

Indigenous Nations' Access to Geospatial Climate Change Data:
The case of the Lummi Nation

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Abstract

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This thesis examines the availability and necessity of climate change data to Indigenous communities, using the Lummi Nation as a case study. The research centers on three main impacts to Lummi waters: sea surface warming, flood vulnerability, and shoreline erosion, which are likely to disproportionately impact Indigenous communities. To analyze these changes, I use a combination of ArcGIS Pro and Google Earth Pro with satellite, aerial, and state and federal GIS data. I then explore the changing water characteristics with what they mean to the Lummi Nation's way of life, and Tribal treaty rights, and the tribe's 2016 climate change report. I find that current public climate data is lacking in a variety of factors and will require more work by state and federal scientific agencies to ensure its usability in Indigenous communities. The analysis utilizes a critical physical geography perspective and Indigenous methodologies explain the need for accessible climate change data from local, state and federal agencies without demands of reciprocity as a way of honoring the Treaty of Point Elliot and demonstrating a contemporary approach to data sovereignty

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Recognition

This work seeks to thank and extend respect and collaboration to the peoples who have called these lands home since time immemorial. As I seek to do decolonial work outside of my own Cherokee Nation's lands, and the lands that we were forcibly removed to, I find it of utmost importance to do critical work for those of the land I inhabit and benefit from. I hope my acknowledgements do not ring empty alongside my work. I acknowledge the Duwamish, Suquamish, and Muckleshoot people of the Seattle area, and the Lummi Nation whose homelands are the site for my research.

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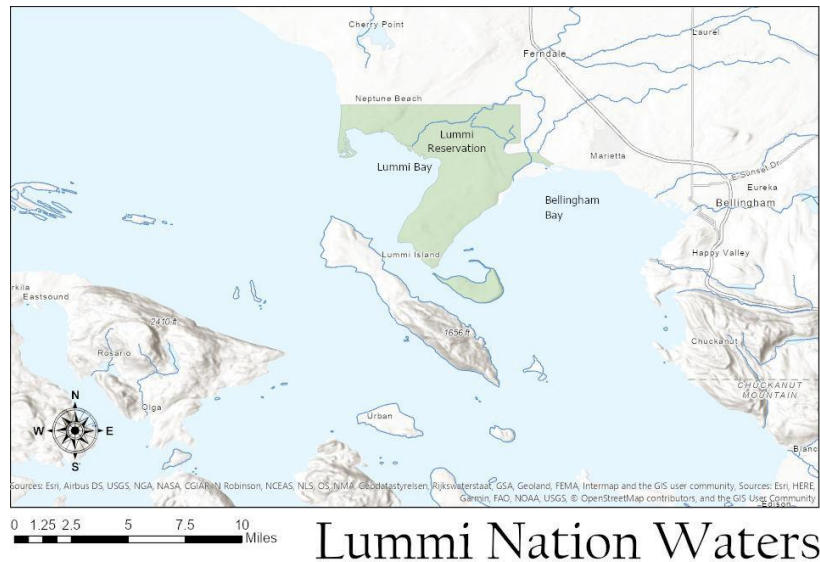


Figure 1: Lummi Nation Reservation and Surrounding Waters (All figures created by author unless otherwise stated)

Abstract

This thesis examines the availability and necessity of climate change data to Indigenous communities, using the Lummi Nation as a case study. The research centers on three main impacts to Lummi waters: sea surface warming, flood vulnerability, and shoreline erosion, which are likely to disproportionately impact Indigenous communities. To analyze these changes, I use a combination of ArcGIS Pro and Google Earth Pro with satellite, aerial, and state and federal GIS data. I then explore the changing water characteristics with what they mean to the Lummi Nation's way of life, and Tribal treaty rights, and the tribe's 2016 climate change report. I find that current public climate data is lacking in a variety of factors and will require more work by state and federal scientific agencies to ensure its usability in Indigenous communities. The analysis utilizes a critical physical geography perspective and Indigenous methodologies explain the need for accessible climate change data from local, state and federal agencies without demands of reciprocity as a way of honoring the Treaty of Point Elliot and demonstrating a contemporary approach to data sovereignty.

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Introduction

The Lummi Nation is actively engaged in climate change mitigation and planning (Lummi Nation, 2016). As citizens of both state/federal governments in the United States and their own Nations, Indigenous communities in the United States grapple with complex layers of information and limited access to data. Climate change and environmental data management is one area where state, federal and tribal governments must organize together on lands of occupation and residence. For their part, government agencies of the federal branch and states have an obligation to provide data for communities to create systems of survival – as both a moral duty and a treaty obligation. For Indigenous communities, that means more than keeping food and clean water in access, and ties in a complex system of cultural and spiritual needs to maintain existence in connection with the resources of a region, and for tribes with treaties like the Lummi Nation, threatens to unravel the promises of natural resource access maintained in treaties.

However, as communities face the threat of climate change impacts, the dearth of data that is easy to find, use, and is comprehensive in geographical scope demonstrates a severe shortcoming in environmental agencies across settler U.S. governments. This research seeks to answer the broad question – *what are the possibilities and limitations of existing available federal and state climate change data* -- through the case of the Lummi Nation. In order to review current data meeting tribal needs, I examined current climate change data and compared it to the Lummi Nation climate change report. I found that the existing climate change data for Washington state can be difficult to find on a localized scale necessary for communities to see how climate change may specifically impact their reservation or lands.

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This research is significant because it reveals a gap in widely available regional data for Indigenous Nations to utilize as they face environmental and cultural changes. Facing difficulties of siloed data, broken links, and settler government data sites that don't give in depth metadata or let you download data restricts Indigenous policymakers and researchers from fully utilizing the data at the hands of settler governments. While access to data is extremely limited, the effects of climate change are broad and will disproportionately affect tribal Nations on treaty lands. I draw on Indigenous Studies to call for access to – and sovereignty over – climate change data that is a tool that Indigenous Nations can use to mitigate climate change harms while protecting the confidentiality of their sovereign territory.

Lummi Recent History in Water Resources

The Lummi Nation is an Indigenous community in present day Washington state. Their name is *Lhaq'temish*, or “People of the Sea.” The reservation lands rest north of Seattle, along the Salish Sea, or the inland waters called the Puget Sound in western culture. While the ancestral lands and waters stretched up and down the Salish Sea and between the waters and Cascade Mountain Range and west of Mount Baker (*qwú'mə kwəłshé:n* in Lummi)- the current reservation lands exist to the west of the city of Bellingham, Washington. The reservation consists of a total of approximately 20,000 acres of uplands and tidelands- ranging from sandy beaches to forested dry land. The reservation consists of miles of shoreline along Lummi and Bellingham Bays (Lummi Nation, 2016).

In recent history, The Treaty of Point Elliot at once removed the Lummi people from their lands and allocated their current reservation lands near Lummi Bay and Bellingham Bay. The Lummi reserved a measure of marine territoriality through the explicit rights to fish in

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“usual and accustomed” areas, with the notable exception of shellfish, from any American citizen’s declared land (Treaty of Point Elliot, art. 2, 5 {1859}). While the Lummi reservation consisted of a reduced amount dry land control to the small region shown in Figure 1, the “usual and accustomed” fishing areas stretched across the Salish Sea, sparking pushback from settler fisheries and governmental agencies in Washington state. Controlling the fisheries, the shellfish, and the waters was a power grab by the state that attempted to disempower Native nations, disempower the federally mandated treaty and court decisions, and strip the Lummi and Coast Salish nations of much of their culture. “...to be a Lummi meant to be involved with the sea, the water, the fish, the shellfish, and the traditional lands of the tribe (Deloria 1978: 89).” Not only integral to food security, the fish of the Coast Salish waterways were also part of the Lummi identity, and the reduction of access to their identity meant easier assimilation and control by state and federal government. Eventually, the Lummi and other Coast Salish peoples won back limited recognition of their marine rights and access to fish in multiple court cases, particularly the US v. Washington Boldt decision (Brown 1994; Frank, 2011; Reid 2015). The state of Washington has provided limited restitution, including funding for salmon hatcheries and increased recognition of Coast Salish peoples as “co-managers” of the hatcheries and the waters necessary for salmon life. Despite the theft of access to the waters due to colonization, the Lummi have maintained their cultural and community ties to the waters, not only through traditional food harvesting, but through community celebrations, recreation, and celebration.



Figures 2 and 3: Author's images from Paddle to Lummi, 2019

Present Day Water Cultural Significance

While travelling by canoe had long been a part of Coast Salish cultures, the 1989 “Paddle to Seattle” was a crucial moment of cultural revitalization that helped renew the traditional canoe journey for the modern communities around so-called Seattle (Johansen, 2012). Since then, the event has gained popularity and recognition far beyond the boundaries of Coast Salish communities, including non-natives and natives from around the globe. In July 2019, the Lummi Nation, joined by citizens of Coast Salish, and numerous other North American and global Indigenous communities celebrated the culmination of a weeks-long canoe journey of paddlers from across the assortment of tribes. The 2019 Paddle to Lummi, or “Sqweshenet Tse Schelangen / Honoring Our way of Life” gathered thousands of spectators and community members to watch the paddlers pull in at the final stop on the beaches of the Lummi Nation, celebrate the communities’ connections to each other and to the water, as well as join together in dance, song, and ceremony (PaddlettoLummi.org, 2019). As the canoes pulled up to the

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shorelines of the Lummi Reservation, I cheered with the others, passing out sack lunches to the tired, smiling paddlers flexing their creaky joints as they got out of their family canoes. The 2019 Paddle to Lummi was just one event of the year's "Canoe Journeys" on the west coast of the United States. Hundreds of paddlers in their canoe families spend weeks on their canoes, traveling from their homelands or a designated starting area and paddle daily, stopping at Indigenous communities' pit-stops that include potlatch celebrations and ceremonies and shelter the paddlers for their strenuous journey ahead. Figures 3 and 4 are images taken from the landing beaches of the Paddle to Lummi during the 2019 canoe journey, showing a very small portion of the canoes that brought the paddlers to the Lummi reservation at the end of their journey.

The cultural connection that the Lummi and many other Coast Salish Indigenous nations experience from the waters has been utilized to address mental and physical wellbeing in Indigenous communities through the practice of Canoe Journeys, like the Paddle to Lummi (Donovan et al., 2015). Before the Paddle to Seattle, the Lummi Nation had long been honoring their community and its connection to water through canoe culture. Created in 1946 to welcome Lummi veterans back into the Lummi community, the Lummi Stommish Water Festival combines Lummi water, war veterans, and canoe culture in a large summer celebration (LummiNationStommish.com, 2020). Lummi citizens and the regional community come together to perform traditional dances, cook salmon, and race canoes in the waters. Access to those waters, for canoeing, ceremony, or food is essential to the Lummi community, it is not just a source of income or land-holding power (Coulthard and Simpson 2016; Reid 2015). In summer 2019, I attended the Paddle to Lummi, to experience firsthand some of the traditions and connections to water. I volunteered alongside Lummi citizens and non-Lummi people from neighboring communities. Each conversation I had, whether with a Lummi person or not, was

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directed towards the connection of the Lummi to the water, their stewardship of the lands, and their use of the resources from the waters, such as the seafoods we were preparing for each days' meals. As recognized by tribal leaders, fishing rights, which require access to the water often through the use of canoes, are an essential aspect of Coast Salish life, bringing economic and cultural gains through returning citizens, expanded education, and reinvestment in well-being and social values (Cantzler & Huynh, 2016). The community heavily relies on the health of the waters to maintain their powerful culture and community ties. Without healthy waters, the Lummi will have to dramatically alter their entire way of life.



Figure 4: Wetland Classification of Lummi Reservation Area Using USFS National Wetlands Inventory Data

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Climate Change and the Lummi Nation

Climate change will impact all inhabitants of Washington state, but for the Lummi Nation, these impacts could deal a heavier blow to their culture, economy, and way of life than to non-Indigenous residents. Acidification and hypoxia will likely contribute to large die-off events of sea life that the Nation relies on, disrupting the entire food chain and system that feeds the salmon, clams, and other traditional foods. Salmon of the Salish Sea currently face threats of habitat loss and degradation resulting from changes in their environment, whether from climate change or direct human influences, leading to a decline in their populations and changes in their life cycles (Lummi Nation, 2016). Species diversity is decreasing, as organisms not able to function in changing waters die out or migrate (Nesbitt, 2015). As life in the waters becomes more difficult, it is likely that only the most adaptable of aquatic species will survive, completely changing the food system and the biome of the bays. With the loss of their own food security, salmon and whales can starve, or simply not come back to their traditional waters. A large piece of Lummi identity could be taken with them, starving a community of its traditional foods, and its cultural core. Not only do the federal and state government owe it to the Lummi Nation and other Tribal entities with legally binding treaties to protect the access to their agreed upon environmental rights, but they owe it to them as American citizens as well, acknowledging that maintaining or protecting Tribal waters and lands is protecting and maintaining American lands as well. Climate change cannot be constrained to geographical borders drawn on a map, and the environmental degradation to the Indigenous communities will harm non-Indigenous Americans as well. By ensuring that tribes have joint control over and access to the environmental data creation and management of state and federal agencies, tribes can better prepare or mitigate the climate challenges ahead.

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The Lummi waters that will be impacted are not just the ones in the Salish Sea. The Lummi Nation reservation consists of over 40% wetlands. Figure 5 shows the diversity of the wetlands contained within the reservation. These wetlands are also at higher vulnerability to being degraded or inundated by seawater during sea level rise or flood events. If damaged, these wetlands could no longer support habitats for crucial fish, shellfish, and wildlife species, as well as become less effective or ineffective as natural flood control barriers. (Lummi Nation CCMAP, 2016) These wetlands are just as important as the more publicized seas and oceans that dominate regional and national datasets, supplying habitats and necessary biological processes that keep the ecosystem running (Osland et al., 2016). When considering the impact of climate change on the lands of the Lummi Nation, the wetlands must be studied due to their sensitivity to chemical changes and existence as a transition area between land and sea.

Critical Physical Geography and Water

My theoretical perspective draws on Indigenous Studies and Critical Physical Geography (CPG). Javier Arce-Nazario states that for Critical Physical Geography to focus on water issues, it is important to recognize the power dynamics shaping the characteristics of the water, not just on the standard measuring tools of water management. By reevaluating geographic methods of studying water resources, geographers can move forward on better implementing the goals of environmental justice and equity (Arce-Nazario, 2018). By including Indigenous perspectives, geographic scholars and researchers can get a better understanding of changes occurring within watersheds, but also move forward with more environmentally equitable policies for the original land stewards of North America.

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While Indigenous Studies and critical physical geography are two disciplines that are rarely in conversation, both of these affords an openness to exploring the interdependence of human/non-human relationships that are exemplified in the Lummi Nation's climate change planning. CPG, according to Lave et al (2018, 6), "allows us to investigate material landscapes, social dynamics, and knowledge politics together, as they con-constitute each other." This language of CPG, however, is something that is not a new, investigative tool to many Indigenous communities and families, such as my own. When in conversation with my Cherokee family, references to our "lands" in northeastern Oklahoma always included the streams, ponds, and other water-based features that maintained the ecosystems of the area. Never once did my family's conversations or trips to the land consist of a clear separation between the "uses" of the lands. We set up tents in the same spot where my grandfather's childhood home used to stand, within a grazing area of the cattle, and a short walk to either fishing ponds or the local graveyard situated in a corner of our farm that the family had opened to the community to lay their loved ones to rest. The same space where economic resources were gained (the cattle, from a local rancher who leased the land from us) was where my family's history still grew. Oral histories were told of my living and dead family, while my parents and grandparents taught us how you catch crawdads in a muddy stream, or what plants were poisonous or edible and any stories the land covered in cow patties held, of bootlegging and rebellion, of survival and perseverance. My experience of the land was not of an entity separate from cultural knowledge. My cultural knowledge was not separate from the grounds beneath my feet or the crawdads dipping into the red clay. For many Indigenous communities, critical physical geography is not an innovation, it is a part of our experience of our communities and the world around us. Critical physical geography is simply a perspective that has been with Indigenous communities since time

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immemorial. As geographers continue in CPG, it is critical that they look into Indigenous epistemologies as they have likely already addressed “new” research from critical physical geographers.

I use the term “lands” to describe not only the dry lands of a region, but also its connected waterways, saturated lands, and marine environments. The term “land” is all-encompassing, and if discussing specific ecosystems, I will make note of it. “Waters” is used to describe all ecosystems containing a majority of either fresh or saltwater, including but not limited to streams, wetlands, and seas. I use this sense of relations from my own experience in my family and our connections to lands, ecological interactions, as well as Indigenous ontologies that describe connections and experiences in relation to space (Coulthard and Simpson, 2016; Daigle, 2016; Baxter et al., 2005). Just as the flora and fauna of land cannot live without water, the water that receives nourishment through the chemical and nutrient cycles cannot live without the land. This thesis uses the terms interchangeably, as they are mutually dependent.

Maps not only represent the story of lands and waterways to society; they are also viewed as the authoritative figure of land and territory (Palmer and Feyerherm, 2018). Geospatial imagery, such as that from satellite data, can be combined with cultural insights to gain a better understanding of the complex and dynamic characteristics of climate change impacts. Mark Palmer, an Indigenous Geographer, showed in his work on combining maps and cultural relationships that it is possible and helpful for geographers and Indigenous communities to work together to create more culturally relevant maps of the lands and their stories and connections to the people who live on them. By working to incorporate Indigenous knowledge into Geography and mapping, my work can help to fight against the domination of colonialist and capitalist

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thought regarding lands and waterways. With greater acknowledgement, tribes must also have greater responsibility and ability to manage their lands and waters.

Indigenous Methodologies

In traditional agrarian political ecology, elements of nature, such as water, plants, animals, and others that human life depends on, can be considered property, and objects of ownership. Those who “own” the resources gain power (Wolf, 1972). Focus is sometimes placed on the shifts of power, control, and economic gain through the lands, rather than a meaningful or cultural connection to the resources outside of power and money (Walker, 2005). Bussey et al (2016) showcase this attitude in their research on the Leech Lake Indian Reservation- when environmental stakeholders were interviewed on local fisheries, non-Indigenous environmental managers reviewed fish species by their economic value, while their Indigenous counterparts distinguished between species by their cultural and spiritual connections to the community. When the Cherokee Nation in Oklahoma sought to take control over their environmental management, federal agencies fought for power by including clauses that counted economic value decline as reasonable cause to take command of the lands back from the Cherokee. Even if the nation was returning lands and waters to healthier situations, federal rules put economic gain over ecological and cultural health (Carroll, 2014). Tribes should not have to fight western perspectives of environmental management to ensure the health and wellbeing of their region and by result, their communities. Political ecology can expand to recognize land as more than economic resources, or raw materials, like how in Indigenous cultures and perspectives of water as something that gives life, is sacred and is to be respected as its own entity (e.g., Carroll, 2015; Curley, 2019; Hoover, 2017; Sundberg, 2014).

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By reframing cultural and climate change work in the lens of Indigenous understandings, geographers and environmental scientists can better craft understandings of the changing lands and societies. By ignoring Indigenous concerns and stewardship of land, settler governments and agencies could harm Indigenous communities even more (Middleton, 2015). For Indigenous communities, their ties to their Tribe are inseparable from their ties to the land (Coulthard, 2010). This connection to the lands and waters they are tied to, as well as the vulnerability to climate change is a universal Indigenous predicament; Indigenous communities are tied to the lands, the waters, their health is our health, Indigenous communities see themselves as the protectors of the lands, as they have been since time immemorial. Biogeochemically and culturally, lands and waters are connected, and are much more than just a resource to be taken from (Carroll, 2014). An impact in the waters can lead to repercussions felt through the organisms of the land, and even change the landscape. With changing lands and waters, traditions and practices may have to change or face eradication in Indigenous communities.

For Indigenous people, natural science and culture are tied deeply into community structures. In a time of climate change science and policy, it is crucial that Indigenous people are part of the process of creating new systems and have the applicable literature and research accessible to their communities. Without access to data and understanding of the scientific and political ramifications of climate change, Indigenous communities are left in the dark (Cameron et al., 2015). With the lack of consistent data from Indigenous-held lands, state and federal ecological entities do their Indigenous counterparts a disservice, and limit communities' ability to interject in the policy-making processes. I address the benefits to Indigenous communities from geospatial environmental data in the following section on GIS and Remote Sensing.

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Indigenous political ecology utilizes geographical space to tie people, environmental knowledge, and culture together in a fabric that becomes weaker without all elements. “Water is Life” has been the rallying cry at many Indigenous environmental protests and events, stemming from the Standing Rock occupation for the KXL pipeline. That three word phrase gets to the heart of Indigenous political ecology- it’s not directly about the politics in the sense of American two-party systems, it’s not about financial gain, it’s about the water- its connection and its importance to a community, and the fierce protection of it. The fight for water rights and access is itself a battle for recognition of communities and their traditional ecological knowledge (Curley, 2019; Estes, 2019). Water is more than a commodity in Indigenous communities, it is something to honor, to rally around, and to protect for the community, for the ecosystem that relies on it, and for the future generations. However, as Indigenous communities become entangled with state and federal management practices, these Indigenous perspectives can be lost or altered to fit a more disconnected approach to resources found in western environmental management (Neville & Coulthard, 2019).

It is crucial that state and federal governments do not just give communities a “seat at the table,” but access to data so they to come up with their own analyses of the environmental change and what must be done. The idea that just allowing Native tribes to listen to the analyses of western scientists to make environmental decisions takes away agency of each individual tribe. By creating collaborative spaces for Indigenous and non-Indigenous environmental scientists and policymakers, climate science and environmental practices can open possibilities of alternative climate and environmental management methods (Carroll, 2014). Instead of having to transition Indigenous knowledge to be understood by western ecologists and policymakers which is the norm, power differentials could be changed to a more equal positioning and allow

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traditional and experienced Indigenous environmental stewardship practices (Richmond et al., 2013). One way to help with this is to provide more data, accessible data, that tribes can instead take, view, analyze, and produce solutions through their own stewardship knowledge and perspective. Having access to raw data, and funding for data collection techniques can help tribes continue to respectfully manage and engage with their resources on their terms, rather than exploitative or extractives perspectives that dominate the powerful resource management institutions currently.

Data collection and management is not new to Indigenous Nations. Through oral histories, totem poles, art, and traditions, tribes have kept their community data stored and mostly within their communities since time immemorial (Pool, 2016). Once colonization began sweeping through Indigenous communities, external settler data structures were instead forced upon Native tribes, often at the expense or destruction of former data collection and retention techniques, and even purposefully used against the tribal communities (Pool, 2016). Indigenous Data Sovereignty, on the other hand is the idea that data created on Indigenous lands should be managed by the Indigenous community of those lands (Snipp, 2016). My research sheds light on how critical it is that Indigenous nations have access to climate change data, but Indigenous Data Sovereignty illustrates the reasons why Tribes need the option to collect their data themselves, with their own chosen techniques, and not be required to share what they do not wish to, for their own reasons of security and privacy to prevent continued settler abuse of Tribes through data manipulation. Even through social media, the prevalence of information shared about tribe's practices or resources by individual members can be harmful, and I have witnessed the reexamination of what is "okay" to post to the public by Indigenous members of social media communities. For example, one user on Twitter stopped sharing language and dance information

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of the Mvskokvlke (Muscogee Creek) people in Oklahoma as their information was used by non-Indigenous people to “pass” as Native on the social media site. Another was informed by elders in her community that some of her posts on Instagram about land practices were to be held only within the community, and not shared to prevent damage to the area and cultural theft and appropriation.

While not necessarily as large-scale as something like climate change, these instances show a need to keep certain data private, and the ability for Nations to change accessibility to their data by non-community members upon realization of misuse or security risk. Access to and the management of collected information allows Indigenous communities to maintain control and independence from the settler state. By not allowing Indigenous communities to withhold data, settler agencies such as Washington State Department of Ecology of the EPA would be ignoring Tribal sovereignty and may even be considered threatening to the Tribe (Snipp, 2016). Not only must states and federal entities make data that is readily available and of use to Tribal communities to ensure maintenance of treaty rights, such as those detailed for the Lummi in regard to fishing, but they would also assist in maintaining Tribal sovereignty by supporting Indigenous communities in funding research that the tribe could maintain within itself through a form of data sovereignty. Current data collection methods by state and federal are not as connected to Tribal community realities and could be better served by being managed by the Tribes themselves (Rodriguez-Lonebear, 2016).

State and federal agencies could benefit from more accurate and appropriate data that would be collected and likely shared in regards to climate change, as Indigenous community members have better understandings of their lands and their characteristics that might impact collected information. A better way forward with climate change data collection on Indigenous

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lands would include more funding given to Tribal nations to collect data, with the understanding that the nation would maintain data sovereignty, and only share data that, in the opinion of the Tribe, was crucial to the needs of climate change mitigation, and protect any sensitive information by keeping it within Tribal data sources, and not sharing it externally.

GIS and Remote Sensing

This study seeks to analyze existing and easily accessible geospatial data that tracks environmental change to understand if it can be a viable option for Tribes facing climate change. A viable option would for Tribes would consist of easy access to find the data, including frequent data and website maintenance of the data portal, as well as sampling locations on or near the Tribes' lands to better represent the localized environmental conditions. By ensuring that Tribes have access to richly detailed environmental data, Indigenous communities can combine their own knowledge and practices within their region with the most up-to-date climate and environmental science data. With geospatial data, Tribes can use this in their own land stewardship, and possibly use the data to help prove ecological change or damage to gain funding for remedial management. "Traditional knowledge and information technology are not mutually exclusive (Taylor et al., 2017, 1)." In accessing satellite data, Indigenous researchers have an additional tool to complement their own deep cultural understandings of the ecosystems of their lands to access and track the environmental and health changes within their waters, even without the high-tech gauging systems often found on non-Native lands within the US. While some Tribes may be able to afford these tools, costs for constructing and maintaining gauging systems would be prohibitive for many communities in financial need (Snipp, 2016). So, this is where remotely sensed data from resources such as Google Earth Engine and Google Earth, and

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public governmental research should be a free and accessible source for Indigenous community water tracking, and why it is sampled in this research. The Lummi Nation is among *many* North American Tribes that has the resources to form its own geospatial and environmental assessment teams, but that is not the case for every Indigenous community. For some, the access to open-source data could be a great benefit if it could be considered to have reliable data and an easy to learn toolkit. For this project, the Lummi Nation already has this data tracked, and by first utilizing the open-source data that is out there, this research can be compared post-production to Lummi environmental records for accuracy and reliability as a test of its ability. While only one test of the resources available, this comparison can inform data creators and software developers what progress is still needed to make geospatial environmental data valid and usable for greater impact.

Radar altimetry and satellite data has been shown to be a viable resource to track the effects of climate change and social change to hydrological resources (Alsdorf and Lettenmaier, 2003). Satellites can now measure sea level height in millimeters, track algae blooms, measure temperature, and see through clouds (Tatem et al., 2009). By using satellite and aerial imagery, borders are no longer visible, and material and financial obstacles of physical data extraction are reduced. Sensitive environments can experience harm reduction if invasive data-gathering procedures are instead transitioned into remote data-collection systems such as satellite and aerial imaging. For Tribes without the workforce to complete data expeditions on their lands, remote sensing is a resource to be considered. For state and federal government or ecological organizations tracking environmental change, this could mean a less-invasive tactic to studying large swaths of land and sea that contain Indigenous reservations or properties. To retain Tribal privacy, agencies could instead send the data collection and processed data to be reviewed by

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Tribal entities to ensure that any privacy concerns could be blurred out or removed before publishing for public use while Indigenous communities could retain the untouched data for their own records.

While privacy concerns remain an issue with remote sensing data collection, its alternative of invasive physical entry, theft of objects or “samples”, or destruction of sensitive areas, and similar privacy concerns appears to be much more harmful to Indigenous lands and waterways. With funding, Tribes could use geospatial data collection technologies such as drones or aerial photogrammetry within their own agencies, removing the need for state, private, or federal interlopers on Tribal lands. With situations where it is more advantageous to keep the geospatial technology and data collection in the hands of state and federal organizations, the reduced need for physical entry could be helpful for Tribes who exercise self-determination by reserving the right to decide whether to grant physical access to scientists, as well as sending out their own scientists or employees to collect the necessary physical data verifications. Due to previous experience with non-Indigenous researchers conducting research on Tribal lands and people, many Indigenous communities can be wary of the presence and intrusion of researchers outside of their community conducting the collection of data on their lands (Austin et al., 2000; Tuhiwai Smith, 2012). For this, it is important that state and federal entities understand some communities may want this data, but may be unwilling to invite researchers to come unto their lands, and state and federal entities must be prepared to work with and be supervised by community members, or be willing to give the tribes the funding and support to conduct the data collection and processes themselves.

Methodology

In response to my understanding of core principles of critical physical geography (Lave et al, 2018), I wanted to supplement my geospatial data analysis with actual engagement with the affected community of the Lummi Nation and other Coast Salish Nations. By volunteering my time to work with the community during the 2019 Paddle to Lummi, I was able to ensure that my analysis of their experiences was not wholly unattached to the community. I used my time preparing traditional foods of shellfish to feed all of the participants of the week, speaking with Lummi and other members of the local community to learn how they personally spoke of and worked with the cultural resources they gained from the waterways. I was also better prepared to decipher the shoreline demarcation areas from satellite imagery as I had been on the tidelands and beaches and was able to see how the water appeared at its intersection with the coastline. While it is possible to utilize geospatial data to visualize and analyze environmental change, the physical changes to the environment do not tell the whole story of connection to the people of the area and I found that by engaging and making my presence a useful one on Lummi lands, I was able to better inform my understanding of particular Coast Salish cultural connections to the waters that are not shown through satellite imagery or spreadsheets of tabular temperature data.

The factors of shoreline change, sea surface temperature, acidification, and sea level rise/flooding were chosen due to their close connection to climate change and their availability of use for comparison within the Lummi Nation Climate Change Mitigation and Adaptation Plan (CCMAP). The years of the late 1990's to today were chosen due to their higher availability of data within the region listed in state and federal databases, likely due to increased technology for

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tracking environmental change. For the shoreline change analysis, Google Earth Pro was the software utilized due to its open platform and free cost of use. Any user with an internet connection can download the program and access historical satellite imagery already compiled and mosaiced. By using this for imagery, policymakers, non-profit organizations, and Tribes can view historic satellite imagery without having to go through hours of coding to stitch together multiple imagery “snapshots” or remove cloud cover. Instead, the imagery comes ready-to-use. However, as it is only an image, deeper analyses like sea surface temperature or height cannot be measured with this tool. For Tribal Nations in areas without excessive cloud cover (as is particularly the case for Coast Salish Nations), utilizing Landsat and other satellite products from Google Earth Engine is more feasible for tracking land cover change, as persistent cloud cover makes using the same products increasingly difficult for communities such as the Lummi Nation in the cloudy Puget Sound.

For the timeline selected of the shoreline change, the available years were chosen based on when the imagery reach a high enough resolution to accurately differentiate and track the shoreline, which was 2003 for much of the coastline for the study area with the Google Earth Pro aerial images. In one section, 2003 imagery was unavailable, so the closest year in the collection was used: 1998. For the most recent data, 2018 was the latest available imagery date at the time of analysis, so a 15-20-year timespan was used for the cartographical display, following shoreline analysis guideline to sampling periods of shoreline change (Boak and Turner, 2005). Shorelines typically only change in small increments per year, so it was unnecessary to do a yearly analysis and by conducting a long-term analysis of 20 years, the analysis can show the enduring transformation of the shoreline.

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Figures 5,6, 7: Shoreline Change on Lummi Reservation. Left: Wide view of Lummi Reservation Area Middle: Close view of Northwestern Lummi Reservation Right: Close view of Southeastern Lummi Reservation

Shoreline Change

Shorelines were measured along the visually discernable intersection of the observable packed sediment of a beach and the seawater, and in cases of doubt due to low resolution areas of the imagery, averaged to the location of low tide. This way, even if the imagery were taken during a high or moderate tide, the characteristics of the sediment could be used to determine low tide's shoreline. Due to the nature of shorelines, their dynamic location changes hourly with the tide, so it was important to find a measurement as close to consistent and reproducible as possible (Boak and Turner, 2005). In Figures 5-7, which are represented at a much smaller scale than what I used to trace the shoreline, shorelines between the years are shown to have shifted, but not solely through accretion or erosion. The changing beach was mostly represented by the movement of finer shoreline material like sand, which had more visible areas of change at areas less protected from waves, such as on the westernmost shorelines.

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Shorelines in the Lummi reservation have shifted in the 20-year window surveyed, adding visible erosion and accretion areas along the reservation. These changing tideland areas, especially those near infrastructure such as roads, homes, or buildings, could become an issue as water encroaches nearer, raising the flood risk for those human structures. Revisited after the original Elliot Point Treaty, the 1930 U.S. vs Stotts case decided that the tidelands were for common use of the Lummi citizens. In 1931 the U.S. vs Boynton case followed the shorelines as a property line marker, and where the shoreline has encroached on private property held within the reservation, the Lummi Nation retains property of the beach, even on non-Lummi private lands. The question of property of the tidelands has been raised in 2002 and 2009 in federal court, each reaching the same conclusion of Lummi community ownership to the tidelands, not private property owners and non-Lummi communities. Even now, nations such as the Lummi are continuously having to fight to save their lands and waters from climate change and settler encroachment. As Lummi property follows the shorelines that demarcate the tidelands, it is crucial that shoreline data is closely tracked for major changes that could impact beach access for shellfish harvesting, ceremony, and recreation of the Lummi people.

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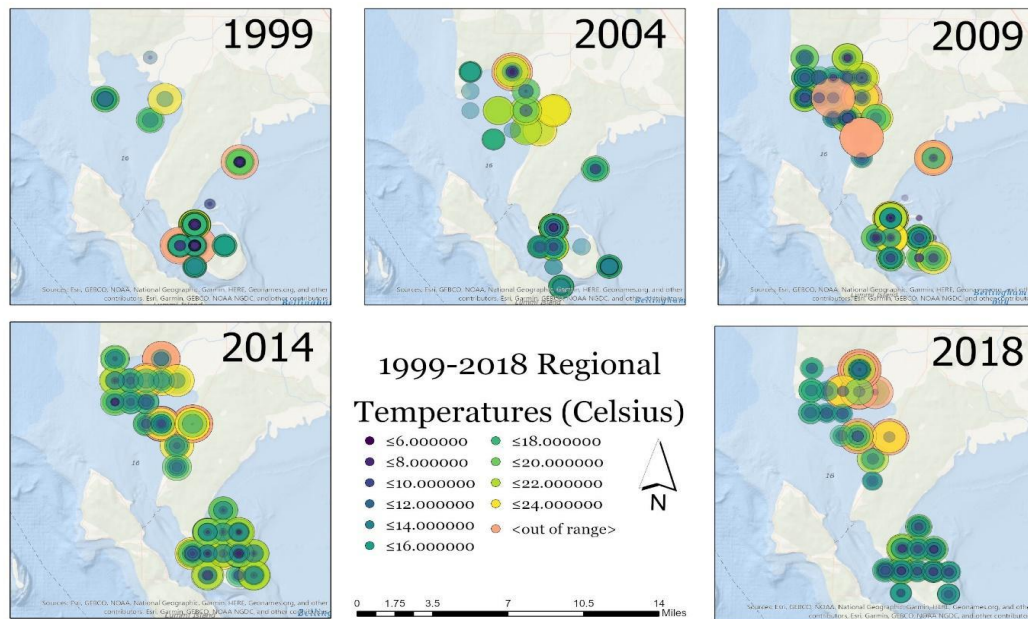


Figure 8: Lummi Reservation SST Records using Water Quality Portal Data

Temperature Change

Historic temperatures were collected through the Water Quality Portal site (Water Quality Portal, 2019). The site combines water quality data from over 400 federal, state, tribal, and non-governmental agencies, and is operated by the USGS, EPA, and the National Water Quality Monitoring Council (NWQMC) according to the Water Quality Portal site. Selected sites were chosen within the Puget Sound region, focusing in on the water sampling stations surrounding the Lummi Nation's federally designated lands. While the number of sampling sites increased with time, recording stations remained fairly sparse in and around the Lummi Nation. Water records were sourced from a similar period as the shoreline change analysis, from 1999-2018, with increasing numbers of records each year. To show a more meaningful analysis of changing water temperatures, histograms of temperature recordings were created, showing the distribution of temperatures by selected year. In Figure 8, I used graduated markers to show temperature records from each designated year. While there is a general increase in stations

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between 1999 and 2018 and therefore an increase in reported temperatures, records were showing an increase in the proportion of temperatures on the higher half of the range as the years progress. Figure 12 showing the year 2014 stands out the most with more temperatures in the upper half of the range than the other years, correlating with the year being the warmest on record for the region. To clarify the results, I created a histogram for each of the year's temperature recordings to show the spread of the temperatures by amount. From 1999 to 2018, the average temperature increased by approximately $.8^{\circ}\text{Celsius}$, with more temperatures occurring above 15°Celsius than in earlier years.

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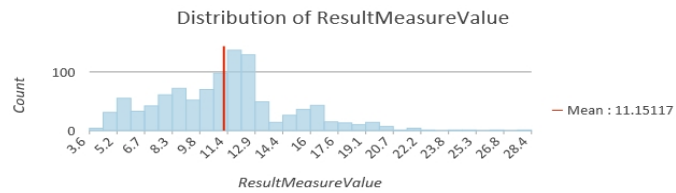


Figure 9: 1999 Temperatures (Celsius)

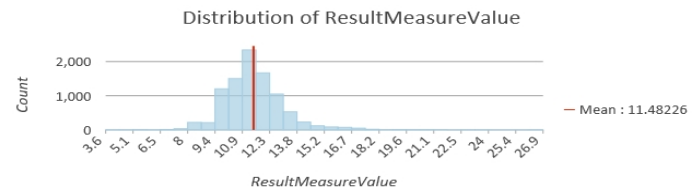


Figure 10: 2004 Temperatures (Celsius)

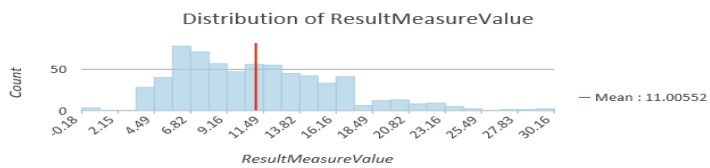


Figure 11: 2009 Temperatures (Celsius)

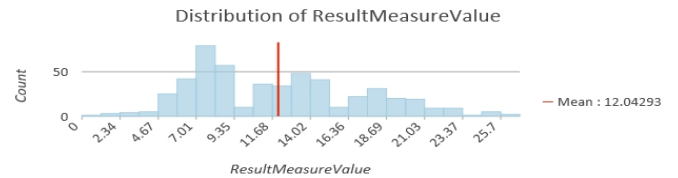


Figure 12: 2014 Temperatures (Celsius)

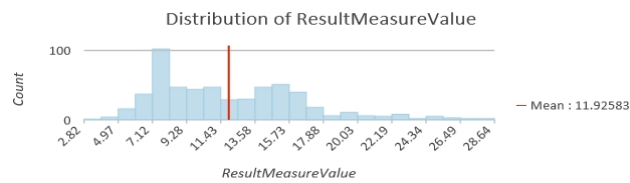


Figure 13: 2018 Temperatures (Celsius)

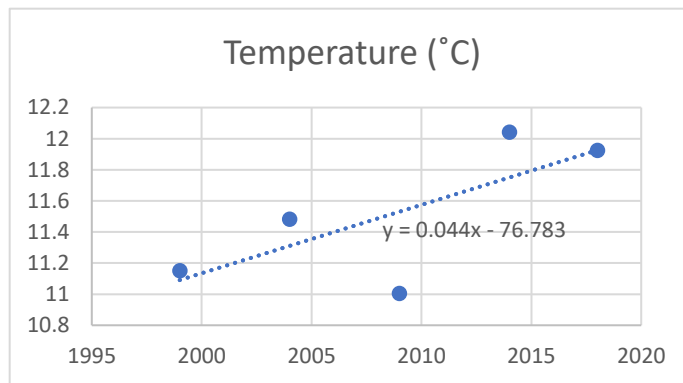


Figure 14: Temperature Change as Linear Equation for Average Temperature Collection of Waters Near Lummi Reservation

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Research on freshwater salmon in Washington state has shown that warming water temperatures can increase stress on salmon, reduce survival and reproductive rates, and even alter their life cycle (Mantua et al., 2010). The Lummi Nation have been operating hatcheries since 1969 with the goals of saving the salmon, with programs including research programs and production to establish and maintain stocks necessary for their way of life. The Lummi Nation operates 3 different salmon hatcheries, which are sensitive to water quality impacts such as acidification and warming (Lummi Nation, 2016). As the waters of the Lummi Nation and their usual and accustomed grounds warm, experience changing discharge rates due to precipitation change and snowmelt, the salmon populations will likely change, if not disappear. Once temperatures reach 15°Celsius, salmon have been shown to experience higher rates of predation and more intense competition with other fish, after 21° C, salmon can experience extreme thermal stress and may not migrate (Mantua et al., 2010). As the waters of Bellingham and Lummi Bay experience a steadily increasing average temperature, even if climate change doesn't get worse and warming rates stay the same, these deeper waters could reach the 15°C threshold by 2085 if using the rate shown in Figure 14. This temperature analysis does not include the shallower, various streams and rivers within and surrounding the Lummi Nation that due to their depth, could have much higher temperatures, impacting the salmon that use those routes during their lifecycle.

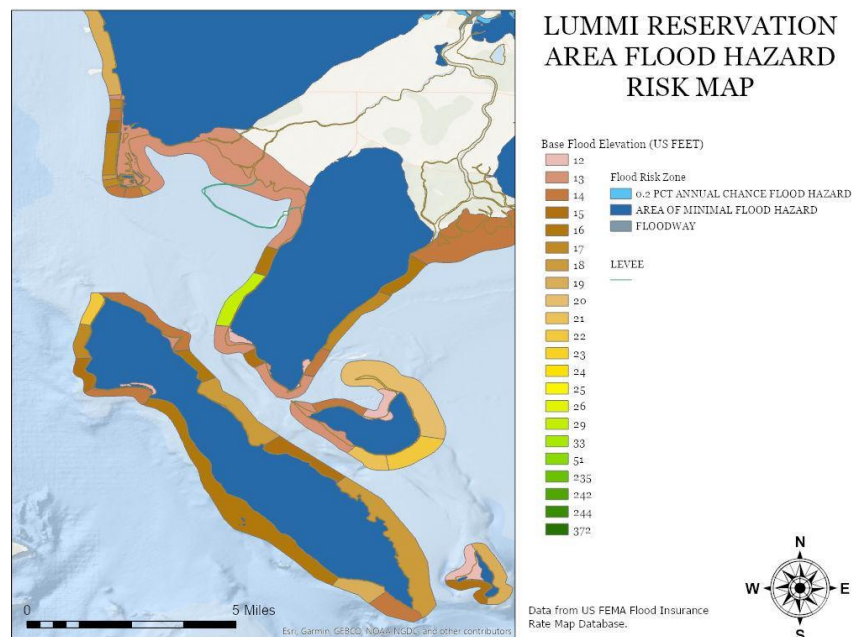


Figure 15: Base Flood Elevation and Flood Risk Estimates Using FEMA Data of Lummi Reservation Area

Flood Risk

The computed elevation to which floodwater is anticipated to rise during the base flood. Base Flood Elevations (BFEs) are the estimated elevation that flood waters are expected rise, and frequently used in FEMA reporting (Luke et al., 2018). This floodplain data was used from existing FEMA data (FEMA, 2020). I focused on the shorelines on the Lummi Island area, where Lummi citizens live (Lummi Nation, 2016). Base flood elevation was mapped for properties along the shoreline to show how elevated the base of a structure would need to be to be less likely inundated by a 100-year flood. Looking at Figure 15, it appears that most of the Lummi reservation rests along shorelines with 20 feet or less of expected BFE, but areas where homes and infrastructure remain lower than their respective BFE are at risk of flooding during a base flood event. Referencing the Lummi Nation household growth maps in ^t the Lummi Nation

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climate report , it is clear that a large majority of Lummi Reservation Households are along the tidelands where flooding is more likely to occur, and as that population increases it is crucial that flooding mitigation strategies are put in place to protect Lummi homes and lives (Lummi Nation, 2016). Sea level rise and its associated flood risk could mean damage or destruction of burial sites and other culturally significant historical materials and areas. Harvesting areas may be washed away or unsafe to access, and the flora and fauna that traditional foods and medicines are sources from could disappear entirely (Lummi Nation, 2016).

Increased sea level rise can not only decrease shoreline area and cover low-lying land, but it may also intensify the frequency and level of impact of coastal flooding and erosion on waterside communities like the Lummi Nation (Mauger et al., 2015). Sea level rise and its expected storm surge and flooding events will not only endanger Lummi infrastructure and life, but it may also decrease access to clamming, treaty-guaranteed fishing, and other food-gathering locations in marshes or sloughs through habitat loss or degradation (Lummi Nation, 2016). Sea level rise has the potential to increase surface runoff occurrences that introduce additional industrial, vehicular, or agricultural pollution to the waterways, making the waters and the food gathered from them more harmful to humans and animals. With unsafe waters, the Lummi and other Coast Salish Nations will likely also experience cultural degradation, as their access to fishing and canoeing and other traditional practices will deteriorate. The usual and accustomed waterways the Lummis and other Coast Salish Tribes are legally ensured access to by treaty to be able to fish will leave them empty-handed if the waters continue to degrade.

Acidification

Salmon and shellfish are highly susceptible to changes in acidification, and the interconnected nature of the Lummi culture could experience a domino effect of collapsing resources and human impacts from the loss of crucial fish and shellfish (Lummi Nation, 2016). Data of acidification has not been made easily accessible in a similar 20-year time frame by state or federal entities within the Puget Sound. It is too early to use the existing data to create any sort of conclusive idea of changing acidification and will need more sampling and time to become useful for prediction. Communities and Tribes seeking this data would likely need to contract out sampling or add it to their list of environmental testing procedures. While there is data published on NANOOS, the Northwest Association of Networked Ocean Observing Systems, in the Salish Sea, data is hard to access and testing buoys are not widespread enough throughout the Sound, nor are there any in Bellingham or Lummi Bays to do an analysis of the immediate and surrounding waters of the reservation (NANOOS, 2020). NOAA's (National Oceanic and Atmospheric Administration) Ocean Acidification Program (OAP) contains global data from the 1970s to today on pH and dissolved inorganic carbon (acidification indicator), but data was hard to access and links often led to error pages. For Tribes to reliably access data, it is crucial that state and federally funded data is navigable to outside users. This difficulty in accessing data is another way that scientists and policymakers limit the use and knowledge of environmental data to the privileged or institutional few.

Analysis

The Lummi Nation has their own water, GIS, and natural resources departments who organized and managed a climate change report with EPA funding. (Lummi Nation, 2016) Not all tribes have the same access to creating these personnel positions in their government, so it is important to view the information discussed in this article and compare its accuracy to the actual report created by the Nation, to get a perspective on the data's viability for use in other tribal communities. While critical attention was paid to the data resources and processing used, it is crucial to view this work as one example of urgent scholarly analysis to ensure treaty rights and equitable access to climate change data. It is important to note that discrepancies could be due to the gaps in easily accessible data, or due to user error. The Lummi Nation Climate Change Mitigation and Adaptation Plan (CCMAP) of 2016 details their own expert climate change findings. For the sake of simplicity, I will stick to the ones discussed here: acidification, sea surface temperature, and sea level.

Sea surface temperature in the Strait of Georgia, part of the Salish Sea near the Lummi Nation were found to be warming at a faster pace than the global rate, at 0.4°F per decade, or approximately .22° C (Lummi Nation, 2016). Using the sea surface temperatures tracked through the Water Quality Portal, my results show an approximate change of .41°Celsius over a 10-year period, using the rate of change between 1999 and 2018. This is a much faster rate, and could be due to shallower waters sampled, the hottest year for Washington state on record for 2014 causing a higher-than expected rate of change, or the difference in latitude, as the Strait of Georgia lies northwest of the Lummi Reservation, and the Water Quality Portal sampling sites fell further south and east. This could also be from an increase in temperatures since the results from the Strait of Georgia were collected for their 2013 report (CIG, 2013).

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Sea level rise findings near the Lummi Nation are inconclusive according to the 2016 report, and can vary widely by area, denoting a need for more tracking in culturally significant areas. The waters of the Lummi Nation are expected to be consistent with or more severe than the global rate of the decrease of pH in ocean waters, and are at a higher risk of more severe acidification due to local hydrologic conditions and characteristics of the Puget Sound (Lummi Nation CCMAP, 2016). With already small amounts of acidification data available for the Salish Sea, its precarious sensitivity to acidification should make it more of a priority for Washington area research in acidification data collection funded by parties responsible to the Lummi Nation, such as state and federal agencies that create environmental data, like the Washington State Department of Ecology, NOAA, and the EPA. Not only does its sensitivity to acidification require more data collection, but its potential impact on Lummi, other Coast Salish nations, and non-native fisheries of the Salish Sea could be economically and ecologically disastrous, destroying habitats and necessary resources for plant and animal life within the waters.

While accessible data could follow similar trendlines as what the Lummi Nation report described, the small amount of available resources made the analysis difficult, and the limited time and region scope affected the quality of the independent analysis. The Lummi Nation should not have to rely on generalized global analyses that may vary wildly from the actual changes and expectations for their region. For communities to keep up, the creation of environmental data in such crucial areas such as SST, acidification, sea level rise, and shoreline erosion can help to inform and protect the residents of this coastal area. Without meaningful data that informs the Lummi Nation of the looming environmental changes, the Lummi community may struggle to protect the lands they have treaty rights to. To keep with the treaties confirming

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access to harvestable lands and waters, Washington state and the US federal government must ensure those lands remain.

Conclusion

Tribes are not the only stakeholders in the environment facing substantial climate and ecological harm. However, it is crucial that state and federal entities tracking environmental degradation recognize that tribes are different than the average non-Indigenous stakeholder population and have a legal and moral attachment to the lands (Austin et al., 2000). Pollution from development, logging, agriculture, and human interference has long been creating negative consequences for the waters of the Salish Sea, producing acidification and hypoxic events that have impacted water quality and habitat health (Nesbitt et al., 2015). Seasonal changes, tectonic shifts, and other non-human events can also alter the ecological characteristics of an area (Miller et al., 2018). Even if climate change were not exacerbating current ecological harms, the Lummi Nation would continue to deal with problems impacting their waterways, from population growth, pollution, and hydropower (Cantzler & Hunyh, 2016).

Data collection, emergency management preparation, and climate change mitigation tactics are all necessary to slow and reduce the toll of environmental degradation on Lummi lands and waters. While it is far too late to stop climate change in its tracks, and there are many brilliant minds working to reduce and reverse carbon emissions, it is possible that just the access to this data tracking the changes could be helpful to communities like the Lummi or other Indigenous nations as they create their own action plans. Not only do tribes need to prepare for the ecological and financial impacts of climate change, but leaders in the community need this

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data as they look to the future, and how their traditions and practices may need to adapt.

“Cultural resources are irreplaceable... when they are gone, they are gone forever (Lummi Nation, 2016, 62).” While non-Indigenous communities can rely solely on mitigation to their lands to return it to the use it once had, or close to it, tribal communities can and will lose far more than just a financial return.

State and federal entities must honor the treaties by ensuring the health and biodiversity of waters of the Lummi Nation and other Indigenous communities who rely culturally, spiritually, and economically on the wellbeing of their lands. The change of environmental management processes to something that uses Indigenous stewardship ideals could be an important and progressive move by state and federal government agencies to respect and implement Indigenous communities (Middleton, 2013). If the fisheries are impacted, states must honor their state and federal treaties with Indigenous communities, like the Boldt decision that ensures the Indigenous tribes in Washington state 50% of the commercial catch each year, to avoid repeating contentious and even violent confrontations of past fishing wars in the state, it is crucial that US and state agencies are already in frequent collaboration with state tribes to prepare for and mitigate the coming changes to the fisheries. While non-Indigenous Salish Sea fishers will be greatly financially impacted by diminishing fish communities, the Lummi and other Coast Salish nations will suffer not only financially, but culturally as well as traditional community events and practices like the Stommish Water Festival, Canoe Journeys, and community harvest meals will struggle to continue. State and federal governments must not treat Indigenous communities as separate from other citizens and avoid giving the same rights to life and religious practices of which include their community practices and needs. Tribes are sovereign and must be treated as such.

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States and federal data collection and policymaking entities will need to foster cooperation and collaborative spirit by first insuring that Tribes' "seat at the table" is well informed with the most up-to-date and localized data, and that public officials truly understand the connections to the natural resources beyond the realm of financial gain. More than a "seat at the table," the Lummi Nation's treaty rights to reproduce their lives and culture means that state and federal agencies are obligated to provide them with the information they need to address climate change impacts while it is still possible. With better data access and creation, Tribes and public government entities can be more impactful in developing policy and education measures of water management procedures (Dolan & Middleton, 2015).

To fully serve the sovereign, yet entangled, nations of Indigenous America, state and federal governments need to understand Indigenous connections to water and ensure that their data collection can serve Indigenous communities and the greater environment. By providing climate change research funding for Native tribes, state and federal agencies can assist in not only gathering more useful data for climate change tracking and mitigation planning, but also encourage Indigenous Data Sovereignty. Water is life, and we need the data to save it.

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