IX. PROJECT PROPOSAL FORMAT (Please limit to 4 pages - not including budget, resumes for project leader(s), or literature cited**)**

Project Title
A Coupled (Ocean and Freshwater) assessment of Climate Change Impacts on Pacific Lamprey and Pacific Eulachon

Funding Announcement #1

Project Leader or Principal Investigator responsible for completion of project

Dr. Rishi Sharma, The Columbia River Inter-Tribal Fish Commission, 729 NE Oregon St., Suite 200, Portland, OR 97232, shar@critfc.org, (503) 238-0667

Cooperators/Partners and anticipated project contributions:

David Graves, The Columbia River Inter-Tribal Fish Commission, 729 NE Oregon St., Suite 200, Portland, OR 97232, grad@critfc.org, (503) 736-3589

Dr. Nathan Mantua, NOAA Fisheries, Southwest Fisheries Science Center, 110 Shaffer Road, Santa Cruz, CA 95060, nate.mantua@noaa.gov, (831) 420-3923. Dr. Mantua has extensive experience in linking large scale climate signals to oceanic conditions and consequential changes in climate patterns on near-shore environments and terrestrial systems. He will collaborate and help the PI in developing these relationships at the scale and relevance for the species being studied, namely Pacific lamprey (*Entosphenus tridentatus*), Pacific Eulachon (*Thaleichthys pacificus*) populations and *Oncorhynchus spp.* (for the cost share components)

Dr. Anthony Farrell, University of British Columbia, Department of Zoology, #4200-6270 University Blvd. Vancouver, B.C., Canada V6T 1Z4, tony.farrell@ubc.ca, (604) 822-6602. Aerobic scope mechanisms are vital for species persistence, i.e. there is a range of estimated temperatures, which is the key to survival due to temperature dependence of aerobic scope mechanisms for lamprey, Pacific Eulachon, and salmonids. Dr. Farrell is an expert on Fish Physiology and will help the PI in understanding this important variable in determining survival, and whether these indices vary for different localized populations due to adaptation to the local environment. Consequentially, if climate change effects are hypothesized to occur on the local habitat and directly or indirectly effect localized temperature, would these species adapt to new aerobic scope relationships, or cease to persist.

Project Summary: (*3 sentences target*)

We propose to evaluate the impacts of future climate change scenarios on the survival and viability of Pacific lamprey (*Entosphenus tridentatus*) and Pacific Eulachon (*Thaleichthys pacificus*) populations that are used as food sources by the Native American tribes of the Columbia River Basin and the coastal areas of Washington and Oregon. This evaluation will couple projected changes to ocean conditions and to freshwater habitat, and consider the effects of these changes on the life cycles of these fish populations. With matching funding, we will expand this analysis to also include select anadromous salmonid populations of importance to the Columbia River tribes.

Project Proposal: *Provide a brief description.*

Pacific Lamprey and Pacific Eulachon are important "first food" sources of Pacific Northwest Native Americans. These fish are already limited by a number of factors (habitat changes, temperature fluctuations, and migration timing changes) and are being considered for protection by management agencies. Under a changing climate, these fish are likely to be impacted both by changes to ocean conditions and food availability and freshwater habitat because of their life histories. Little research today has assessed the magnitude or nature of these impacts on these two species, despite their importance to tribes.

We propose to evaluate these impacts by:

(1) Developing hypothesized relationships between ocean variability and conditions in freshwater streams and rivers affecting the survival and viability of these species through performance (aerobic scope) mechanisms or directly related to survival and abundance data (if available);
and
(2) Using this information to build coupled ocean-freshwater models, to forecast impacts to Pacific Lamprey and Pacific Eulachon populations under future climate change scenarios;

The overall project goals really are to test the following hypotheses:(1) ocean productivity as expressed by sea surface temperature (Sea Surface Temperature - SST) anomalies (positive or negative) are inversely related with marine survival of lamprey, eulachon and some key salmon spp. across our study area; and,
(2) that large scale ocean-atmospheric processes like the El Niño Southern Oscillation (ENSO; Wolter & Timlin, 1998) and the Pacific Decadal Oscillation (PDO; Mantua *et. al.*, 1997) impact the local conditions in near-shore coastal waters, freshwater conditions and thus also affect the survival of lamprey, eulachon and salmonids.

From southeast Alaska to northern California, juvenile salmonids, Pacific Eulachon and Pacific Lamprey typically leave the freshwater environment to enter an ocean that is either in or near a state of transition from winter to spring conditions (Quinn 2005). Depending on the timing of this spring transition, out-migrants could encounter spring-like conditions characterized by a coastal ocean that has experienced significant upwelling that supports nutrient enrichment and elevated primary productivity, or winter-like conditions characterized by downwelling that favors low nutrients and low primary productivity, or the transition between the two (Bakun, 1996). While juvenile Chinook salmon spend a large amount of time on the coastal shelf immediately after ocean entry either migrating along the coast or staying close to their natal rivers (Trudel *et. al.*, 2009), not much is known about the life-history of Eulachon or lamprey. This early marine life history phase has been shown to be extremely important with many studies linking inter-annual variations in different aspects of ocean conditions such as upwelling and water temperature with indicators of *Oncorhynchus spp*. marine survival (Logerwell *et. al.*, 2003; Peterson & Schwing, 2003; Lawson *et. al.,* 2004; Peterson *et. al.*, 2006), and we hypothesize that this will be equally important for lamprey and eulachon (though very little is known about this subject, and the PI's will first scope this hypothesis out based on available data in the 1st year, and then develop a more thorough analysis over the 2nd year of this project). Marine conditions will be assessed primarily through SST, Upwelling and Sea Level Pressure.

In addition global climate signals like the ENSO, and PDO will be linked to these mechanisms in the same manner as Sharma et. al. (2013) build coupled time-series models of climate changes and how they impact a key trait (e.g. survival) of the species being studied.

Key ocean environmental data will measure coastal ocean conditions from March to August, the primary months of ocean entry of eulachon, lamprey and salmonids evaluated in this study. We will use monthly mean Bakun Upwelling Indices from March to August in the outmigrating year, obtained from the Pacific Fisheries Environmental Laboratory (PFEL: http://www.pfeg.noaa.gov/pfel/; Schwing et al. 1996). We will also use monthly average gridded SST from March to August in the outmigrating year from NOAA's extended reconstructed sea surface temperature data described by Smith and Reynolds (2004) (http://www.esrl.noaa.gov/psd/data/gridded/data.noaa.ersst.html). Station locations were along the coastal shelf from 42^{o} N to 60^{o} N at 2-degree intervals along the coast. Additional nearshore SST data were obtained from BC lighthouse stations for Canadian waters (http://www-sci.pac.dfo.mpo.gc.ca/osap/data/SearchTools/Searchlighthouse_e.html).

Freshwater conditions will be assessed by examining current and projected changes to stream flow and stream temperature under future climate change scenarios, using data and findings from recent research in the Pacific Northwest (Crozier et al. 2008, Elsner et al. 2010, UWCIG 2010, Isaak et al. 2012).

The work will follow a two phased approach, first trying to develop empirical relationships with key environmental variables and survival. Abundance for lamprey and eulachon. The second phase will involve some simple models that build on existing work to couple ocean and freshwater climate change impacts on anadromous salmonids, using a similar method to one underway to assess changes to Washington State Coho populations (Mantua and Beetz, In Progress). These models will assimilate changing ocean and freshwater conditions in order to assess population metrics such as annual growth, mean abundance, and probability of extinction.

We will implement the models with regional climate change scenarios to develop scenarios for future ocean conditions and for stream temperature and flows, in order to estimate how Pacific Lamprey and Pacific Eulachon population viability will respond to climate change scenarios.

Matching funds will allow us to complete this project in two years, and with additional matching funds we will expand the project to also adopt this approach in assessing anadromous salmonid populations of interest to Columbia River Basin Tribes, possibly including stream and ocean type Chinook, Salmon and possibly some steelhead populations.

Objective and Need: *What will you accomplish? How will this project contribute to the NPLCC goals? What is the need within the NPLCC landscape?*

Like Salmon, Pacific Lamprey and Pacific Eulachalon are important food sources for the Native American tribes of the Columbia River Basin. These first foods are likely threatened by climate change through a myriad of impacts which will affect the life cycles of these fishes, including shifts in stream flow, warmer stream temperatures, and changes to ocean upwelling conditions and food availability. In order for the tribes to prepare for changes to these food sources, an assessment of how these impacts will affect different populations. Such an assessment must couple ocean changes with freshwater changes from future climate scenario in order to understand how the entire life cycle will be affected. Management of these stocks is a joint concern of the tribes and state and federal agencies, but is hindered by the lack of reliable information about how their abundance and survival may be threatened by climate change.

This project would contribute to the stated goals of the NPLCC, specifically:

(i) Maximize the ability of partners to make informed decisions with respect to conservation and sustainable resource management or priority natural and cultural resources subject to climate change and related large-scale stressors in the NPLCC region;

(iv) Promote identification, use and sharing of science, traditional knowledge and other relevant information to support conservation/sustainable resource management, and adaptive management decisions;

We will use three different methods to disseminate the progress and findings of this project to a wide and appropriate audience:

(a) Publication in a peer-reviewed scientific journal. This will allow the credible dissemination of the techniques and findings of this research to a scientific audience.

(b) Presentations to regional management groups, which include state, federal, and tribal fisheries managers. This will allow fisheries managers to incorporate these findings into their operations. These regional management groups include:

(i) The Columbia Management Advisory Committee (This is the bi-state (OR/WA) body set up to regulate fisheries in the Columbia River Basin.)

(ii) USvOR Technical Advisory Committee (consists of biologists from the state, tribal, and federal agencies that are party to the USvOR case.)

(iii) PSC Technical Committee (Interest from this group would likely be restricted to how the findings apply to salmon, since lamprey and eulachon are not part of the PS Treaty).

(iv) Columbia River InterTribal Fish Commission (Is comprised of representatives from the fish and wildlife committees of each of our four member tribes).

(c) Publication of a description of the project and access to its data on the CRITFC web site. An online synopsis of the project and its findings can be helpful in achieving a quick understanding of the work, and transparent and available data from this project can be of assistance to those who wish to understand or use the data in-depth. We have three different pages designed for these purposes on our website:

* Scientific Reports page: http://www.critfc.org/fish-and-watersheds/fishery-science/scientific-reports/

* Climate Change Scientific Resources page: http://www.critfc.org/fish-and-watersheds/climate-change/climate-change-scientific-resources/

* Data Download page: http://www.critfc.org/fish-and-watersheds/fishery-science/data-resources-for-scientists/critfc-data-download/

Methods: *How will the objectives be attained? What work activities or tasks will be done? Include specific procedures, methodologies, or protocols. Will there be any key cooperators, and what will their role be (identify any in-kind support provided)?*

As mentioned above, The overall project goals really are to test the following hypotheses: (1) ocean productivity as expressed by Sea Surface Temperature anomalies (positive or negative) are inversely related with marine survival of lamprey, eulachon and some key salmon spp. across our study area; and, (2) that large scale ocean-atmospheric processes like the El Niño Southern Oscillation (ENSO; Wolter & Timlin, 1998) and the Pacific Decadal Oscillation (PDO; Mantua *et. al.*, 1997) impact the local conditions in near-shore coastal waters, freshwater conditions and thus also affect the survival of lamprey, eulachon and salmonids.

This will be done directly through establishing empirical relationships based on available abundance and survival data of Pacific lamprey and Eulachon (the 1st phase of this project) with environmental data in the freshwater and ocean areas of their habitat. The second phase will develop models that will assimilate changing ocean and freshwater conditions in order to assess population metrics such as annual growth, mean abundance, and probability of extinction. We will implement the model with regional climate change scenarios to develop scenarios for future ocean conditions and for stream temperature and flows, in order to estimate how Pacific lamprey and Pacific eulachon population viability will respond to climate change scenarios.

In addition to this, we will also link large scale climate signals to localized signals for the species being studied, and develop possible physiological mechanisms (aerobic scope mechanisms) that would explain a decline in survival collaborating with experts in the field from UBC and NOAA.

This work is being supported by BPA Grant on Climate change (for the cost share on the salmonid pieces), and both Dr. Nathan Mantua and Dr. Tony Farrell (UBC) will donate their time to the project.

Geographic Extent: *Describe the geographic area for both project focus and ability to extrapolate information*.

The geographic extent of this project is focused on the entire life cycle range of Pacific Lamprey and Pacific Eulachon populations of the Columbia River Basin, including the freshwater streams, rivers, and coastal where they occur inland, and the eastern Pacific Ocean and estuaries (see map Figure 1).

Timeline of Schedules, Products and Outcomes: *Provide a timeline with dates and tasks.*
Identify products and outcomes. Include key project work items and dates for events such as start-up, interim milestones, presentations, deliverables, submittal of final report, and project completion.

12/1/13: Project Start.

06/01/14: Data collated and preliminary exploratory analysis started.

12/01/14: First phase completed

03/01/15: Preliminary models developed relating climate change signals to species survival, abundance and persistence.

9/30/15: Project Complete.

Disclaimer regarding Data Sharing: *Briefly describe any known restrictions on sharing of the data expected to be generated by this project.* We reserve the right to only publish this data in a summary format, under permission of the tribes.

Budget: A completed SF-424A (Non-Construction Programs) is required for nonfederal applicants (http://apply07.grants.gov/apply/FormLinks?family=15). Federal applicants are not required to use the SF-424A; however, they should include the same budget information, including match, in their applications.

Citations:

Bakun, A. 1996. Patterns in the Ocean. California Sea Grant. 323 pp.

Crozier L., Zabel RW, Hamlet A.F (2008) Predicting differential effects of climate change at the population level with life-cycle models of spring Chinook salmon. Global Change Biology 14: 236-249.

Elsner MM, L Cuo, N Voisin, J Deems, AF Hamlet, JA Vano, KEB Mickelson, SY Lee, DP Lettenmaier (2010) Implications of 21st century climate change for the hydrology of Washington State. Climatic Change 102(1-2): 225-260

Isaak DJ, S Wollrab, D Horan, 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

Logerwell, L., Mantua, N., Lawson, P., Francis, R. and Agostini, V. 2002. Tracking environmental process in the coastal zone for understanding and predicting Oregon coho (*Oncorhynchus kisutch*) marine survival. Fisheries Oceanography Vol. 12 (6).

Logerwell, L., Mantua, N., Lawson, P., Francis, R. & Agostini, V. 2003. Tracking environmental process in the coastal zone for understanding and predicting Oregon coho (*Oncorhynchus kisutch*) marine survival. *Fisheries Oceanography* **12**, 554-568.

Mantua, N, J Beetz (In Progress) Quantitative tools for evaluating the effects of climate change on the population dynamics of pacific salmon. Current Research: University of Washington Climate Impacts Group/NOAA Fisheries.

Peterson, W, T. and Schwing, F.B. 2003. A New Climate Regime in Northeast Pacific Ecosystems. Geophy. Res. Letters 30: 6-1:6-4.

Peterson, W.T., Hooff, R.C., Morgan, C.A., Hunter, K.L., Casillas, E., & Ferguson, J.W. (2006). Ocean conditions and salmon survival in the northern California current. Web document, http://www.nwfsc.noaa.gov/research/divisions/fed/ecosysrep.pdf

Quinn, T. P. 2005. The Behavior and Ecology of Pacific Salmon and Trout. University of Washington Press, Seattle.

Schwing, F.B., O'Farrell, M.,Steger, J.M., and Baltz, K. 1996. Coastal Upwelling Indices West Coast of North America 1946-95. NOAA-TM-NMFS-SWFSC-231. PFEL, Pacific Grove, CA.

Sharma, R., Velez- Espino, A., Wertheimer, A., Mantua, N., and Francis, R.C. 2013. Relating Spatial and temporal variability of climate and ocean variability to survival of Pacific NW Chinook. *Fisheries Oceanography* 22:14-31

Smith, T.M. and Reynolds, R.W. 2004. Improved extended reconstruction of SST (1854-1997). Journal of Climate 17: 2466-2477.

Trudel, M., Fisher, J., Orsi, J.A., Morris, J.F.T., Thiess, M.E., Sweeting, R.M., Hinton, S. Fergusson, E.A., & Welch, D.E. 2009. Distribution and migration of juvenile Chinook salmon derived from coded wire tag recoveries along the continental shelf of western North America. *Transactions of the American Fisheries Society* **138**, 1369-1391

University of Washington Climate Impacts Group (UWCIG) (2010) Hydrologic Climate Change Scenarios for the Pacific Northwest Columbia River Basin and Coastal Drainages. http://www.hydro.washington.edu/2860/

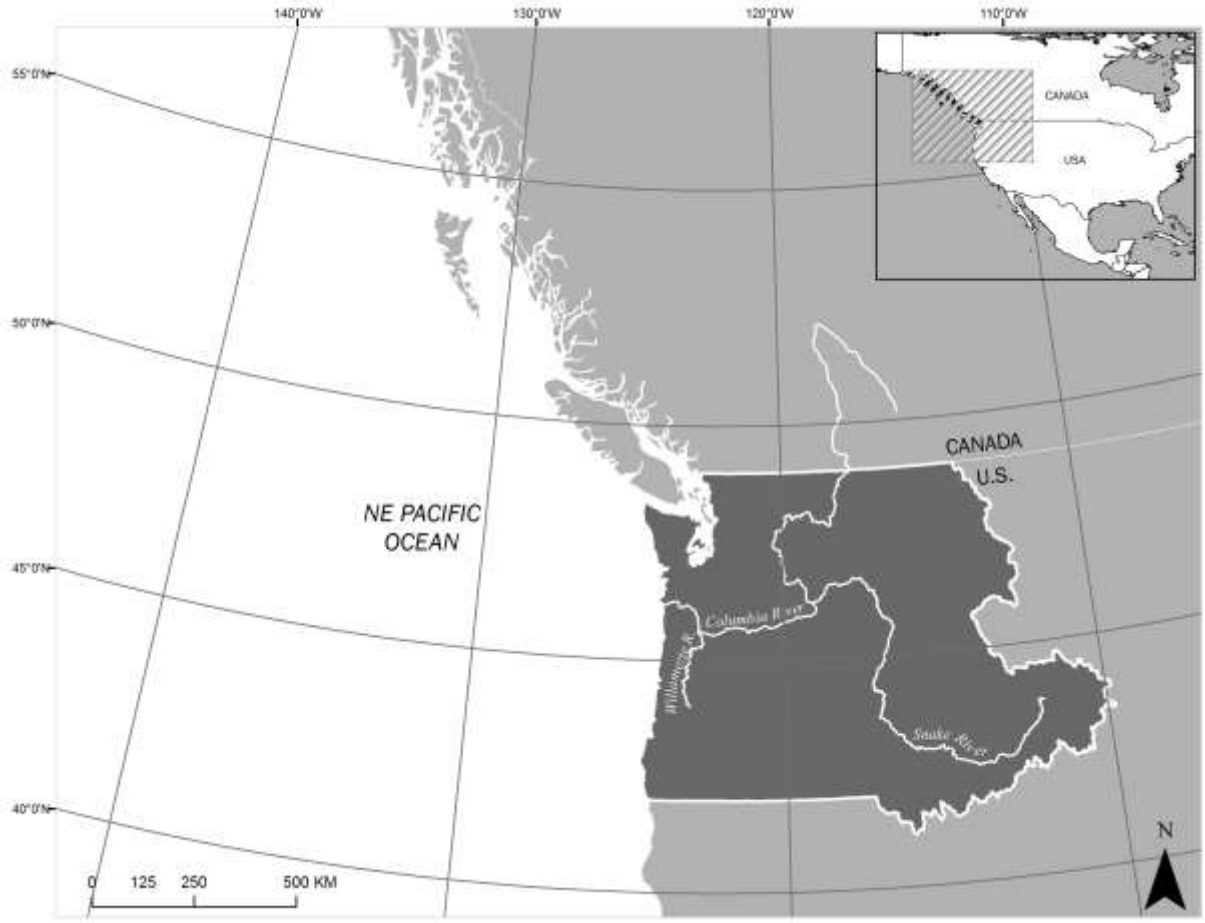

Figure 1: map of the study region being proposed