Project Title: Towards developing an interagency stream temperature database and high-resolution stream temperature model for British Columbia with a focus on pilot watersheds in the NPLCC and GNLCC

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Project Summary: Stream temperature data will be acquired from federal and provincial government agencies, as well as other data holders in British Columbia to eventually be housed in an interagency database. Spatial statistical models for river networks like those used for NorWeST will be used with existing and readily available stream temperature data to develop a consistent set of high-resolution predictions for all streams and reaches within two pilot areas: an interior location represented by the Nicola River watershed in the Great Norther LCC and a coastal location represented by the Somass River watershed within the North Pacific LCC (Panels 1 & 2 respectively in Fig 1). Work in these proposed pilot areas would include processing of spatial data and applying existing technical protocols for stream temperature modelling to facilitate future expansion of the approach across the GNLCC and NPLCC in British Columbia. An ultimate goal is to provide a consistent set of international stream temperature scenarios for planning and vulnerability assessments for aquatic species.

Category for Proposal: This proposal fits into Category C: Applying GNLCC science to management outcomes, in particular Option 2: The extension services model since the project would not develop new science. Rather it would leverage methods applied to/funded by other LCCs and apply them to a new geographic area.

Need: Water temperature plays a fundamental role in structuring freshwater ecosystems. It influences the physiology and behavior of fish through all life history stages, affecting growth, survival and distribution of individuals and populations, as well as species interactions within fish communities (Caissie 2006). Moreover, evidence suggests that changing climate conditions have led to warming of streams across western North America and future projections suggest that warming will continue for the foreseeable future (Isaak et al. 2010; Nelitz et al. 2010; Isaak et al. 2012). Such thermal changes can lead to fragmentation of freshwater habitats across the landscape, especially for vulnerable species such as bull trout and Pacific salmon. Managers of aquatic ecosystems across the Great Northern and North Pacific Landscape Conservation Cooperatives need to consider the implications of climate change and other stressors on their management actions (e.g., riparian management, flow management, aquatic connectivity, habitat restoration, aquatic species conservation). Yet in British Columbia broad-scale planning efforts are, at present, only possible by using crude climate surrogates like air temperature or elevation, which can be weakly correlated with stream temperatures (Wenger et al. 2011). In British Columbia a regulatory tool is available that allows managers to designate "Temperature Sensitive Streams" (TSS) to protect critical fish-bearing streams that could be altered by stream heating due to forest harvesting in riparian and upslope areas as well as climate change (Reese-Hansen et al. 2012). This regulatory tool, however, has had limited application and its use could be enabled by providing a stronger information/evidence base to support decision making.

The temperature modeling infrastructure developed through this project would provide a science-based tool for enhancing management, monitoring, and coordination of stakeholder engagement around aquatic resources in British Columbia and internationally with the U.S. This work would leverage the technologies, protocols, and advancements made through the NorWeST project that was funded for the U.S. portion of the Great Northern and North Pacific Landscape Conservation Cooperatives (Isaak et al. 2011), while also integrating the related experience and data developed in British Columbia (Moore et al. 2013; Hague and Patterson 2014; Parkinson et al. 2015).

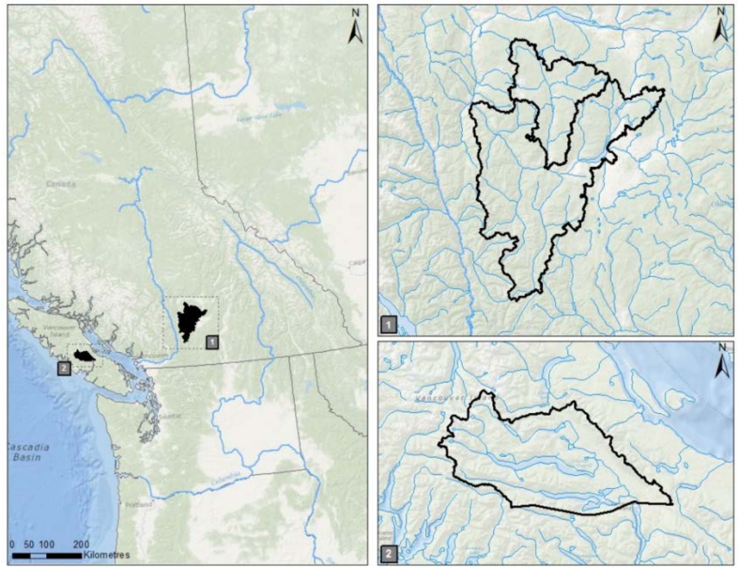

Fig 1. Locations of two proposed pilot watersheds within the Great Northern (1-Nicola) and North Pacific LCCs (2-Somass).

The tool would be built by compiling data from numerous existing agency temperature monitoring efforts in British Columbia with the purpose of providing a common modeling framework and set of reference conditions to help overcome inconsistencies otherwise arising from basin-by-basin or more local-scale applications of temperature models. Project outputs would include developing an interagency stream temperature database and spatially continuous maps of stream temperature derived from a regional temperature model. The intent would be to apply already established methods/protocols to two proposed pilot watersheds (see Fig 1). Application of these methods would require working with new spatial layers and data sets to test the transferability of protocols for eventual wider scale application across the northern portions of the GNLCC and NPLCC in British Columbia. These areas have been selected due to the amount and spatial extent of temperature data. Their selection would be confirmed in the early stages of this project since we don't fully know the extent of data until we start the project, though alternative high priority locations include the Squamish, Puntledge, San Juan, and Nicomekl River systems.

As demonstrated through applications elsewhere, the project outputs can eventually (1) reduce and quantify uncertainty when planning for future climate conditions, and (2) facilitate 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. In particular, this information can significantly reduce uncertainties 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 (e.g., bull trout, Pacific salmon, or any aquatic species of concern). In the northwestern U.S. where NorWeST temperature scenarios have previously been developed, the information has been rapidly adopted in regional climate vulnerability assessments for bull trout, cutthroat trout, and salmon, used in decision support tools, and is enabling a suite of applications related to traditional assessments of thermal conditions and monitoring efforts in streams (e.g., cumulative effects, TMDL regulatory standards, Isaak et al. 2014). The accuracy of the NorWeST stream temperature predictions, their ease of use within GIS, and development from data collected by those working in the local aquatics community translates to rapid adoption and use in decision making.

Objective: The primary objective of this project is to provide an accurate assessment and description of historical stream temperatures and thermal habitat distributions for aquatic species in two pilot watersheds within British Columbia, Canada. The resulting information is expected to serve as a science-based decision support tool such that planning efforts, regulatory tools, and management actions around aquatic environments can be implemented more efficiently and with greater confidence. The objective is not to make recommendations regarding specific management actions in different locations, only to provide accurate information that is fundamental to informed discussions about prioritizing actions. Specific tasks include: (1) compiling stream temperature data from various sources across the province, (2) developing the architecture for a comprehensive, interagency stream temperature database where these data can be housed in the future, (3) piloting existing protocols developed elsewhere for application to the spatial layers and stream temperature data in two pilot watersheds in British Columbia, (4) developing a stream temperature model that incorporates important climate drivers, riparian conditions, and geomorphic factors, and (5) using the model to predict historic patterns in stream temperatures for streams in the two pilot watersheds.

Methods: This project would be completed in five stages.

Stage 1. Capacity building: To leverage the experience, methodologies, and protocols developed for the NorWeST project by the US Forest Service, members of the project team would travel to the Boise Aquatic Sciences Laboratory to engage in several days of training to learn how to apply the methods developed in the US Pacific Northwest to spatial and tabular data sets from British Columbia (if remote interaction is insufficient).

Stage 2. Data acquisition & database architecture development: A data request would be distributed through the project PIs, partners, and others across the network of aquatic professionals in British Columbia to request and acquire stream temperature data that has been collected by various organizations and raise awareness about this initiative. Effort for data acquisition would be scaled to the available resources in the budget. A formal data sharing agreement would be used to ensure there is a clear understanding among contributors about potential uses of data, while still allowing contributors to publish any research associated with these data. To the extent that data can be shared easily across purposes, this activity would leverage past data compilations efforts (e.g., Nelitz et al. 2008; Khan 2014).

A database developer would provide oversight of the data acquisition and develop the architecture for a relational database to support both data compilation and stream temperature modelling. Although data would be gathered and requested from across the province, a limited amount of data entry would occur for sampling locations within the two pilot watersheds. Quality assurance, entry of additional data, and externally facing user-access features would be explored in future phases of work.

Stage 3. Processing of stream network: British Columbia's Freshwater Atlas would be used as the basis for developing the spatial statistical stream-network model (http://geobc.gov.bc.ca/base-mapping/atlas/fwa/). As part of the model development process, the hydrology network topology needs to be checked for errors that sometime occur at tributary confluences or the flow directionality that is assigned to stream reaches. Reconditioning of the network would be done by a GIS specialist following established protocols (Peterson and Ver Hoef 2014; Peterson 2013). These protocols were applied previously in the NorWeST stream temperature project (Isaak et al. 2011) to recondition the NHDPlus layer for the U.S. and need to be tested against BC's data layers.

Stage 4. Stream temperature modelling: Spatial statistical stream network models would be used to model patterns in stream temperature data (Ver Hoef et al. 2006; Ver Hoef and Peterson 2010; more information at: http://www.fs.fed.us/rm/boise/AWAE/projects/SpatialStreamNetworks.shtml). These spatial models accommodate clustering and non-independence among observations and are well suited to applications involving databases aggregated from multiple agencies. Isaak et al. (2010; 2014) provide examples using the spatial statistical models with interagency temperature databases. Some of the processing steps for fitting the spatial statistical stream-network models are currently done using two ArcGIS custom toolsets: FLoWS (Theobald et al. 2006) and STARS (Peterson and Ver Hoef 2014; Peterson 2013). With this model, high-resolution maps of thermal conditions based on watershed characteristics and current climate conditions would be developed. Watershed characteristics would be derived using existing spatial data layers for British Columbia that have been applied in other stream temperature modelling studies (Nelitz et al. 2007; Moore et al. 2013). Climate data would be provided either by the Pacific Climate Impacts Consortium (http://www.pacificclimate.org/data/statistically-downscaled-climate-scenarios) or through readily available data portals (ClimateWNA, see Wang et al. 2012).

Stage 5. Communication and outreach: A series of external facing activities are envisioned to raise awareness of the project, facilitate collection of stream temperature data, support durability and uptake of project achievements, and enable future expansion. First, a series of communications to the network of aquatic organizations and professionals across British Columbia would be required to compile stream temperature data from across the province. Next, conference calls are expected with the project team and other aquatic scientists and managers from across British Columbia to inform broader outreach and guide some of the technical aspects of this project. Near project completion, a webinar would be convened with aquatic scientists and managers from across British Columbia to demonstrate results from the spatial stream temperature model, the interagency database, and opportunities to improve future stream temperature monitoring (i.e., address gaps across the landscape). Next, since there is no guarantee of the long-term durability, maintenance, and expansions of the database and the related products, discussions will be required to identify an organization that can house and maintain the database and mapping products in the longer term. Organizations that are a part of the project team have an interest in serving in that role, yet require some commitment around long term funding. For instance, the Province of BC has expressed interest in uploading static versions of the model's outputs into their publicly available GeoBC Data Warehouse (http://www.data.gov.bc.ca/dbc/geographic/index.page) and the Pacific Salmon Foundation is currently developing salmon data portals for parts of British Columbia. Over the course of this project we would seek additional funding to support longer term maintenance of the database and related products, as well as broader geographic expansion of the modelling framework.

The team involves a strong multi-agency partnership with unparalleled experience of individuals in complementary roles. The Pacific Salmon Foundation would serve in a project coordination role to administer the project, coordinate completion of activities, undertake outreach with data contributors, and facilitate communication with data users. The BC Ministry of Forests, Lands, and Natural Resource Operations would serve as a link to provincial spatial data layers and temperature data sets, as well as ensure relevance of the work to regulatory requirements for designating "Temperature Sensitive Streams." Fisheries and Oceans Canada would contribute stream temperature data and provide relevance to their investments in science and management around Pacific salmon. Researchers with the BC Ministry of Environment and University of British Columbia can contribute relevant experience and data having worked extensively for decades across the landscape in BC. Pacific Climate Impacts Consortium would assist in compiling stream temperature data and provide easy access to air temperature projections to inform predictions of future changes in thermal landscapes. Lastly, ESSA would serve in a technical role to undertake database development and stream temperature modelling.

Deliverables: Numerous deliverables [with anticipated completion dates] will be produced including: (1) the architecture for an interagency database populated with limited data from the pilot watersheds [Feb 2016], (2) spatially continuous maps of stream temperatures for historic climatic conditions [Apr 2016], (3) outreach activities (e.g., notices/announcements and/or webinars) to raise awareness about the project, request data from others, and communicate findings from the project [May 2016], and (4) a final report documenting the approach, transferability of existing protocols to BC, and modelling results [Jun 2016].

Statement of compliance: The Project coordinator and Principal Investigator have read the Great Northern Landscape Conservation Cooperative Information Management, Delivery, and Sharing Standards and agree to comply with those standards. Based on previous experience we anticipate the need to filter some of the stream temperature data to withhold data that contributors do not want distributed. A data sharing agreement would be used to clarify terms around using and sharing data from contributors. Past experience in the northwestern U.S. has shown that the majority of contributors (~95%) have given permission to distribute their data. Model results and related geospatial information in pilot watersheds would be available with no restrictions.

Schedule: We assume the project would begin in July 2015 and be completed by June 2016 (see Table 1).

Table 1. Project schedule by quarter and calendar year with timing of core deliverables.

	2015				2016			
Project stages	Q3		Q4		Q1		Q2	
(1) Capacity building	ST	CB						
(2) Data compilation and database development		X	X	X	DB			
(3) Processing of stream network		X	X	X				
(4) Stream temperature modelling						X	MP	
(5) Communication and outreach								OR/FR

<u>Key work items:</u> ST: Project start (Jul '15), CB: Training with USFS (Sep '15), DB: Database (Feb '16), MP: Map preparation (Apr '16), OR: Outreach (May '16), and FR: Final report and project completion (Jun '16).

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