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Swinomish Indian Tribal Community

A Federally Recognized Indian Tribe Organized Pursuant to 25 U.S.C. § 476
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Final Progress Report

Recipient: Swinomish Indian Tribal Community

Project Title: Correlation and Climate Sensitivity of Human Health and Environmental Indicators in the Salish Sea project

Agreement number: No. F12AP00994

Date of report: March 30, 2104

Period of time covered by the report: September 16, 2012 -- December 30, 2013

Project accomplishments with the goals and objectives of the award:

Task 1: Finalize project partnership with British Columbia First Nation

We formed a partnership with the Tsleil-Waututh First Nation.

Task 2: Compile existing data on chosen environmental indicators for the two project communities.

Puget Sound Partnership, U.S. Environmental Protection Agency and Environment Canada scientists and land managers have identified a number of environmental indicators applicable throughout the Salish Sea to evaluate the status, or health, of the trans-boundary water body. Evaluating the current status of a set of environmental indicators is a first step toward ranking and prioritizing management and restoration actions in order to improve the health of the Salish Sea as an ecosystem. For this project, Swinomish and Tsleil-Waututh each selected a pair of environmental indicators, inventoried available data relating to those indicators, and created projections of the status of those indicators in relation to climate change. Criteria for indicator use included: 1) applicable to lands within reservation/reserve boundaries (site-specific rather than landscape scale (e.g. orcas or birds); 2) sufficient existing data supporting the indicator; and 3) indicators were culturally appropriate for the Swinomish and Tsleil-Waututh communities.

For the Swinomish comparison, shellfish beds and shoreline armoring were selected as Swinomish has an established shellfish monitoring program with nearly two decades of data on shellfish density and species composition for several Reservation beaches. Inventories of amount and types of shoreline armoring are continuously updated for the Swinomish Reservation shorelines.

For Tsleil-Waututh, shellfish beds and shoreline archaeological resources were selected. The Nation has an objective of re-establishing a traditional shellfish harvest that has been closed by water and sediment pollution for at least 40 years. Monitoring is ongoing and restoration plans are under development, but the community is concerned that sea level rise will limit future opportunities. This rise in sea level also threatens to undermine numerous shoreline archeological sites and this prospect affects the health of the community.

The case study area for the Swinomish portion of this pilot project was Lone Tree Point located on the western shore of the Swinomish Reservation in northern Puget Sound (Figure 1). This study area was selected because of the availability of extensive shellfish monitoring data, a long record of monthly paralytic shellfish poisoning (PSP) data, shoreline habitat characteristics, and a current digital elevation model. These data sets were essential for assessing vulnerabilities and impacts, and generating maps of current status and future change. Lone Tree Point was also selected because it is one of the most valued and highly utilized areas on the Swinomish Reservation. Frequent Tribal access is predominantly for cultural and economic activities, helping to make mapping results of sufficient concern to engage community members in participating in the workshop.

The case study area for the Tsleil-Waututh portion of the pilot project was the shoreline and intertidal area extending from Maplewood Flats to Cates Park on the north shore of Burrard Inlet just east of Second Narrows. Burrard Indian Reserve No. 3 is located along this stretch of shoreline and a majority of Tsleil-Waututh community members live there. The area once served as a tremendous source of natural resources as documented in the many archaeological sites located there. Like Swinomish, this area is a focal point for the community and sure to generate interest in workshop participation.

A number of digital datasets representing shellfish biomass (Barber et al. 2012), sediment characteristics (Ritter et al. 1996), beach elevation (Grossman and Horne, in review), and shoreline armoring type were synthesized from existing sources to model climate change impacts to the chosen environmental indicators in each community. Table 1 summarizes the datasets Swinomish employed. Datasets were compiled into an Environmental Systems Research Institute Geographical Information Systems (GIS) database and plotted using ArcGIS 10.1. Though the datasets represent the best available science with the highest level of resolution for the study area, maps and results presented in this report were generated to characterize relative differences in impacts and do not claim to predict actual impacts nor the response to all possible forcing parameters.

Two shellfish species, butter clams (*Saxidomus gigantean*) and native littlenecks (*Leukoma staminea*), were chosen for this study as they are or were the primary shellfish harvested by the Swinomish and Tsleil-Waututh peoples for commercial, recreational, ceremonial, and subsistence uses. It is generally known

that the habitat for butter and native littleneck clams, (referred to here as shellfish), extends from subtidal depths to roughly 1.5 meters above Mean Low Lower Water (MLLW) in areas with mixed cobble, gravel and finer sediment particles and commonly with broken shell. For our analyses, the lower elevation band of harvest area was set to the 0.3 meter elevation contour below MLLW, the level of extreme summer low tides at the study site. The upper elevation band of harvest area was set to 1.5 meters above MLLW.

At Swinomish, using a new high-resolution Digital Elevation Model, a polygon was generated for the potential shellfish harvest band along Lone Tree Point in ArcGIS using the upper and lower shellfish habitat bands described above. The shellfish harvest band was refined further using the 1996 Washington State Department of Natural Resources, Aquatic Habitat Division, Shoreline Habitat Program's substrate polygons, removing areas of the beach where substrate types are unsuitable for shellfish habitat (such as bedrock or mud). Shellfish biomass polygons from 2011 (Barber et al. 2012) were used to delineate and validate the upper boundary and sediment characteristics of the harvest bands.

Future shellfish harvest area polygons were generated by taking the methodology described above and projecting the upper and lower shellfish contours higher on the beach face based on projected sea level rise of 1.29 meters (high estimate) for the Salish Sea by 2100 (Mote et al. 2008; National Academy of Sciences 2012; Vermeer and Rahmstorf 2009). Shellfish harvest area was then calculated from these projected bands, the change reflecting variations in area along shore due to beach morphology. A similar, but more simple exercise was completed at Tsleil-Waututh to define current shellfish habitat and projected habitat in 2100; additional layers of archeological site polygons were added to the Tsleil-Waututh maps to show current location and projected inundation in 2100 from sea level rise. For Swinomish, shoreline armoring was plotted against the current and year 2100 projected shellfish harvest bands to illustrate locations along Lone Tree Point where the shoreline would be unable to migrate as sea levels change.

TABLE 1. Swinomish Environmental Indicator Data Sources (shellfish habitat and beach armoring)

Dataset	Source	Provides
Shellfish: 2012 *S. gigantean* and *L. staminea* biomass and location data	Swinomish Fisheries Department	Polygons which provide the basis for the possible range of harvestable shellfish
1996 1:24,000 Sediment Characteristics	Washington State Department of Natural Resources, Aquatic Resources Division, Shoreline Habitat Program	Polygon and line coverage of intertidal shoreline characteristics
Shoreline Armoring	Swinomish Planning Department	Line data representing man-made structures along the Swinomish Reservation shoreline

2011 Orthorectified color aerial photography	USDA-FSA Aerial Photography Field Office	Aerial photography of the study site
Digital Elevation Model	U.S. Geological Survey	High resolution elevation data for the study site

Results of Environmental Indicator Inventory and Mapping

At Swinomish, the analyses of environmental indicators focused on examining likely impacts of climate change and shoreline armoring on tribal shellfish resources. While sophisticated numerical models are required to forecast changes in shoreline morphology (position, orientation, elevation profile) and substrate as sea level rise influences coastal recession. This project compared the relative loss of projected shellfish harvest area from sea level rise. Model outputs were created specifically for use in the community workshop in order to test the utility of integrating environmental indicators with community health indicators. While many other drivers will influence the future status of shellfish beds, the focus here on sea level rise inundation, a dominant driver in this low-energy estuary environment, assumes non-armored shorelines migrate landward with sea level rise while armored shorelines can not.

Based on the mapping exercise, Lone Tree Point currently has 11.0 hectares of harvestable shellfish area situated across a low-sloping subtidal "low tide terrace" and a relatively steep mid and upper beach face. With a projected sea-level rise of 1.29 meters by 2100, the lowest extent of the harvest band across the low-tide terrace will become subtidal and inaccessible, and the upper harvest band will migrate landward where (lack of) armoring allows. Shellfish beds could be reduced to 8.0 hectares by the change in inundation alone by the year 2100, a 27% loss (Figure 1) largely driven by the larger area inundated across the low-tide terrace. This estimate is likely an underestimate of the impact to shellfish and harvest area. A pair of armored and unarmored profiles of the northern portion of Lone Tree Point highlight the potential for habitat degradation and reduction of access to shellfish harvest areas. Currently, the shore-profile at the armored station is roughly half the length of the unarmored shore-profile (Figure 2). Shoreline armoring will likely further degrade the quality of shellfish habitat by preventing local sediment contributions to the beach, enhance scour that leads to erosion and substrate coarsening (Kraus and McDougal 1996) and degrade water-quality through increased turbidity through resuspension of fine sediment.

At Tsleil-Waututh, the analyses of environmental indicators examined the impacts of climate change on community shellfish resources and archeological sites. The same caveats for the Swinomish analyses of environmental indicators apply. The results show a loss of 75% of current intertidal shellfish habitat, and damage to the majority of the archeological sites along the shoreline.

These results and appropriate background information on climate change and sea-level rise impacts to shellfish (and archeological sites at TWN) were presented to the Swinomish and Tsleil-Waututh communities through a power-point presentation. The presentation was created to inform the community

members of the potential threats climate change will have on their cultural resources.

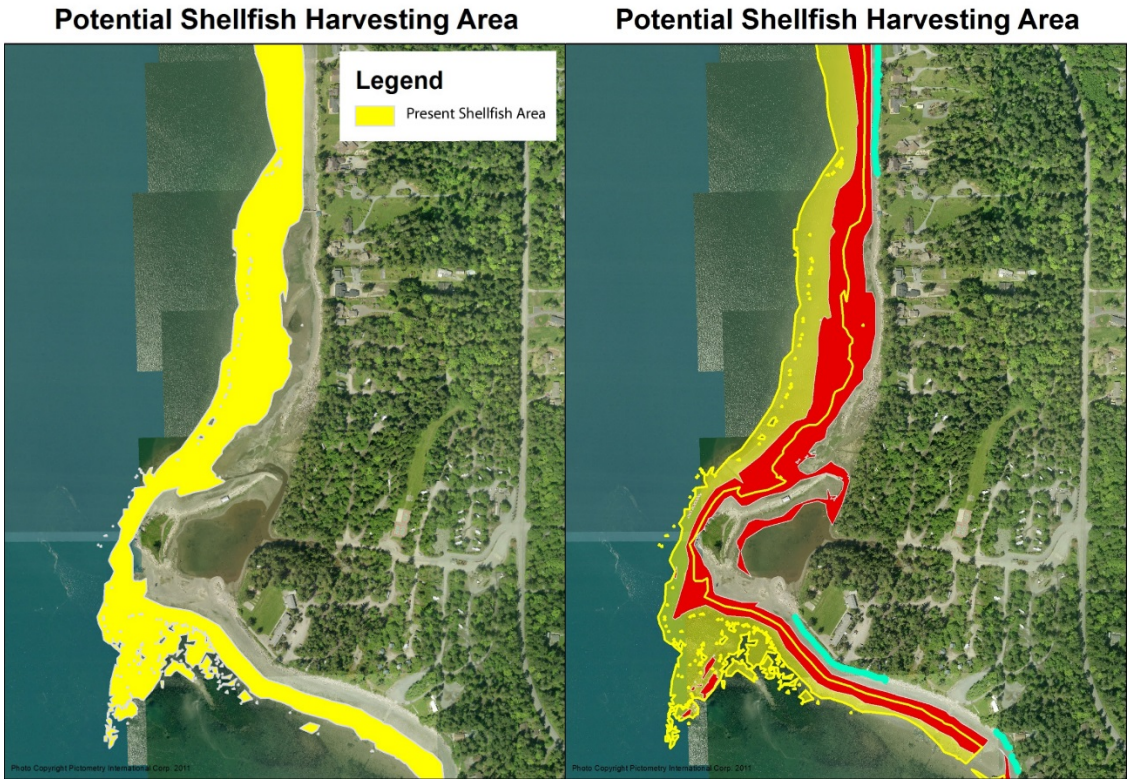

Figure 1. Current (yellow left) and future (red band on right) scenarios for potential shellfish harvesting area and current shoreline armoring (blue) at Lone Tree Point on the western shore of the Swinomish Reservation.

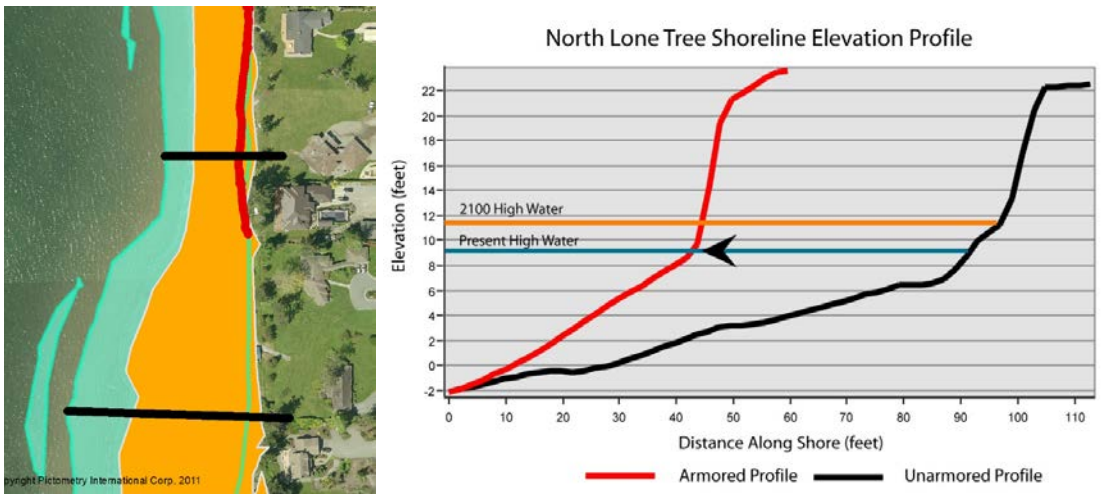

Figure 2. Cross-shore elevation profiles at Lone Tree Point highlighting current beach profiles at an armored (red) and unarmored (black) station with current and projected (yr. 2100) high water levels.

Task 3: Gather and assess community health data

Each community analyzed how community health, as presented in the IHIs, may be connected to the chosen environmental indicators. This task was primarily a literature review combined with ground-truthing via interviews with community knowledge holders (for defining who is an expert, see: Davis and Wagner 2003). Literature review sources included community reports (e.g., Annual Reports, historic atlas), publications by government agencies (e.g., Health Canada, U.S. EPA), and academic papers. At Swinomish, much of this information had been gathered during the creation of the Indigenous Health Indicators (IHIs) (Table 2); the list provided a template of source types and locations for Tsleil-Waututh.

Project staff evaluated each IHI in the context of current community health data, current environmental indicator data, and how community members might define and assess each IHI. The outcomes were descriptions that were unique to each community but still aligned with the overall IHI set. For example, at Swinomish the indicator that referred to gatherings and ceremonies and the reciprocal respect between people and natural resources is called Cultural Use. At Tsleil-Waututh, this indicator was termed Cultural and Spiritual Practices. Naming the health indicator in terms most used by community members avoids confusion as to what the indicator represents and, ultimately, respects how each community defines and talks about health.

Table 2. Indigenous Health Indicators (Donatuto, Gregory, and Campbell in review)

Community Connection: Members actively participate in community functions and help each other, particularly in connection with the harvest, preparation, and storage of natural resources.
Natural Resources Security: Local natural resources (air, water, land, plants and animals) are abundant, accessible and support a healthy ecosystem(s) and healthy human community. The community equitably shares these natural resources.
Cultural Use: The community is able to perform their cultural traditions in a respectful and fulfilling way using the local natural resources.
Education: Knowledge, values and beliefs are actively passed from elders to youth.
Self Determination: Communities develop and enact their own healing, development and restoration programs.
Well-being: Community members maintain connections to meaningful locations, confident that their health and the health of the next seven generations are not at risk due to contaminated natural resources.

Task 4: Cross-walk community health and environmental indicators

Each community hosted one workshop to test the IHIs in the context of shoreline environmental responses to climate change. Because this project was exploratory in nature, demographic representation was not necessary; staff personally invited 10-20 experts and elders to attend the workshop (Table 3). Researchers presented the workshop in PowerPoint, and participants answered questions using wireless, handheld polling devices. Responses were calculated using TurningPoint software, and summary results were immediately shown on the screen. Individuals' answers remained anonymous. Workshops were structured as follows: 1) collect demographic data; 2) evaluate and rank the current health status in the community using the IHIs; 3) discuss maps and data of projected climate change impacts to: shoreline armoring (at Swinomish), shellfish habitat (Swinomish and Tsleil-Waututh), and archaeological resources (Tsleil-Waututh); 4) evaluate and rank projected status of the IHIs in the future, based on projected climate change-driven impacts; and 5) assess priority concerns of the IHIs in the context of the projected climate change impacts.

Table 3. Workshop Demographics

	Swinomish	Tsleil-Waututh
Workshop participant #	16	8
Female	12	3
Male	4	5
Ages: 21-40	6	2
41-60	5	3
61+	5	3

Workshop participants used a constructed scale to evaluate the IHIs in parts 2 and 4 of the workshop. A constructed scale is a simple descriptive index (e.g., a Likert scale). Scales translate qualitative information into quantitative scores, without losing the information associated with the score, and without sharing proprietary information. Oral histories, scientific information, maps and other images can be associated with a specific rating on a scale (Keeney and Gregory 2005; Gregory et al. 2012). Indigenous communities employing descriptive ranking techniques to assess priorities is not a new idea (e.g., McDaniels and Trousdale 2005). The scale used in the workshops corresponded with a statement about health status: "1 - very bad," "2 - not very good," "3 - pretty good," and "4 - great".[1]

Part 5 of the workshop used pair-wise comparisons for weighting the indicators (von Winterfeldt 1986). Weighting is necessary to elucidate each indicator's relative importance. Not all of the indicators may have equal importance to the participants; knowing which indicators are the highest priorities benefits planning and decision-making. Based on pre-tests, participants found pair-wise comparisons the easiest weighting method to understand and complete (compared to swing weighting[2]). The weighting exercise enabled participants to prioritize the indicators of highest concern and the indicators most likely to be impaired (noting that these prioritizations may not be the same). A lower prioritization would not mean that the indicator is less important, only that it requires less immediate attention, due to greater resiliency or adaptive capacity to the specific climate change impacts presented.

The trial run of the IHIs would be considered successful if: 1) the participants felt that the indicators accurately reflected key aspects of community health; 2) the indicators were useful in thinking about impacts to health based on a specific

1 In pretests, community members preferred to use a "forced choice" four point scale so that there is no neutral "middle road" option (Allen and Seaman 2007).

2 Swing weighting asks participants to imagine a change in each indicator from its worst to best levels, comparing the amount of benefit derived from the swing of the bottom indicator to the benefit derived from the swing of the top indicator (i.e., a ratio comparison), then to quantify the benefit as a percentage of the "swing value" of the top indicator.

context (in this case, climate change); and 3) the participants were comfortable with the ranking and weighting exercises.

Results from parts 2, 4, and 5 of the workshop questions were used to generate an experimental impact assessment of the IHIs. Due to the exploratory nature of the project and small data sets, project researchers utilized simple avenues for experimenting with creating impact assessment metrics that aligned with the metrics used in the Swinomish Impact Assessment Technical Report (2009) and Climate Change Adaptation Action Plan (2010). The Swinomish reports employed a four-point descriptive scale of "low, medium, medium-high, high" in rating impact sensitivity (exposure/ susceptibility), probability of impact, estimated risk, potential priority and adaptive capacity for coastal and upland resources, physical health and community infrastructure and services. A scale mirroring the Swinomish reports was used with an additional positive (non-negative impact) measure of "potential opportunity" to address indicators ranked as healthier in the future compared to today. Project researchers calculated the projected impacts for each indicator by comparing the total percent of answers ranked by participants with a 1 or 2 for the current health status to the total percent of answers ranked 1 or 2 for the projected future health. The result was a percent change, positive or negative, between the current and future health status of each indicator. Indicators with a positive percent change were rated as a "potential opportunity." Indicators with a 25% or less decrease in health were ranked as "low."[3] Indicators with a 26% to 50% decrease in health were given a ranking of "medium." Indicators in the range of 51% to 75% were labeled "medium-high," and indicators above 76% were considered "high" on the impact ranking scale. Part 5, weighting the indicators, allowed project researchers to compare the "most highly impacted" indicator results to the indicators ranked as "highest priorities," thus providing opportunities for focusing climate change planning efforts.

Discussing the projected changes to the shoreline using maps as visual aids made strong impressions on the community members present at both workshops. Participant interest in the information sparked numerous conversations, at times bringing up suggestions for specific adaptation actions. Discourse between the project team and the community members was positive yet poignant—community members felt health would be affected by coastal climate change impacts, but remained hopeful about viable options to explore through the adaptation planning process.

The pilot project met all of the criteria to be considered a success. Participants felt the indicators accurately reflected key aspects of community health and were useful in thinking about health impacts from climate change. Participants were also comfortable completing the ranking and weighting exercises.

At the Swinomish workshop (results in Table 4), participants ranked Cultural Use as most impacted in 2100, followed by Natural Resources Security, Self

3 A change in health of 10% or 15% could be considered much more than a "low" impact; this method would necessitate much more detailed scaling and ranking analyses if employed in actual assessments..

Determination, and Community Connection. As one community member explained, "Recognizing the indicators and talking about them is a way to start to deal with them. These things, impacts to our way of life, are way down deep and you maybe cannot see it, but it weighs on your whole spirituality; you get fatigued, spiritually worn out." Participants emphasized that in the context of climate change and relative to other community health indicators, concern for Cultural Use was low. The group anticipated that Cultural Use would be less sensitive to harm from climate change. As one Swinomish participant said, "we don't worry as much about culture for this, it will always be with us." However, beyond climate change concerns, the group remained very concerned about the state of Cultural Use and its impact on community health in general.

Community members were most concerned about projected climate change impacts to Natural Resources Security, followed by Self Determination, Well-being, and Education. Although Education was rated fairly high as a concern, community members ranked the health status of this indicator as improving in the future. One participant's comment provided insight: "Climate change is changing our resources. We are horrified, but the more you learn, the more you learn you can do something." This highlights that the workshop itself can be considered an educational opportunity as well.

At the Tsleil-Waututh workshop (results in Table 5), participants ranked Natural Resources Security as the indicator most impacted in the future. The highest concerns were for Natural Resources Security and Well-being. Climate change-induced reduction of everyday beach use and associated damage to archaeological sites weakens Tsleil-Waututh community health, as it disrupts Tsleil-Waututh members' connections to their ancestors, a foundation/cornerstone of their cultural responsibility. The group ranked the Well-being health status as improving in the future (with the caveat that Well-being is not less of a concern in general). Education was ranked both as improving in the future and as a low concern in the context of the climate change projections. Participants stressed that Education is a top priority for the Nation and they remain concerned about the state of education and its impact on community health. The Tsleil-Waututh participants were positive about their health projections overall: Education, Community Connection and Cultural Use (called Cultural and Spiritual Practices at Tsleil-Waututh) were all ranked as improving in the future (Table 5). In future workshops, additional questions probing why people projected the health status of indicators to improve or decline will be included.

The style of the workshop—centered on a PowerPoint and using polling devices that collated numerical ranking data--limited the IHI exploratory trials in the ability to evaluate non-scripted discussions that arose (i.e., why participants felt that a particular health indicator would improve or decline over time). Weighting the IHIs was also a limitation. Although weighting is important in prioritizing and making choices, none of the weighting techniques proved ideal. In pre-trials, swing weighting proved more cognitively difficult than choosing between two options (paired comparisons). In order for the paired comparisons to work, however, all participants must complete the entire paired-comparison weighting exercise. If one or more participants decided not to answer one or more paired comparison

questions, it was not possible to complete the calculations or a validity test in order to assess whether people answered in a logical and meaningful way. Yet, as part of the workshop process, no participant is required to answer all of the questions; it is strictly voluntary. Methods for incorporating information from discussions and the use of other weighting methods will be considered in future IHI workshops.

This project did not attempt to make comparisons between the two communities. Each community, even neighboring communities, is unique. Comparing differences between communities will not aid in evaluating the efficacy of the IHIs. The purpose of piloting the workshops in each community was to test whether the IHIs would reflect a community's particular concerns and priorities, so project researchers anticipated the results would not be the same in each community and that assumption was confirmed.

Table 4. Swinomish Community Health Sensitivity Matrix

	Projected Impacts: *Low* → *High*				
	Potential opportunity (+ % Δ)	**Low (0 to -25% Δ)**	**Medium (-26 to -50% Δ)**	**Medium-high (-51% to -75% Δ)**	**High (> -75% Δ)**
Priority concerns:			**CC**		**CU**
Low ↓ *High*	**ED**	**WB**	**SD**		
			NRS		

Δ = change; results are not representative of the community; results are for discussion purposes only

NRS = Natural Resources Security
ED = Education
SD = Self Determination
CU = Cultural Use
CC = Community Connection
WB = Well-Being

Table 5. Tsleil-Waututh Community Health Sensitivity Matrix

	Projected Impacts: *Low* → *High*				
	Potential opportunity (+ % Δ)	**Low (0 to -25% Δ)**	**Medium (-26 to -50% Δ)**	**Medium-high (-51% to -75% Δ)**	**High vulnerability (> -75% Δ)**
Priority concerns:	**ED**	**SD**			
Low ↓ *High*	**CC, CSP**				
	WB				**NRS**

Δ = change; results are not representative of the community; results are for discussion purposes only.

NRS = Natural Resources Security
ED = Education
SD = Self Determination
CSP = Cultural and Spiritual Practices (Cultural Use at Swinomish)
CC = Community Connection
WB = Well-Being

Task 5: Develop climate sensitivity influence diagram

Shoreline morphology, shellfish habitat, and community adaptation decisions will be influenced by a complex interaction of sea-level rise, storms surge, waves and other climate change drivers. The influence diagram (Figure 3) provides an initial framework for characterizing and modeling drivers and outcomes of environmental and social processes. It also serves as a Bayesian and scenario-based modeling framework. This framework can be used to examine likely outcomes of scenarios as well as quantify the influence of uncertainty in individual drivers. Defining uncertainty helps to inform next steps in model refinement, data collection, and community needs. For example, a decision to maintain or remove shoreline armoring can be examined using IHIs to evaluate the community's priorities given trade-offs between preserving coastal protection infrastructure or maintaining viable shellfish harvest area. Other biophysical processes affecting shellfish habitat and access to harvest due to projected changes in wave energy and shellfish substrate linked to runoff and sediment delivery are recommended for subsequent research to refine the shellfish harvest area projection results explored here.

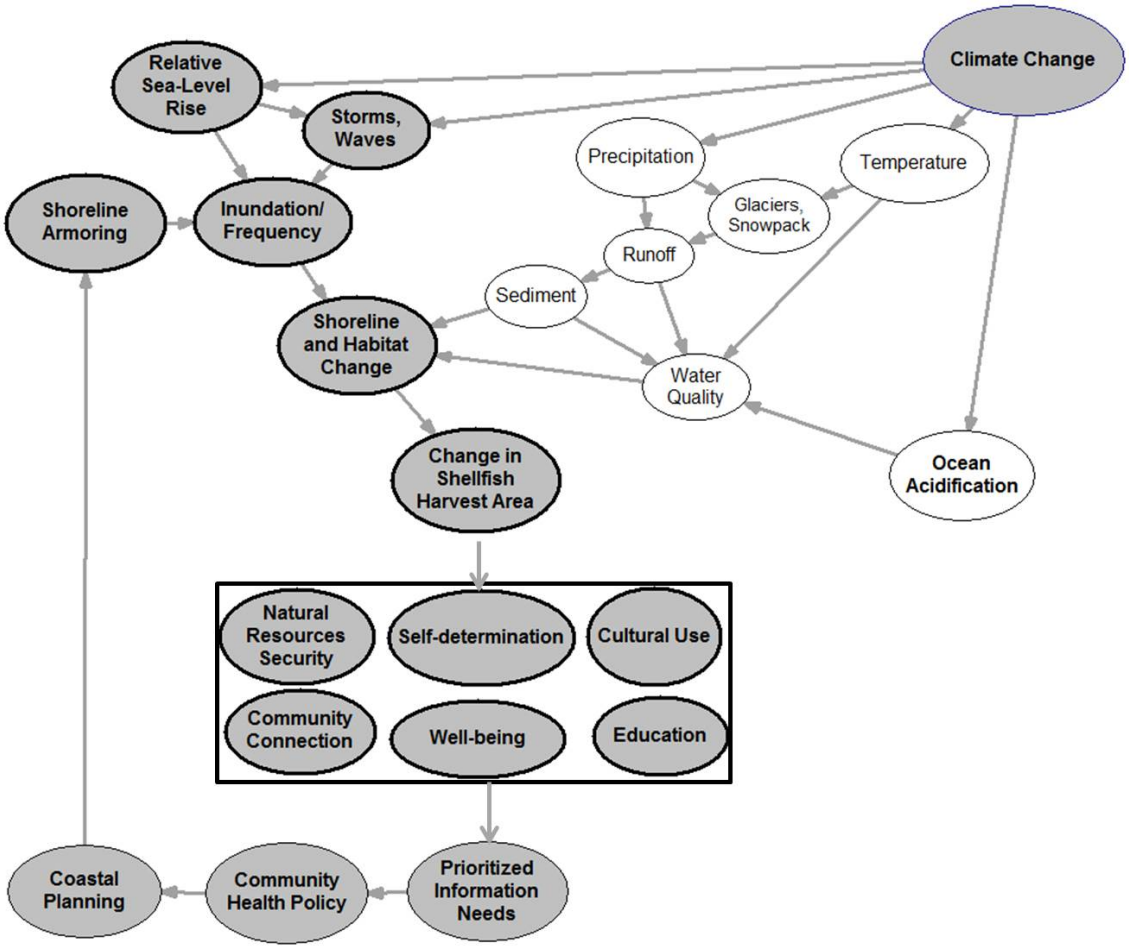

Figure 3. Simplified influence diagram illustrating driver-response linkages between environmental and social (decision) processes affecting shellfish harvest area and identified Indigenous Health Indicators to inform coastal planning. Processes addressed in this study (shaded in grey) will be refined with analyses of additional climate change and ocean acidification drivers in the next phases of the study.

Task 6: Reporting of results

The project team submitted a mid-term report and an annual report on schedule. A manuscript titled, "Indigenous community health and climate change: Integrating biophysical and social science indicators" was submitted to and accepted by the peer review publication, Coastal Management Journal. Publication is expected in 2014.

We did not experience any issues that affected our ability to achieve the goals and objectives of this project.

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