



## **Nooksack Indian Tribe: Rivers and Glaciers — Keeping salmon and the ecosystem healthy in light of climate change and distressed ecosystems**

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The Nooksack Indian Tribe resides in the Northwest tip of Washington State. Their homeland extends throughout the Nooksack River watershed. This area includes an area from the Georgia Straight (Salish Sea) to Mount Baker (west to east) and from just over the border of British Columbia down to Skagit County, WA. Additionally, traditional use and management areas extended beyond these boundaries; some of these areas were shared between the Nooksack Indian Tribe and other indigenous peoples such as the Lummi Nation. Today, the Tribe is headquartered in Deming, Washington, 15 miles east of Bellingham. This profile draws on the work of the Nooksack Indian Tribe to address climate change impacts on the hydrology of the Nooksack River and salmon survival and recovery. These efforts include the recent study by Grah and Beaulieu (2013), which is included in the recently published special issue of [Climatic Change](#) dedicated to issues facing tribal people as well as a summary of this work in the Tribal Chapter of the [Northwest Climate Assessment](#).

### ***Tribal Concerns: Climate Change Impacts on Nooksack River Hydrology and Pacific Salmon***

In response to concerns about the Nooksack River and the glaciers that drain into it, the Nooksack Indian Tribe is undertaking efforts to address climate change and its impacts on Nooksack Usual and Accustomed lands and its people. In a study on changes to glaciers feeding the Nooksack River watershed caused by climate change, Grah and Beaulieu (2013) state that *“the possible extinction of salmonids, particularly spring Chinook salmon, from the Nooksack River is unacceptable because the Tribe is dependent on these species, and being place-based, the Tribe cannot move its geographic base or homeland to where salmon will be located under future climatic conditions.”*

The acknowledgement that the Nooksack people cannot simply move in response to climate impacts has motivated the Tribe to act to protect their lands, treaty resources, and people. The Nooksack Indian Tribe is focusing on degraded salmon habitat and maintaining harvestable levels of salmon in the face of climate change. Specifically, the Tribe is exploring climate impacts facing their lands as a way to address the continued health of salmon: riparian ecosystem health, stream and river temperatures, sediment loading in the watershed, and impacts of climate change on glaciers and the hydrology of the Nooksack River. Salmon in the Nooksack River are already severely stressed by a variety of factors including wide scale-watershed alteration by forest practices, channelization of the

river, pollution and human-induced habitat loss.

Climate impacts, therefore, have the potential to cause major additional harm to salmonid populations in the Nooksack River. Mitigating the impacts of climate change is therefore an integral part of ensuring that the Nooksack watershed is able to continue supporting salmon at harvestable levels.



Logjams restore habitat for juvenile salmon on the Nooksack River. Photo Credit: Oliver Grah

### ***Nooksack Tribe’s Response to Climate Concerns***

In response to mounting climate impacts, the Nooksack Indian Tribe is undertaking several efforts. The Tribe is collaborating with the Environmental Protection Agency (EPA) on a pilot research project investigating how to meet water temperature Total Maximum Daily Load (TMDL) standards for the Nooksack River so that the TMDL takes into account climate impacts and legacy impacts to salmon, and

how to plan habitat restoration projects that are robust and effective in the face of climate change. This effort will help inform salmon habitat restoration efforts on how to prepare for likely climate change. The Tribe is also researching the effects of climate change on glacier survival in the Nooksack River watershed. Glaciers comprise a critical part of the hydrological system in the watershed, and impacts to glaciers will alter the flow rates, water temperature, and seasonality of flow in the Nooksack River and other rivers. In particular, climate change will likely further reduce late summer flows and increase water temperatures at a time that is most critical to the survival of spring Chinook salmon. Below is a description of both of these efforts in more detail.

#### *Collaboration with EPA for TMDL/Climate Change pilot research project*

The Nooksack Indian Tribe has determined that existing methods of performing the temperature TMDL project do not adequately address concerns around salmon habitat and health. The water quality standard for temperature is based on the beneficial use of several species of salmon habitat and fish survival. A TMDL is the maximum amount of pollutant that a river can absorb and still meet water quality standards. Current TMDL standards do not adequately take climate change impacts into account nor do they address habitat restoration as a tool to facilitate temperature reduction and species recovery. The Nooksack Indian Tribe has identified that the challenges salmon face due to pollution, coupled with emerging climate impacts, will pose serious obstacles to salmon health in the future. Given that the TMDL is designed to protect water quality in rivers, and that climate impacts will effectively reduce the quality of the Nooksack River by making it less habitable for salmon, the Tribe hopes to develop restoration strategies that facilitate compliance with the TMDL and that help salmon survive in the face of climate change.

There are several intersecting limitations to current TMDL implementation. In addition to not addressing climate change in any fashion, the TMDL for the Nooksack River also does not directly address watershed health. The TMDL for the South Fork Nooksack River was implemented without taking into account other ecosystem services that also relates to stream temperature and health of the Nooksack watershed; it instead limited baseline measures of river health (e.g., riparian shading) to the buffer area immediately around the river. Therefore, it was limited in its capacity to address how restoration would change the baseline of river health. The Tribe is collaborating with the EPA, Washington Department of Ecology, and Tetra Tech to develop a better understanding of how to integrate restoration planning and climate change impacts into future TMDL implementation, both for the Nooksack River and as a potential improvement for the TMDL model as a whole with application to other similar watersheds.

The Nooksack Tribe has identified mitigating currently excessive river temperatures and temperature increases and lower flows as a result of climate change as key to maintaining salmon health and harvestable quantities. Including climate change impacts in the TMDL and taking steps to restore salmon habitat in the face of climate change will help Nooksack people to adapt to and mitigate climate change impacts.



Ongoing restoration efforts have positive effects on the water quality of the Nooksack River.  
Photo Credit: Oliver Grah



Glaciers on Mount Baker. Photo Credit: Oliver Grah

### ***Glacier ablation rates and effects on stream flows***

Glaciers are a critical aspect of the Nooksack River watershed hydrological system. Glacier melt in the mid- to late summer provides a large portion of river flows at a particularly critical time for spring Chinook salmon. Glaciers in the region and within the Nooksack River watershed are already being substantially impacted by climate change. For instance, some of the glaciers on Mount Baker have receded over 1,000 feet in the last 20 years. This represents a substantial reduction in ice volume. At present rates of glacial melting, several glaciers that feed the Nooksack River watershed may disappear completely. With current trends in the reduction of glaciers and predictions with continued climate change, river flows in the mid-

to late summer will be further reduced and temperatures will increase, creating even larger challenges to salmon survival. Given the drastic changes that this would have on river hydrology and the health of the riparian zone, and given the additional challenges this would pose to mitigating the past impacts of land use on riparian and stream habitat, the Tribe has undertaken a study to better understand how glaciers are currently ablating, how this is affecting stream and river health, and what this will mean for salmon health in the face of climate change.

### ***Climate Trends for Glaciers***

The glaciers that feed the Nooksack River watershed are found on Mt. Baker, Mt. Shuksan and other nearby peaks in the North Cascades. On Mt. Baker alone, at least eight glaciers feed the watershed. There are approximately 148 glaciers, glacierets, and perennial snowfields with a combined area of 40,828,294 m<sup>2</sup> (15.76 mi<sup>2</sup>) that drain into the Nooksack River, most of which are unnamed. Thus, glaciers provide a substantial source of water to the Nooksack River during the melt season, in August and September. The study used existing monitoring data to investigate current rates of glacial loss and changes to precipitation and snow accumulation and melt patterns that glaciers rely upon. Over the last fifty years, annual snowpack has decreased by 25% in the North Cascades, due to both increasing temperatures and reduction in precipitation. More precipitation is falling as rain instead of snow, which has led to a subsequent decrease in glacial mass, and has in turn altered stream flows.

Long term trends from local weather stations indicate that mean annual air temperatures in the Nooksack watershed have increased by 1.4°C (2.5°F) from 1895 to 2010 (Grah and Beaulieu, 2013), although the amount of increase varies by monitoring station. Consistent with regional trends, summer temperatures have increased 1.7°C (3°F) and winter temperatures have increased 1.1°C (2°F) from 1895-2010 (Grah and Beaulieu, 2013). As the Nooksack River watershed has a maritime climate, it has experienced less temperature change than is typical in the region. An important difference from regional climate trends is that summer precipitation has increased in the Nooksack watershed by 11%, while winter precipitation has decreased by 26%. This is unusual, as regional Northwest climate projections indicate that typically summer precipitation will decrease, and winter precipitation will increase (Snover et al., 2013).

Shifting precipitation patterns and increasing temperatures are causing a decrease in glacier mass and extent. The melting season is occurring early and not lasting as long as in recent history in the North Cascades, while at the same time less snow is accumulating. These factors together mean that glaciers are rapidly melting. Previous studies have found that in the North Cascades, as much as 75%

of all glaciers are melting and will continue to melt (Pelto, 2008; Riedel and Larabee, 2011). Current monitoring projects indicate that many of the smaller glaciers on Mt. Baker and throughout the North Cascades are unlikely to survive current warming trends. In response to this data, the Tribe has begun to conduct monitoring studies of glaciers that have particular importance to Nooksack River watershed health. The Nooksack Indian Tribe is collaborating with the University of Washington to model glacier behavior in response to climate change. The field data that the Tribe is collecting will be used in the glacier modeling effort. Results of this work will feed into modeling of altered hydrology of the Nooksack River in response to climate change.

### *Impacts to the Nooksack River*

Changes to glacier mass and ablation will subsequently impact river and stream flows, water temperatures, and sediment dynamics, which will ultimately have the potential to dramatically alter salmon habitat. Existing data summarized in the study has found that average summer streamflow for the Nooksack River has decreased nearly 30% between 1963 and 2003, while winter streamflow increased only 1%. As meltwater from snowpack and glaciers makes up approximately 30% of summer flows for the Nooksack River, changes to the amount of snowmelt and glacier melt have serious implications for streamflows.

Given the glacial retreat, earlier melting snowpack, and reduced area of snow accumulation, rivers are likely to experience earlier spring runoff and prolonged low summertime flow conditions in the face of climate change. This will create a change in the seasonality of stream and river flows in the watershed, with peak flow starting earlier in the year as well as stream flows tapering off earlier in the year. For example, April to September runoff is projected to decrease by up to 28% by the 2040s and by 40% by the 2080's (Snover et al., 2013). However, peak discharge in the winter may increase approximately 30% as a result of climate change. According to existing climate modeling, the impacts to summer flows will not be uniform throughout the watershed. Fine-scale modeling projects suggest that some areas of the watershed will suffer more substantial decreases in summer flows than others. For the next 20 years, there will likely be accelerating glacier melt in response to reduced snow accumulation and warming temperatures. As a result, there may be a temporary increase in glacier melt that may increase late summer flows. However, over the long run, as the glaciers further retreat and the mass of ice available to melt greatly decreases, late summer flows will likely decrease by approximately 40 percent. The Tribe is collaborating with Western Washington University to model altered Nooksack River watershed hydrology caused by climate change. The glacier modeling previously mentioned will be linked to this modeling effort. The results of the hydrology modeling work will be used to assess impacts to salmon and salmon habitat, and subsequently used in salmon habitat restoration planning.

Existing sediment dynamics will also be altered with continued climate change. As glaciers continue to melt, sediment trapped in the ice or at the forelands of the glaciers will be carried downstream. With increased rain-on-snow events and increased frequency, magnitude and intensity of precipitation, there will be an increased frequency of landslides at these forelands due to supersaturated sediment and soil. These effects in addition to legacy impacts from land use, agriculture, timber harvest, and channelization of the river, will cause heightened levels of suspended sediment and gravel in streams in rivers that has the potential



Ablating Sholes Glacier on Mount Baker.  
Photo Credit: Oliver Grah

to clog salmon spawning gravels, remove riparian buffers that provide shade, increase heat loading via conduction, and cause biological harm to fish. Current estimates of suspended sediment and bedload concentrations in the Nooksack River are underway, which will inform best management practices in the watershed as well as salmon habitat restoration.

### *Impacts to Salmonids*

The Nooksack River watershed is habitat for nine species of indigenous salmonids. Salmon runs in the Nooksack River are already severely depleted. While exact counts are not available, they are estimated to be between 2% and 8% of runs during the late 1800's. In part because salmonid populations in the Nooksack River watershed are already so stressed by existing watershed impacts, or legacy impacts, climate impacts have some serious implications for salmonid habitat and health in the future. A main concern facing salmonids today is habitat degradation, altered hydrology, and increased critical time (late summer) water temperatures. Climate impacts have the potential to further degrade salmon habitat by altering sedimentation quantities, timing, and patterns. Additionally, increasing water temperatures are projected to adversely alter thermal refugia that salmonids depend upon and on the biology of salmon. The reduction in snowmelt and glacial runoff will further exacerbate temperature increases. These cold water late season sources of water help to keep the Nooksack River watershed's rivers and streams cool, and reductions in their flow are projected to further increase water temperatures. Given that the Nooksack River is already listed as Clean Water Act Category 5 on the federal Clean Water Act 303(d) list—it has already been flagged for its high temperatures—climate impacts may have serious implications for salmonid health.

Existing research on climate impacts and salmon health indicate that for situations such as the Nooksack River watershed, immediate effective habitat restoration may considerably ameliorate climate impacts. Potential restoration strategies include restoring floodplains, providing access of the river to its floodplain, restoring hydrology to floodplain wetlands, re-foresting riparian zones, and restoring flow regimes for streams and rivers. Currently, the Tribe is focusing on engineered log jams as a means to provide coldwater refugia for salmon during the late summer critical times when flows are the lowest and water temperatures are the highest. The Nooksack project team notes that these strategies have potential to moderate climate impacts to salmonids in the watershed.

### ***Moving Forward***

The work of the Nooksack Indian Tribe utilizes science to address unresolved issues in climate change planning and policy in the Nooksack River watershed. The Nooksack Indian Tribe's work to address glacier ablation, altered hydrology, reduced summertime flows, and increased temperatures, and to modify restoration strategies to be more effective in the face of climate change highlights how science and policy form a vital part of addressing climate impacts for tribes. The Nooksack Indian Tribe identifies the loss of salmon as a result of climate change as "unacceptable" because of the immense cultural, subsistence, and economic importance of salmon to Nooksack people. This strong statement about the health of both salmon and the Nooksack people guides the work of the Tribe in addressing climate change. The Nooksack Tribe brings together indigenous perspectives on the importance of salmon with scientific research and environmental standards. From this perspective, the Tribe has identified habitat restoration and other actions to reduce existing stressors on salmonids as the best strategy to ensure the continued health of salmonids moving forward. Tackling climate issues from multiple angles facilitates successful adaptation for the Tribe by enabling them to aid salmonids as they persist in a changing climate.

## Resources:

Nooksack Tribe. <http://www.nooksacktribe.org/>

Grah O, Beaulieu J (2013) [The effect of climate change on glacier ablation and baseflow support in the Nooksack River basin and implications on Pacific salmonid species protection and recovery](#). Climatic Change. DOI 10.1007/s10584-013-0747-y.

Lynn et al. (2013) Chapter 8: Northwest Tribes: Cultural Impacts and Adaptation Responses. In: Dalton, M.M., P.W. Mote, and A.K. Snover [Eds.]. 2013. [Climate Change in the Northwest: Implications for Our Landscapes, Waters, and Communities](#). Washington, DC: Island Press.

Pelto, M.S. 2008. [Impact of climate change on North Cascade alpine glaciers and alpine runoff](#). *Northwest Science* **82** (1): 65-75.

Riedel, J., and M. A. Larrabee. 2011. [North Cascades National Park Complex glacier mass balance monitoring annual report, Water year 2009: North Coast and Cascades Network](#). *Natural Resource Technical Report NPS/NCCN/NRTR—2011/483*. National Park Service, Fort Collins, Colorado.

Snover, A.K., G.S. Mauger, L.C. Whitley Binder, M. Krosby, and I. Tohver. 2013. [Climate Change Impacts and Adaptation in Washington State: Technical Summaries for Decision Makers](#). State of Knowledge Report prepared for the Washington State Department of Ecology. Climate Impacts Group, University of Washington, Seattle.

*For more information, please contact:*

Oliver Grah  
Water Resources Program Manager  
Nooksack Indian Tribe Natural Resources Department  
P.O. Box 157, Deming, WA 98244  
360-592-5176  
[ograh@nooksack-nsn.gov](mailto:ograh@nooksack-nsn.gov)

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### ***Tribal Climate Change Profile Project:***

The University of Oregon Environmental Studies Program and the USDA Forest Service Pacific Northwest Research Station are developing tribal climate change project profiles as a pathway to increasing knowledge among tribal and non-tribal organizations interested in learning about climate change mitigation and adaptation efforts. Each profile is intended to illustrate innovative approaches to addressing climate change challenges and will describe the successes and lessons learned associated with planning and implementation. For more information about the PNW Tribal Climate Change Project, contact Kathy Lynn at [kathy@uoregon.edu](mailto:kathy@uoregon.edu), or visit <http://tribalclimate.uoregon.edu/>.

Carson Viles, a University of Oregon undergraduate research assistant with the Project, is coordinating development of these profiles. Carson is an enrolled member of the Confederated Tribes of Siletz Indians. He is in the Clark Honors College and is pursuing a degree in Environmental Studies. Carson can be contacted at [cviles@uoregon.edu](mailto:cviles@uoregon.edu).