: Charles H. Luce

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Education

Ph.D.	Civil Engineering	Utah State University	2000	
M.S.	Hydrology	University of Washington	1990	
B.S.	Forest Management	University of Washington	1986,	*Magna Cum Laude*

Professional Experience

1998-Present: Research Hydrologist, Rocky Mountain Research Station, Boise, Idaho.
1991-1998: Research Hydrologist, Intermountain Research Station, Moscow, Idaho.

Awards and Honors

USDA Forest Service Rocky Mountain Research Station, Best Scientific Publication 2009
Water Resources Research Editors' Citation for Excellence in Refereeing, 2003
Certificate of Merit, USDA Forest Service, for Rapid Development of a Model, 1991

Patents

Magnetostrictive Precipitation Gage, Patent No.: US 6,490,917 B1, December 10, 2002
Method for Sensing Evaporation of a Liquid, Pat. No.: US 6,789,417 B2, September 14, 2004.

Refereed Journal Articles

Luce, C. H., D. Tonina, F. P. Gariglio, and R. Applebee, 2013, Solutions for the diurnally forced advection-diffusion equation to estimate bulk fluid velocity and diffusivity in streambeds from temperature time series, Water Resour. Res., 49, 488-506, doi:10.1029/2012WR012380.

Adams, H.D., C.H. Luce, D.D. Breshears, M. Weiler, V.C. Hale, C.D. Allen, A.M.S. Smith, T.E. Huxman, 2012. Ecohydrological consequences of drought- and infestation- triggered tree die-off: insights and hypotheses. Ecohydrology, 5: 145-159.. doi: 10.1002/eco.233.

Goode, J. R., C. H. Luce, and J. M. Buffington. 2012. 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.

Wenger, S.J.; Isaak, D.J.; Luce, C.H.; Neville, H.M.; Fausch, K.D.; Dunham, J.B.; Dauwalter, D.C.; Young, M.K.; Elsner, M.M.; Rieman, B.E.; Hamlet, A.F.; Williams, J.E. 2011. Flow regime, temperture, and biotic interactions drive differential declines of trout species under climate change. Proceedings of the National Academy of Science (PNAS). 108(34): 14175-14180.

Holden, Z.A., C.H. Luce, M. Crimmins, and P. Morgan, 2012, Wildfire Extent and severity correlated with annual streamflow distribution and timing in the Pacific Northwest, USA (1984-2005), Ecohydrology, 5(5), 677-684 DOI: 10.1002/eco.257

Wenger, S. J., C. H. Luce, A. F. Hamlet, D. J. Isaak, and H. M. Neville, 2010, Macroscale hydrologic modeling of ecologically relevant flow metrics, Water Resour. Res., 46, W09513, doi:10.1029/2009WR008839.

Luce, C.H. and D.G. Tarboton. 2010. Evaluation of alternative formulae for calculation of surface temperature in snowmelt models using frequency analysis of temperature observations. Hydrology and Earth System Sciences, 14(3):535-543

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

Tonina, D., Luce, C.H., Clayton, S., Alì, M.D., Barry, J.J., Rieman, B.E., Goodwin, P., Buffington, J.M., Berenbrock, C., 2008, Hydrological Response to Timber Harvest in Northern Idaho: Implications for Channel Scour and Persistence of Salmonids, Hydrological Processes, 22(17):3223-3235.

Biosketch for Jason B. Dunham, Ph.D. April 2013

Professional Preparation

Oregon State University, BS, Zoology, 1987; Arizona State University, MS, Zoology, 1995; University of Nevada-Reno, Ecology, Evolution and Conservation Biology, Ph.D., 1997

Recent appointments

U.S. Geological Survey, Supervisory Research Aquatic Ecologist (GS-14): 2005 – date; Oregon State University Department of Fisheries and Wildlife, Courtesy Graduate Faculty: 2005 – date; Guest Instructor, Willamette University, 2013; College of Idaho, Adjunct Faculty, 2004; University of Idaho, Lecturer, Ecohydraulics Research Group: 2003-2005; Boise State University, Adjunct Faculty, Department of Biology: 2003-2005; U.S. Forest Service, Research Fishery Biologist (GS-13): 2000-2005

Selected recent publications (go here for a complete list of >60 available)

Arismendi, I., Johnson, S.L., Dunham, J.B., Haggerty, R., 2013, Descriptors of natural thermal regimes in streams and their responsiveness to change in the Pacific Northwest of North America. DOI- 10.1111/fwb.12094: Freshwater Biology, p. online.

Arismendi, I., Johnson, S.L., Dunham, J.B., Haggerty, R., Hockman-Wert, D.P., 2012, The paradox of cooling streams in a warming world- Regional climate trends do not parallel variable local trends in stream temperature in the Pacific continental United States: Geophysical Research Letters, v. 39, p. L10401.

Arismendi, I., Safeeq, M., Johnson, S.L., Dunham, J.B., Haggerty, R., 2012, Increasing synchrony of high temperature and low flow in western North American streams- double trouble for coldwater biota? DOI-10.1007/s10750-012-1327-2: Hydrobiologia, p. online.

Hoffman, Jr., R., Dunham, J.B., Hansen, B.P., 2012, Aquatic Organism Passage at Road Stream Crossings - Synthesis and Guidelines for Effectiveness Monitoring: U.S. Geological Survey Open-File Report 2012-1090, p. 64.

Kitanishi, S., Yamamoto, T., Koizumi, I., Dunham, J.B., Higashi, S., 2012, Fine-scale relationships between sex, life history, and dispersal of masu salmon: Ecology and Evolution, v. 2, no. 5, p. 920-929.

McMillan, J.R., Dunham, J.B., Reeves, G.H., Mills, J.S., Jordan, C.E., 2012, Individual condition and stream temperature influence early maturation of rainbow and steelhead trout, *Oncorhynchus mykiss*: Environmental Biology of Fishes, v. 93, no. 3, p. 343-355.

David E. Nagel

Physical Scientist/GIS Analyst

Primary expertise includes spatial analysis, modeling, and remote sensing for hydrologic, geomorphic, and aquatics applications. Specialties include stream temperature modeling, automated valley confinement mapping, and landslide potential modeling.

EDUCATION

M.S. Environmental Monitoring, University of Wisconsin – Madison, Institute of Environmental Studies, 1995.
B.S., Resource Development, Michigan State University, College of Agriculture and Natural Resources, 1986.

PROFESSIONAL EXPERIENCE

Physical Scientist/GIS Analyst, USDA Forest Service, Rocky Mountain Research Station, Boise Aquatic Sciences Lab, FERA Team. Boise, ID. 2/02 - present.
GIS and Remote Sensing Analyst, USDA Forest Service, PNW Research Station, Seattle Forestry Sciences Lab, FERA Team. Seattle, WA. 8/99 - 2/02.
Senior Analyst, Remote Sensing and GIS, Earth Information Systems Corporation (EISYS, Inc.). Fort Collins, CO. 6/97 to 8/99.
Image Processing and GIS Analyst, Wisconsin Department of Natural Resources, Madison, WI. 1/94 to 6/97.
Research Assistant, Environmental Remote Sensing Center, University of Wisconsin-Madison. Madison, WI. 9/91 to 5/94.
GIS and Remote Sensing Project Manager, Earth Resources Data Analysis Systems (ERDAS, Inc.). Atlanta, GA. 10/86 to 8/91.

RECENT PRESENTATIONS

Nagel, D., D. Isaak, D. Horan, G. Chandler, S. Parkes, S. Wenger, S. Wollrab, J. Dunham and D. Hockman-Wert. 2013. *High Resolution Geospatial Stream Temperature Data for the Northwest U.S., A User's Guide for the NorWeST Regional Database and Model.* Western Division American Fisheries Society Conference, April 15-18.

Nagel, D., Buffington, J.M., Luce, C., 2011. *A Simple Drainage Enforcement Procedure for Estimating Catchment Area Using DEM Data.* NW GIS User Conference, Oct. 17-21, Boise, ID.

Nagel, D., Buffington, J.M., Isaak, D., 2010. *Estimating Stream Gradient Using NHD Stream Lines and DEM Data*. ESRI International User Conference, July 12-16, San Diego, CA.

Nagel, D., D. Isaak, B. E. Rieman, S. Adams, D. Horan, and C. Luce, 2010. *A Map of Thermally Suitable Bull Trout Habitat: Current and Projected Climate Conditions Across the Interior Columbia Basin*. ESRI International User Conference, July 12-16, San Diego, CA.

Nagel, D., C. Luce., D. Isaak, and B. Rieman, 2008. *Stream Temperature and Thermal Networks, A GIS and Remote Sensing Approach to Assess Aquatic Habitat.* The Twelfth Biennial USDA Forest Service Remote Sensing Applications Conference, 2008. April 15-17, Salt Lake City, UT.

Nagel, D., C. Luce., D. Isaak, and B. Rieman, 2007. *Toward Stream Temperature Prediction at the Drainage Basin Scale, A GIS and Remote Sensing Approach.* The 22nd Annual Northwest GIS Users' Conference and Training, September 10-14, Tacoma, WA.