Hypoxia in Hood Canal:

Using Modern Science and Traditional Ecological Knowledge to Enhance Our Understanding of a Degraded Ecosystem

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Brian S. Cary

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This Thesis for the Master of Environmental Studies Degree

by

Brian S. Cary

has been approved for

The Evergreen State College

by

_____

Tyrus Smith

Member of the Faculty

_____

Date

ABSTRACT

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Brian S. Cary

The health of the Puget Sound and Hood Canal has been severely degraded over the past several decades. Washington State's Governor has dedicated millions to initiate a recovery plan and the state legislature passed House Bill 1883 recognizing that tribal elders and other long term residents of the Hood Canal area may provide "critical insight" beneficial to all attempting to restore this ecosystem. This study examines how the Traditional Ecological Knowledge derived from the oral histories of the Skokomish Tribe can inform western science and restoration efforts. The oral histories analyzed herein provide useful information regarding: 1) Habitat Utilization and Loss, 2) Changes in Species Abundance, 3) Management Approaches, and 4) History, Impacts, and Potential Causes of Hypoxic events.

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Introduction

More organisms than could be counted died Tuesday September 19, 2006 in Hood Canal. Among the dead lay shrimp, Dungeness crab, lingcod, flounder, and other fish apparently caught in a kill zone created by poorly oxygenated waters. Between midnight and 6 a.m., a surge of water dangerously low in dissolved oxygen (hypoxic) surged to the surface killing most organisms in a six mile stretch of the canal. Over a thirty-five mile stretch many others died or were severely stressed (Lalena Amiotte, personal communication). Although similar events occurred in 2002, 2003, and 2004 this recent event affected a greater portion of the waterway and the levels of dissolved oxygen reached new lows. Anthropogenic and natural forces are believed to be responsible.

Washington State Governor Chris Gregoire has responded by committing millions of dollars to the restoration of Puget Sounds degraded waters and ecosystem. The State of Washington's 59th Legislature passed House Bill 1883. The bill presents several findings which will provide the outline for this paper.

> (1) The legislature finds that Hood Canal is a marine water of the state in significant peril. (2) The legislature also finds that low dissolved oxygen concentrations have occurred in Hood Canal for many years and that these conditions have created a serious environmental health concern. The legislature further finds that substantial fish kills have occurred in Hood Canal in recent years, and scientists and other report significant changes in marine species behavior in Hood Canal. The legislature finds that the factors contributing to Hood Canal's low dissolved oxygen problems are complex and that investigation is needed to understand both the problem and its potential solutions. The legislature also finds that a historical perspective is important in understanding Hood Canal's problems. The legislature recognizes the tribal elders and other long-term residents of the Hood Canal area are a great source of knowledge regarding the history of Hood Canal. The legislature finds these tribal elders and others may provide critical insight into the history, impacts, and potential causes of the low dissolved oxygen concentrations occurring in Hood Canal. (3) The legislature intends to initiate a process for university students to interview tribal elders and other who have knowledge of the history of conditions along Hood Canal to collect information regarding the history and impacts of Hood Canal's low dissolved oxygen concentrations (HB 1883 see appendix A).

This paper is an effort to illustrate the declining health of Hood Canal and explore how local ecological knowledge may inform restoration efforts. In this study, a scientific literature review will be used to describe the declining health of Puget Sound, with an emphasis on Hood Canal and incidents of hypoxia. Moreover, data taken from qualitative interviews with long term residents of the Hood Canal region will be used to further assess and understand the health of this ecosystem.

The objective of this study is to examine how traditional ecological knowledge (TEK), may inform western science. This will be accomplished by analyzing interview data documenting the oral histories provided by members of the Skokomish Indian Tribe. The research question guiding this study is…, how can the oral histories of the Skokomish Tribe enhance our understanding of the declining health of Hood Canal and inform restoration efforts?

Literature Review and Scientific understanding

Chapter 1: Human dependence on marine systems.

Human survival and well-being is linked to healthy marine ecosystems. Covering more than 70 percent of the Earth's surface, marine ecosystems make up a large part of our planet. A variety of marine ecosystems exist: oceans, estuaries, lagoons, coral reefs, rocky subtidal, and intertidal. Oceans are the largest producers of biomass as well as the source of most of the earth's biodiversity. Representing the base of the marine food web are zooplankton and phytoplankton and at the top of this web are mammals such as whales, seals and humans. This complex marine food web supplies mankind with 20 percent of their food supply and phytoplankton is responsible for generating 90 percent of

the Earth's oxygen (Oceans by the numbers 2006). The oceans generate weather patterns and play significant roles in controlling greenhouse gasses (PSU, "Ninth Report" 9). They provide us with food and income as well as nourishment from species we depend on for animal feed, fertilizers, cosmetics and food additives (Environmental Protection Agency 2007). Yet, aquatic ecosystems are suffering worldwide. The demand on these systems is escalating as the world's population increases. In fact, in the last 150 years human impact on the worlds oceans have multiplied twenty-fold (Woodward IX).

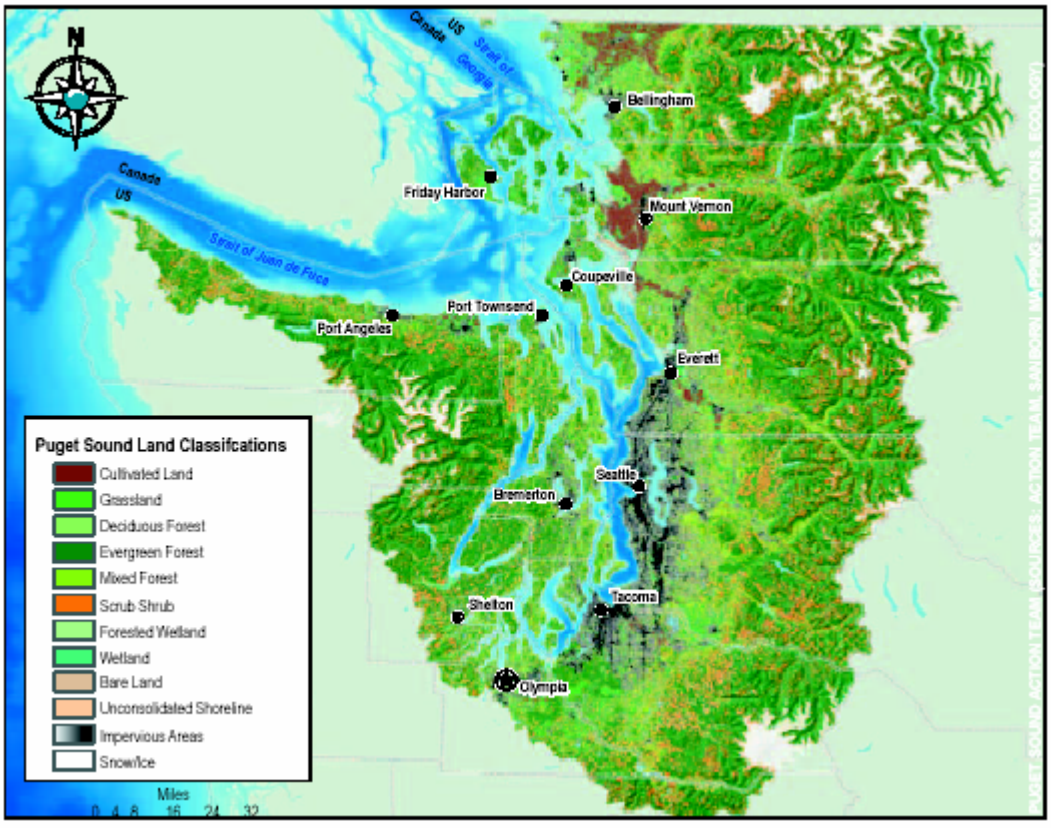

Figure 1. Map of the Puget Sound Region identifying types of land cover.
Source: http://www.psat.wa.gov/Publications/state_sound07/2007_stateofthesound.pdf

Chapter 2: Puget Sound

The health of the Puget Sound ecosystem has been impacted by land use changes (Figure 1). In recent years, the region has experienced growth and development attributed with stressing the Puget Sound ecosystem. Alberti et al. (69) provides startling evidence indicating dramatic land cover changes in Puget Sound between 1991 and 1999. These changes are most evident in the Puget Sound lowlands due to urbanization. Alberti (69) reports new development for one percent of the total area during the nineties. Lands designated as forested have diminished by 55 percent for the same time period. Forest cover decreased by 8.5 percent and impervious land cover has increased by more than 6 percent in those areas considered highly developed (ie., land with greater than 75 percent impervious cover). Nearly half of the land cover reduction has occurred within the Seattle metro area. Seven percent of the Puget Sound region below 1000 feet elevation is covered by impervious surfaces. In the Hood Canal region during the 1990's much of the forest was removed (Figure 2). According to the PSAT (State of the Sound, 9), biological function is significantly impaired in watersheds where impervious surfaces near ten percent.

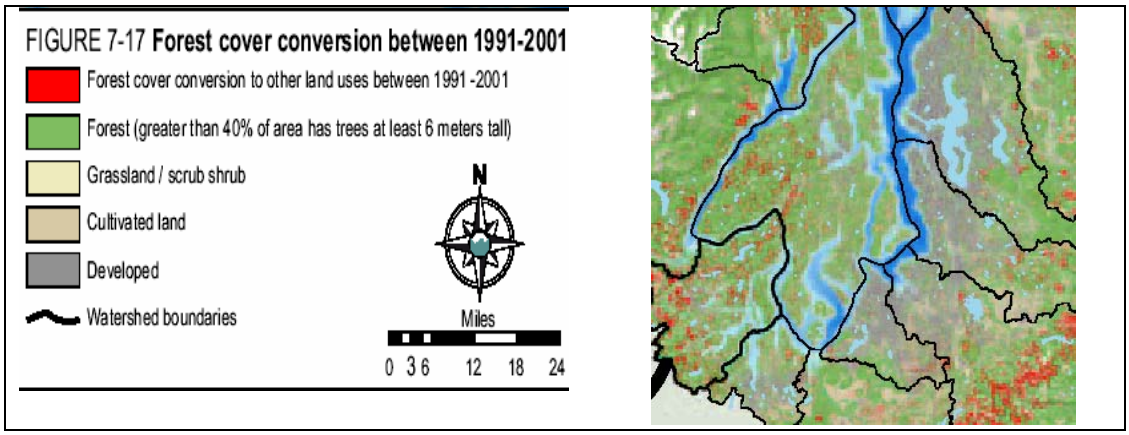

Figure 2. Figure shows forest cover conversion for the Puget Sound and Hood Canal. Red cells depict recent conversions and gray are those areas developed. Source: Skokomish Natural Resource Department. Note: resizing this image resulted in the loss of accuracy for the scale-bar.

Puget Sound's ecosystem is increasingly becoming compromised by a variety of stresses common to marine ecosystems worldwide. Some of these include over-harvesting of marine species for consumption, coastal development, eutrophication, climate change (PSU, "Ninth Report" 13), and the introduction of exotic species (Environmental Protection Agency 2007). Some regions are more stressed than others. A steady loss of habitat, increased water pollution, sediments laden with increasingly high levels of toxins, and alarming declines in the populations of some fish and wildlife are some of the challenges facing the Puget Sound region today.

Marine ecosystems are a sink for many toxins released into the air, soil, and water ways. Toxins are just one of the problems jeopardizing marine ecosystems. Marine waters are the repositories for a wide ranging collection of toxic compounds of both natural and synthetic origins which can seriously impact the health of the marine ecosystem. These toxins include industrial chemicals such as Polychlorinated biphenyls (PCBs) and flame retardants, pesticides, metals, and pharmaceuticals (PSU, "Ninth Report" 130). As humans are currently the top level consumer of marine fish and seafood, the toxins released into these ecosystems are returned to humans through the foods they eat. Consumption of these contaminants by humans and other mammals is linked to various biological effects including immune suppression and reproductive failure (PSU, "Ninth Report" 134).

Toxic contaminants harmful to the Puget Sound ecosystem are wide-ranging in their design as well as the methods in which they enter this ecosystem. Some are synthesized to meet industrial needs and to protect crops while others are byproducts of

fuel combustion or manufacturing. Many of these are known to become highly concentrated in the environment as a result of human activities (PSU, "Ninth Report" 130). These chemicals are discharged into the environment through vehicle exhaust pipes, industry smokestacks and outfall pipes, and by pesticide application. Additional ways which chemicals are discharged into the environment include chemical and oil spills, landfill leaching, and the deterioration of manmade materials such as tires and pavement (PSU, "Ninth Report" 130). The Puget Sound Action Team (PSU, "Ninth Report" 130) lists six metals to be among the highest concern and found in Puget Sound. These metals are: arsenic, cadmium, copper, lead, mercury, and tributyl tin. Additionally, of concern are seven organic compounds: Polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), pesticides, dioxins and furans, phthalate esters, polybrominated diphenyl ethers (PBDEs), and various hormone-disrupting chemicals (PSU, "Ninth Report" 130). The damage these toxins are capable of doing is proportional to the length of time they remain in the Puget Sound.

The length of time toxins remain within Puget Sound is longer than in other urbanized estuaries of North America. This long residence time is the result of the geomorphology of Puget Sound as well as several physical properties of marine water. This means that Puget Sound's biota is exposed to toxins for long periods of time. The negative impact of lengthy residence time is bioaccumulation. Bioaccumulation is a term used to describe an increase in the concentration of a chemical in an organism over time, compared to the concentration of that chemical in the environment (Extoxnet 1993). This is an issue of concern for all organisms residing in the Puget Sound region.

In fact, Chinook salmon in Puget Sound are reported to have between two and six times the PCB levels than Chinook from Alaska, Oregon and British Columbia (PSU, "Ninth Report" 129). Chinook Salmon in Puget Sound have between five and seventeen times the PBDE's compared to other west coast populations (PSAT, "News Release" 2007). PBDE's (flame retardants) are expected to surpass PCBs in Puget Sound foodwebs within the next 13 years; scientists estimate that levels of PBDE's are doubling every four years in marine mammals (PSU, "Ninth Report" 130). In the past 20 years, PBDE concentrations have risen form 50 parts per billion in fatty tissue to more that 1,000 ppb (PSAT, "News Release" 2007).

Endocrine-disrupting compounds are detected in 20 percent of surface water samples from King County's lakes, river, streams, and stormwater discharges (PSU, "Ninth Report" 131). How do these endocrine disrupting compounds affect organisms? English sole provides one example. Male English sole sampled from various Puget Sound locations are producing vitellogenin (PSU, "Ninth Report" 131). Vitellogenin is an egg-protein which is normally only found in female fish. Male fish producing female proteins is frightening.

Present state of sediment in Puget Sound

The sediment in Puget Sound is assessed by the Washington State Department of Ecology (ECY). Between 1997 and 1999 sediments were sampled from random locations throughout Puget Sound in a collaborative effort by the Department of Ecology and the National Oceanic and Atmospheric Administration (NOAA). This effort revealed information regarding the severity, spatial patterns, and the spatial extent of benthic

community contamination as determined from measurements of sediment chemistry, toxicity, and benthic invertebrate analyses. The study discovered that around 1 percent of the sediment was degraded, 31 percent of the sediments were of intermediate quality, and 68 percent was of high quality (Long et al 2003). Not surprisingly, the degraded samples were collected within the unbanized bays, especially harbors, and industrial waterways adjacent to urban centers along Puget Sound (Long et al 2003). The areas classified as degraded are predominantly located in the most biologically sensitive areas, river deltas utilized by many species.

Importance of High quality sediments

High quality sediments are fundamental in the maintenance of the ecosystem and economy around Puget Sound. Following the bigger fish eats littler fish analogy; detritus feeders living in contaminated sediments pass the contaminants up the food chain. When these contaminants reach humans through the consumption of fish and shellfish illness and even death may result. Cancer and aberrant neurological, reproductive, and immune system issues are additional health concerns possible from exposure to these contaminants (PSU, "Ninth Report" 134). The characteristics of Puget Sound, its multiple watersheds, and the properties of marine water contribute to this ecosystems vulnerability.

Concern over the Health of Puget Sound.

Concern for the health of the Puget Sound has recently reached new heights but this concern is not a new phenomena. Historic concern over pollution and Puget Sound

date back to the 1920's when shellfish growers expressed concern over pulp mill pollution (History of Puget Sound Cleanup Efforts 2006). During the 1960's industries including pulp mills began to treat toxic waste prior to it being discharged into the Sound. During the early 1970's the Washington State Department of Ecology was created to monitor statewide pollution control efforts and the federal Clean Water Act was passed (History of Puget Sound Cleanup Efforts 2006).

During the late 1970's and early 1980's the closing of shellfish beds, bottomfish tumors, weakening salmon runs, dead grey whales' and the Superfund listing of Tacoma City tideflats increased the publics awareness concerning Puget Sounds health. In 1985 the Puget Sound Water Quality Authority formed and was assigned the task of generating a water quality plan. This plan was finalized in 1987. In 1992 a state law passed mandating the enforcement of shellfish protection districts by local governments. However this law does not require the enforcement of cleanup plans pertaining to shellfish growing area closures (History of Puget Sound Cleanup Efforts 2006). In 1996 the Puget Sound Action Team replaced the Puget Sound Water Quality Authority. Puget Sound Chinook salmon became federally listed as threatened under the Endangered Species Act in 1999 and in 2005 the Puget Sound Orca whale population was listed as endangered. Many additional species are federally and state listed (Appendix B). More recent concerns are focused on the declining levels of dissolved oxygen.

In recent years low levels of dissolved oxygen (DO) in Puget Sound waters are elevating the concern for the Puget Sound region. Scientists, through measurements taken from stations placed throughout the Sound, have noted an apparent downward trend of DO concentration. In fact between 1998 and 2000, 62 percent of the monitoring

stations noted low (> 3 mg/l and <= 5 mg/l) or very low (< =3 mg/l) DO (PSU, "Ninth Report" 107). Between 2001 and 2005 this figure rose to 84 percent, an increase of 20 percent over seven years (PSU, "Ninth Report" 107). Areas of Puget Sound with very low concentration of DO are Budd Inlet, Penn Cove, Saratoga Passage, Possesion Sound, Belling Bay, Nisqually Reach, and southern Hood Canal (PSU, "Ninth Report" 107).

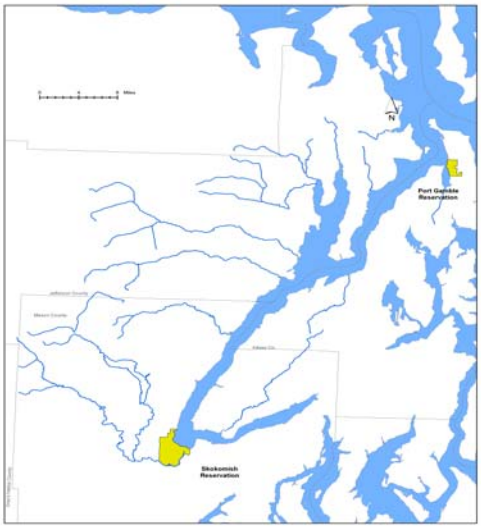

Figure 3. Map of Hood Canal. Source: Skokomish Natural Resource Center

Chapter 3: Hood Canal

Hood Canal is the westernmost waterway of Washington States Puget Sound. Its shoreline is shared by three of Washington's counties; Jefferson, Kitsap, and Mason. This glacier carved fjord measures more than sixty miles (100 km) long (FIGURE 3). The width varies between 0.5 and 4 miles across with an average width of 1.5 miles. The depth of the Canal ranges from tidal flats to 600 feet deep (Hull and Bryan 1). Linking Hood Canal with Puget Sound in the north is Admiralty Inlet. Compared to the greater

Puget Sound and the rest of Hood Canal, Admiralty Inlet is relatively shallow. Just 55 meters deep this shallow sill limits deep water exchange and guarantees slow circulation times within Hood Canal (Sound Science 17). Fresh water flows into Hood Canal from several rivers. The largest, with a flow of 60 m^3s^{-1}, is the Skokomish River (Warner et al 2). Smaller rivers include the Dosewallips, Hamma Hamma, Quilcene, Duckabush, and the Kitsap. These rivers combined contribute an additional 90 m^3s^{-1} of freshwater to the upper layers of Hood Canal (Warner et al 2).

Hood Canal extends southwest from Admiralty Inlet approximately 45 miles where it then hooks northeast at the "Great Bend" and extends 15 miles to its head at the Union River estuary close to the town of Belfair. The canal is a highly productive estuary and is strongly stratified. Its circulation is slow compared to the greater Puget Sound (PSAT "Ninth Report" 107). These traits make Hood Canal susceptible to eutrophication and hypoxia. Eutrophification is the accelerated production of organic matter in a waterbody as a result of the addition of nutrients (Bricker et al 1). Hypoxia refers to a reduced concentration of dissolved oxygen; waters with dissolved oxygen concentrations of 2 mg/l or less (USGS 2006).

In fact, compared to other regions of Puget Sound, the Hood Canal is reported to be exceptionally sensitive to eutrophification (Snover et al 25). Algae, or phytoplankton, require sunlight and the nutrients nitrogen and carbon. When sufficient nutrients are available free floating phytoplankton (plants) thrive, especially in the summer. The problem arises as waste products, including dead phytoplankton, sink into deeper waters where decomposition by bacteria consumes dissolved oxygen. The waste generated from algal blooms is exaggerated as the algae die and sink, thereby creating conditions where

bacterial populations expand and utilize all the dissolved oxygen. This process creates a hypoxic condition which limits the oxygen available for the fish and benthic organisms occupying those deeper waters. In the worst case scenario anoxia (absence of oxygen) may develop.

In 2003, for the first time in Washington State's history, the Washington State Department of Fish and Wildlife (WDFW) closed a fishery as a result of water quality issues (Sound Science 17). The issue was low dissolved oxygen (hypoxia) and WDFW closed commercial and recreational fishing throughout the Hood Canal for all finfish except salmon and trout and for octopus and squid. Hypoxic episodes in Hood Canal are not new phenomena however, it appears these episodes of hypoxia are affecting larger areas of the canal and lasting for longer periods of time (PSAT, "Preliminary Assessment" 4).

Limiting the occurrence of algal blooms in Hood Canal historically was a limited nutrient supply. Since Europeans settled in the region, anthropogenic influences have intensified the amount of nutrients entering these waters. Humans contribute nutrients to marine systems in several ways. Bricker et al (1) lists agricultural practices, wastewater treatment plants, urban runoff, and the burning of fossil fuels as sources of increased nutrient runoff in estuarine environments. Six primary anthropogenic sources of nitrogen in Hood Canal waters have been identified. Combined, these sources contribute between 86 and 319 tones per year. The largest contribution came from onsite sewage systems (35-219 tons). Following sewage in decreasing order of influx are stormwater runoff (11-22 tons), Chum salmon carcasses[1] (15-22 tons), agricultural animal waste (16-20 tons),

[1] As of 2004 chum salmon carcass dumping ceased to occur in Hood Canal. Carcasses are now used for composting (personal communication with Skokomish Tribal Fishermen).

forestry related inputs (0.5-5 tons), and point source pollution (0.3-3 tons) (Hood Canal Low Dissolved Oxygen Background). Hatchery discharges and fertilizers are an additional source of nutrient enrichment leading to phytoplankton growth in the Canal (Sound Science 17). Nitrogen enters Hood Canal by natural means as well.

The influx of marine nitrogen loading is much larger than influxes related to anthropogenic loading. The Hood Canal Dissolved Oxygen Program (HCDOP) reports nitrogen loading from seawater flushing in the northern portion of the canal to be between 8,700 and 31,200 metric tons. Still, more accurate measurements remain elusive due to the difficult nature of collecting accurate and consistent measurements as well as questions pertaining to just how much nitrogen each source actually delivers to the canal.

Derelict Fishing Gear

One other source of nutrients deserves mentioning. This potential source of nitrification is derelict fishing gear. At present, the amount of gear in Hood Canal eludes quantification yet; some generalizations and specific examples are reported to enable the reader to elucidate the potential contribution from derelict gear.

Derelict fishing gear consists of lost or abandoned gillnets, trawl nets, purse seine nets, aquaculture nets, crab, shrimp, and octopus pots, lines, ropes, and various other fishing gear components (Washington Department of Fish and Wildlife 2002). Reportedly, this gear is found throughout Puget Sound, Hood Canal, the Strait of Juan de Fuca, and in many of the rivers where commercial and recreational fishing occurs (Washington Department of Fish and Wildlife 2002).

While the ability to estimate exactly how much derelict gear is in Puget Sound eludes us, some estimates have been generated. WDFW reports alarming figures resulting from the annual 2002 bottom trawl survey for bottom fish (Olympic Coast 2007). Reportedly, this survey led to the recovery of nearly 1,200 metric tons of derelict fishing gear from Hood Canal, Whidbey basin, and the South and Central Sound. Additionally, National Oceanic and Atmospheric Administration (NOAA) (Olympic Coast 2007) asserts an annual 10-20 percent loss of gear for gillnet fishermen. From this figure and a documented history of permits issued, the Northwest Straits Foundation (NWSF) estimate several thousand derelict gillnets remain in the Puget Sound. Tom Cowan of the Northwest Straits Commission's Derelict Fishing Gear Project believes hundreds of tons of derelict gear remain in Puget Sound (Kivisto 2002).

Once lost, gillnets can continue to entangle invertebrates, fish, birds, marine mammals and people. NWC (2005) believes that derelict gillnets impact the environment for more than 20 years and that gillnets have the greatest impact on salmonids and seabirds (Table 1). Gillnets also harm habitat. These nets have meshes capable of trapping fine sediment out of the water column which generate fine layers of silt. Silt, once deposited over rocky substrate, suffocates sessile organisms (Olympic Coast 2007). Additionally, nets over rocks and reefs prohibit access to caves and depressions important to juvenile and adult rockfish. Finally, concerning diver safety, gillnets are one of the most dangerous types of derelict fishing gear to be recovered in Washington waters (NWSC 2002).

Location of net	Specific Species	salmon sp.	seabirds	Dungeness crabs	Rockfish/lingcod
S. Lummi Is (2003)	12 Chinook	147	1 seabird	Unspecified number	
Bellingham Bay (2003)	1 steelhead; 3 Chinook	68			
Lopez Is. 46 different nets	1 harbor seal	2	43	1	Some of each

Table 1. Location and mortality figures for some derelict gillnets removed from Puget Sound between 2003 and 2005. http://www.nwstraits.org

Estimating the mortality from derelict gillnets is complicated. Northwest Straits (2006) reports that tallying the observed dead fish during recovery operations provides a significant underestimate of that gears impact on the biological community. To support this claim the NWC (16) provide two reasons. One is that recovery operations are conducted during winter and early spring when visibility is high but adult salmon are scarce. The second reason is that derelict nets provide good habitat for starfish as these nets are a consistent source of food for the starfish. After nets are present for a period of time, populations of large starfish become established and these starfish rapidly consume any organisms entangled in the net. Starfish are only one of the many scavengers consuming trapped organisms. Often, it is only the bones left behind providing researches with mortality estimates. The NRC (18) documented one to three foot deep piles of bird bones under one derelict net near the San Juan Islands. Presumably these bones had drifted down over the years from decomposing carcasses. Hypoxic conditions in Hood Canal can lead to increased mortality affecting scavengers' ability to consume bycatch. As dead organisms accumulate, bacteria populations expand and further diminish deep water DO concentrations exasperating the problem.

Natural Resources Consultants, Inc (NRC) has been contracted by NWSC to manage the derelict fishing gear survey's and removal operations. As of 2005 NRC had invested more than 87 days effort removing derelict gear from locations throughout the sound including: Dungeness Bay, Birch Bay, south Lopez Island, Lummi Island, Everett Bay and Port Susan Bay. Gear recovered included 686 derelict crab, shrimp and octopus pots/traps, and 260 nets. These nets alone covered 72.6 acres (3.15 million square feet) of habitat (Horst et al 1). Trapped in this gear were 498 fish, more than 1,100 living and deceased crabs, four dead marine mammals, and 90 dead marine birds (Horst et al 1). It is important to remember that this mortality count represents only a weeks worth of capture. Considering anthropogenic sources of eutrophication, the impact of derelict fishing gear remains uncertain.

Eutrophic conditions are influenced by anthropogenic influences other than nutrient additions. For example, it is acknowledged that modifications to estuarine flushing rates occur from the building of dams and modification of stream channels. In Hood Canal the largest of the rivers, the Skokomish River has been dammed since 1926. Additionally, development and dredging alters the ability of estuaries and wetlands to assimilate nutrients and destroys habitat for filter feeders and sea grasses capable of cleansing water (Bricker et al 2). The shoreline and wetlands of Hood Canal have been heavily modified.

Hood Canal History

During the 1990's work was underway to determine whether or not Hood Canal was undergoing changes regarding the frequency and intensity of its naturally low DO

conditions, and importantly if changes were occurring, were anthropogenic influences to blame (Newton et al. 2002). Several data sets exist which have allowed the creation of an historical timeline. The University of Washington has monitored these marine waters since the 1950's. Since 1975, the Washington State Department of Ecology (ECY) has monitored the Puget Sound, including Hood Canal, as a response to the Federal Clean Water Act. Since 2003, a citizen volunteer effort organized through the Hood Canal Salmon Enhancement Group (HCSEG) has tested Hood Canal water weekly. The data shows that levels of DO seasonally reach low levels in southern Hood Canal but that in recent years the episodes of hypoxia are covering larger areas (PSU "Ninth Report" 107), persisting for longer periods of time (Newton et al. 2002) , and spreading further northwards (PSAT, "Ninth Report" 107; Newton et al 2002). In 2004 deepwater oxygen concentrations were determined to be at an all time low between Dabob Bay and the Great Bend (PSAT, "Ninth Report" 107). In 2006, the low DO levels seen in 2004 were surpassed. Since this time, concern regarding Hood Canal has steadily increased. So too has the realization that the Canals natural sensitivity to eutrophification is intensified by human activity (Puget Sound Action Team and Hood Canal Coordinating Council 2004).

Chapter 4: Hypoxia in Hood Canal and some properties of water

Hood Canal, due to its geomorphology, high nutrient inputs, and slow flushing bottom waters is especially susceptible to eutrophification and associated hypoxic events. Over the past several years levels of dissolved oxygen have declined so much that many fish, shellfish, and invertebrates are at risk (Hood Canal Dissolved Oxygen Program 2000). This problem is especially severe in the southern half of Hood Canal. The

problem is attributed to three factors. 1) Poor water circulation and flushing, 2) water stratification which hinders deep waters from mixing with surface waters, and 3) the increased anthropogenic input of nutrients, especially nitrogen (Hood Canal Dissolved Oxygen Program 2000). Examining the causes of these three factors uncovers local features which influence the severity of a hypoxic event in Hood Canal. Below I will describe some of these.

The amount of dissolved oxygen within the waters of Hood Canal is determined by both biotic and abiotic factors. Abiotic factors include the waters temperature, density, salinity, nutrient concentration, and stratification and circulation. Biotic factors involve photosynthesis and the rise and fall of algal communities. Each of these properties is important in understanding Hood Canal's susceptibility to eutrophication and hypoxic events.

Dissolved Oxygen (DO)

In general dissolved oxygen concentrations vary in fresh and saline water as a result of several physical properties of water and the biological processes of photosynthesis and respiration (PSAT, "Ninth Report" 105). Fresh water DO concentrations are lower than DO concentrations in saline water. Additionally, seasonal fluctuations are observed. Generally in the southern Hood Canal the average dissolved oxygen increases throughout the winter and into spring (Warner 2007). DO levels are increased in the upper layer of the water column when aquatic plants photosynthesize and when the water column is mixed from wind action. Additionally, the deep waters of the Canal can be replenished when colder deep waters from outside the canal spill over the sill at Admiralty Inlet and mix with surface waters containing higher levels of DO

(Warner 2007) see figure 4. This occurs as a result of ocean upwelling; a seasonal event. Upwelling along the Pacific Ocean coast occurs during the late spring and into summer when northerly winds along the Pacific coast initiate the delivery of cold, highly-saline, nutrient-rich waters to the surface. This water enters the Strait of Juan de Fuca and replaces the deeper waters of Puget Sound and eventually Hood Canal.

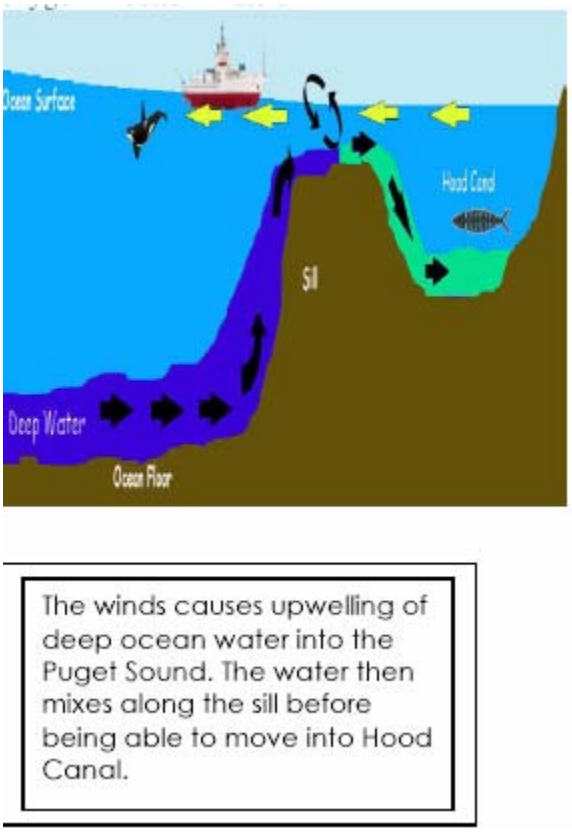

Figure 4. Figure shows a mechanism by which deep waters in Hood Canal are replenished with more oxygenated waters. Source: (Hood Canal expose 2006).

Phytoplankton blooms are another seasonal event that impacts the algae growth in the photic zone. These blooms may eventually reduce oxygen concentrations in deeper water. During the summer, the flushing mentioned previously slows considerably and often stops altogether thereby retarding the inflow of oxygen rich waters. Therefore, during the late summer Hood Canal experiences its lowest levels of oxygen (Warner

2007). As algae die off and settle to the bottom of the canal, bacteria use oxygen to decompose the algal material. In waters which are not well mixed hypoxic conditions may persist. When DO diminishes beyond a certain threshold some marine organisms, especially those immobile, may become stressed and or die.

Salinity, Temperature and Density

Salinity, temperature and density are influential in the degree of stratification observed in Hood Canal. Seasonally, these influences fluctuate. The temperature of surface waters in Hood Canal are the result of changes in air temperature, cloud cover, solar radiation, and wind speed. During the summer months of July and August the air temperature, solar radiation, and water temperatures reach their maximum; likewise, during February these influences are at a minimum (PSAT, "Ninth Report" 101). During the spring and early summer when snowmelt in the mountains fills the streams and empties into Puget Sound, salinity levels are low at the surface. During late summer and through to December, salinity peaks as a result of depressed river flows and upwelling (PSAT, "Ninth Report" 102). Remember, salinity and temperatures influence the waters density. As a result of the seasonal cycles of both temperature and salinity described above, the *surface* waters of Hood Canal and Puget Sound tend to be less dense during spring and summer than in the fall and winter. Fresh water is less dense than saline water so fresh water inputs tend to remain on top of the denser deeper saline water. These variations in density affect the potential circulation in the water column. When density gradients in the water column become large, the water column is said to be stratified.

Stratification

Stratification describes a layered water column. It occurs in Puget Sound and Hood Canal when less dense fresh water floats atop heavier, cooler, and more dense saline water. In Puget Sound the intensity of stratification is influenced most by the input of riverine waters and the level of solar radiation (PSAT, "Ninth Report" 103). During spring and summer, when fresh water input is greatest, the stratification in the Sound is at its greatest. During fall and winter, in the greater Puget Sound, as the density gradient diminishes the water column becomes well mixed or less stratified (PSAT, "Ninth Report" 103). Stratified waters limit nutrient mixing and oxygen circulation. Hood Canal due to its geomorphology is always more stratified than the greater Puget Sound. In fact, Hood Canal is strongly stratified for most of the year and the bottom waters at the southern end the Canal may only be replaced only once per year at the tail end of summer if at all (Warner 2007). When the Puget Sound is strongly stratified, Hood Canals deep waters do not get flushed and the deep water dissolved oxygen concentrations are not replenished.

Nutrient concentrations

Nutrient concentrations tend to be limited in the upper layers of marine waters as a result of phytoplankton utilizing these nutrients in the photic zone. Phytoplankton have a high demand for nitrogen and phosphorous. These nutrients can be replaced in several ways: coastal upwelling, vertical diffusion from deeper waters, and surface runoff from streams, rivers, treatment plants, and stormwater (Sound Science 16). In late summer, when recreational use and the residential population around the Canal are

greatest, the oceanographic conditions favor “the creation of low levels of dissolved oxygen” (Puget Sound Action Team and Hood Canal Coordinating Council). As the human presence and influence in the Hood Canal watershed has intensified over the years so too has the canals supply of nitrogen and organic materials. However, these replacement sources may result in over enrichment of the surface waters especially when influenced by humans. When this happens, harmful algal blooms may occur.

Biotic influences on dissolved oxygen: Algae Blooms

In systems such as Hood Canal, stratification, nutrient enrichment, and limited circulation often lead to algal blooms (Sound Science 16). Algal blooms deplete surface nutrients and deep water oxygen through photosynthesis. Photosynthesis occurs as algae utilize sunlight filtering into the water column. Therefore, photosynthesis is limited to the upper portions of the water column penetrable by sunlight. In stratified waters an algal bloom eventually settles into deeper waters where it decomposes with the aide of microorganisms (Sound Science 16). The result of these biotic processes is an oxygen gradient in water columns with the most oxygen rich waters near the surface. In some cases water mixing can replenish oxygen concentrations in deep water. However, in waters which are stratified (eg. Hood Canal), deep water is not mixed and becomes oxygen limited. In summary, oxygen in marine systems is influenced by the seawater density and stratification, organic production/respiration, seawater flushing or circulation, and anthropogenic nutrient or carbon loading. Hood Canal is well stratified, nutrient rich, experiences limited flushing and circulation, and is heavily supplemented with nutrients from anthropogenic sources.

Chapter 5:
Puget Sound Partnership: Governor Gregoire's plan for restoration.

In December 2005, Washington State's Governor Chris Gregoire appointed 21 leaders to the Puget Sound Partnership. These leaders represent local, state, federal, and tribal governments as well as building and timber industries, shellfish growers, agriculture and environmental interests and port authorities. Governor Gregoire dedicated 52 million dollars to restore and protect Puget Sound, declaring that "cleaning and protecting Puget Sound must be at the top of [Washington's] state agenda" (Puget Sound Partnership 2006). The Partnership was given 10 months to "develop recommendations for preserving the health and ecosystem of Puget Sound, and to help educate and enlist the public in achieving recovery of the Sound by 2020" (Puget Sound Partnership 2006). Vital to the recovery of the sound are restoration efforts aimed at improving water quality, habitat, species and ecosystem health over the long term.

In an effort to address the Governors objective of a healthy functioning Puget Sound ecosystem by 2020, the Puget Sound Partnership submitted in December 2006 their final recommendations for action. Restoring an ecosystem as large and complex as the Puget Sound will require a holistic, or system wide, approach (Puget Sound Partnership 2006). Elements deemed critical by the Partnership include

> setting priorities for action and measuring results; assigning responsibilities for action and holding the parties to their commitments; having the ability to make binding decisions that are clear to those affected by them; tracking and reporting of the effort, and accounting for results.

If a healthy ecosystem is the objective, a clear definition of a healthy ecosystem is required. The Puget Sound Partnership (2006) identifies three important properties which identify a healthy ecosystem:

- The system is "*resilient* to changes in natural- and human-caused changes in environmental conditions
- has built-in redundancy in its parts so that not all members of a species or habitat type are limited to a single location. Spreading the risk of catastrophic losses of species or habitats improves the ability of the ecosystem to withstand localized losses of key components
- has a representative sample of the diversity of species and habitat types that characterized its historical state.

Therefore, in the efforts to sustain a functioning Puget Sound ecosystem beyond the year 2020, these three properties must be enhanced, restored, and protected.

As pointed out by the Partnership, past restoration efforts have focused on individual ecosystem elements such as an individual species or single sources of ecosystem degradation. These new recommendations maintain that success will occur only though a system wide approach which focuses on the connections between land, water, and species. It is the interconnectedness of these elements which sustained the Puget Sound ecosystem for millions of years. With these connections in mind, the Partnership identified eight priorities. They are: protect Puget Sound habitat; restore damaged forests, rivers, shorelines, and marine waters; accelerate control and clean-up of toxic pollution; significantly reduce pollution from human and animal wastes and other sources; significantly reduce polluted stormwater runoff; ensure adequate water for people, fish and wildlife, and the environment; protect ecosystem biodiversity and recover imperiled species; build and support our human capacity to protect and sustain the environment (Puget Sound Partnership 2006).

Immediate Priorities

From the priorities mentioned above, Governor Gregoire requested that Partnership identify five actions "where state leadership and significant funding will demonstrate a serious commitment for a sustained, vibrant ecosystem that supports communities and our rich natural resources" (Puget Sound Partnership 2006).

The first priority involves cleaning up the areas with inadequate or failing septic systems, working first on those septic systems located in sensitive marine areas.

Protecting habitat is the second priority. The PSP contends that legal compliance with existing habitat protection laws that protect habitat, water quality, and stream flows be well funded by the state. These lands should be purchased from land owners willing to sell parcels located along estuaries, marine shorelines, and within watersheds to enhance habitat important to aquatic and terrestrial species of concern.

The third priority insists restoration projects focus on forests, rivers, shorelines, and marine waters.

The fourth priority is focused on toxic pollution. This pollution is a serious threat to the Puget Sound ecosystem and accordingly the Puget Sound Partnership has suggested five areas affected by toxic pollution which the state should generously fund. They are: the acceleration of clean up efforts for every polluted site within one half mile of the Puget Sound shoreline; harboring a tug at Neah Bay to support the prevention of catastrophic oil spills; a strategy to phase out, limit, and control the release of toxics into the environment[2]; increasing the financial assistance for water recycling projects aimed at the reduction of demand for potable water as well as limiting the discharge of toxins,

[2] April 17, 2007 Gov. Chris Gregoire signed into law a measure which prohibits the manufacture, sale or distribution of most items containing PBDEs (La Corte 2007).

nutrients, and pathogens into lotic systems. The last point will aid in reducing the demand for potable water thereby leaving more water in the rivers and streams.

The fifth priority involves significant reductions in stormwater runoff. At present, eighty percent of the Puget Sound population's stormwater is actively managed. In order to improve upon this eighty percent, PSP advocates; coordinating efforts between the state, federal, and local governments to measure results; enhancing programs that maximize stormwater infiltration and meet water quality objectives with incentives, technical advice, education, funding, and changes in regulation; actively support projects supported by the Department of Transportation and the Department of Ecology which seek basin wide approaches to stormwater management. The PSP recognizes a need to highlight low impact development projects and encourage local governments to develop and promote low impact developments as well as to prioritize urban stormwater retrofits where runoff is responsible for environmental degradation. Finally "immediately form a task force charged with developing a more complete set of actions to address the adverse impacts of water pollution" (Puget Sound Partnership 2006).

This plan appears comprehensive, it looks good on paper. But, how does this plan for action differ from the previous attempts to conserve the Puget Sound? Since 1983 an impressive looking list of events has occurred (Appendix C). Yet, since the late 1970's the Puget Sound ecosystem has become increasingly degraded. The most obvious way that this new plan differs from previous attempts lies in this approaches effort to restore the ecosystem from a system wide approach as mentioned above.

Humans have lived in the Puget Sound region for thousands of years and according to the histories preserved in oral traditions, and supported by western science,

these recent problems with ecosystem health are a new phenomenon. In 1900 there were only 250,000 people living in the twelve counties around the Puget Sound. In 1940 this population reached 1 million. Projected for the year 2025 it is estimated that between 4.7 and 6.1 million people will be living around the Sound (Sound Science 69). With this increase in human presence and the already heavily degraded environment, the stresses on Puget Sound's ecosystem are quickly intensifying and the room for failed attempts is rapidly diminishing.

According to the PSP (2006), measuring progress during restoration from an ecosystem wide approach requires defining large scale or 'ecosystem-scale' goals. The stated objective is a healthy Puget Sound ecosystem. Concerning the best strategy it is important to figure out 'how much' is needed to classify the system as healthy as pointed out by the PSP (2006). "For many of these outcomes, more discussion between a scientific team, the larger scientific community, and the policy leadership of the new entity will be needed to set these quantitative standards" (PSP 2006). Absent from this sentence is any mention of the regions long term residents. However, House Bill 1883 acknowledges the contributions possible from the Hood Canal regions long term residents. For thousands of years prior to European settlement, the Native peoples and the components of the Hood Canal ecosystem coexisted. During this time those three properties identified by the PSP which identify a healthy ecosystem remained intact. It seems reasonable that the local tribes could provide critical information concerning the past conditions and the relationships among the regions organisms. This is supported by Calheiros et al (684) who point out the deep understanding local people often possess of

their environment attained from generations of living, oftentimes sustainably, within these environments.

Chapter 6: Historical Perspective

Benefits of Participatory research and TEK

Scientific research is more often than not utilized as the source of acquiring biological data. The Puget Sound Partnership provides a very succinct definition of a healthy ecosystem. A portion of this definition maintains that a healthy ecosystem "has a representative sample of the diversity of species and habitat types that characterized its historical state". One way to do so is to maintain records of the various species assemblages over time and to specify what is representative from these records. However, historical records may be less than ideal due to at least three methodological circumstances. First, the records may only cover a short time period. Second, the information recorded may be incomplete or insufficient in providing the desired details. Third, concerning how the record is to be used, the historical reference may be too broad or narrow. Fortunately, acquiring biological data can be obtained in other ways. Traditional Ecological Knowledge (TEK) is one approach.

Some advocates of TEK claim it capable of improving the scientific research through sometimes better information (Huntington 1270). TEK is derived from extensive observation of a particular area and its associated species. This information often extends years beyond an individuals own lifetime by means of oral histories or the sharing of a resource among users. Therefore, I will attempt to utilize TEK to inform scientific findings pertaining to the health of the Hood Canal ecosystem. This will be

accomplished by analyzing the oral histories of Skokomish Tribe members and utilizing such data to explain how members of this community characterize the environmental history and overall environmental quality of this particular area and its associated species.

Chapter 7:
Methodology

The PSP (2006) advises a record be kept to track the most valued species, habitats, and water quality attributes in an effort to "learn as we proceed about the mechanistic linkages among ecosystem elements and how human actions affect them" (A-7). I believe some of this information is already known; available to those who listen to the oral histories of the Skokomish people and other long term residents of the region. It is my intention to analyze transcripts derived from the Skokomish Tribe during interviews collected by participants of The Evergreen State College Native American Studies "Heritage" Program. The purpose of HB1883 and the "Heritage" Program is to "provide critical insight into the history, impacts, and potential causes of the low dissolved oxygen concentrations occurring in Hood Canal". By analyzing the transcripts from the Heritage interviews, specifically responses to the questions in Appendix D, new information pertinent to my research question may be uncovered. Of particular interest is how these oral histories document: 1) Species Composition, i.e., what species were present in the past, 2) Habitat Utilization, i.e., which habitats they utilized, 3) Species Assemblages and Interactions, i.e. what sort of relationships exist among the organisms, 4) Management Approaches. Together such information will speak directly to the objective of the PSP (2006) who seek to "better understand the mechanistic linkages among ecosystem elements and how human actions affect them".

The ‘Heritage’ interviews took place between March and June 2007. During this time fifty interviews were to be conducted. Individuals were sought out based upon age and occupation, as well as an individual’s interest to participate. Tribal fishermen were the focal population of the Heritage programs interviews and tribal elders were assumed to have the greatest amount history to share. Fishermen represent a large portion of the Skokomish community as a substantial portion of the tribe’s economy is and was centered on various fisheries. Not all interviews occurred with tribal fishermen directly as several of the interviews occurred with the families of these fisherman as well as tribal elders. The most consistent method of locating an individual occurred in the form of referrals and recommendations from tribal members some of which were involved in the Heritage program. I participated in the majority of interviews analyzed below. Additionally, of the six transcripts analyzed for this study I transcribed half of them. Interviews were recorded with a video camera. The audio portions of the tapes were transcribed with the computer program Express Scribe v4.11. As transcripts were completed, I analyzed them for information pertaining to the historical species and habitat compositions of the marine, riparian, and upland habitats as remembered by the Skokomish people. Additionally to validate the objectives of HB 1883 I sought information related to the history, impacts and potential causes of low dissolved oxygen in Hood Canal. Finally, in consideration of the objectives of the PSP and pertinent to the restoration of the Puget Sound Ecosystem, I extracted information pertinent to sustainable resource use.

Research Design

This ethnographic research design was adopted to recover information held by the Community of the Skokomish Indian Tribe with regard to the low dissolved oxygen concerns centered on the Hood Canal. The research model is derived from a combination of local and scientific knowledge. The recent scientific knowledge for the Hood Canal region is extensive and provides the basis from which survey questions were constructed. Additionally, this scientific knowledge provided a base from which to interpret survey responses and to better understand the knowledge derived from the Skokomish community. "The researcher learns through careful listening, interpreting and conversing with individuals" (Calheiros et al 690).

The Skokomish People

Residing along the southern end of Hood Canal is a population of people who have been present since time immemorial[3]. These people are the Skokomish. The Skokomish people are the decedents of the Twana Indians, a Salishan people who historically occupied the Hood Canal drainage basin (Culture and History of the Skokomish Tribe). First European contact occurred in 1792. After signing the Point-No-Point Treaty in 1855, the Skokomish moved to their reservation on Hood Canal near the mouth of the north fork Skokomish River. The reservation boundaries, defined during the 1870's, encompass more than five thousand acres of forested uplands and a floodplain, wetland mosaic heavily influenced by river and tidal forces. Currently the tribe has 750 enrolled members.

[3] "Immemorial" is defined as "reaching beyond the limits of memory, tradition, or recorded history."

The Skokomish people were selected for research due to the fact that they have been in the region since time immemorial and because of their intimate relationship with the environment. Twana society was based on, and still is to a large degree, wild food resources including fishing, hunting, and gathering (Government to Government Training Manual). Tribal fisherman and other long term residents of the region are assumed to have an intimate knowledge of the Canal's ecosystem health as well as historical information derived from multigenerational fishing family lineages.

Chapter 8: Findings
Introduction

In the passages presented below the voices of those being interviewed are presented as direct quotes allowing the reader the opportunity to hear each voice responding to specific questions. In the first passage Delbert Miller, a Skokomish Spiritual Leader and tribal elder, describes habitats certain species historically depended on, what species were present, and factors he believes are responsible for Hood Canal's degradation. In the passages that follow, many of Delbert's memories are echoed. Like Delbert Miller, each of these voices reveals changes personally witnessed or shared among family members through oral histories. These changes cover wide ranging topics including the ways in which the resources are managed, harvested, and available; the causes of declining water quality, species abundance, habitat availability and hypoxic events. Some of these interviews touched on possible solutions and the importance of recording the oral histories of tribal elders before that knowledge is lost forever. This prophecy below illustrates how the Skokomish realize the TEK possessed is valuable.

Delbert Miller: We were told of a prophecy by a man named Tah-lu(g) – he said that there would be a day coming where the land, and the sea, and the sky would become dirty. There would be a people who are going to come and change everything, and that what we would call "spoh-lotch" – means "the world turned upside down". The coming of the people from Europe would come and change everything – the world would turn upside down. And when that happens, the land, and the sea, and the sky would become dirty, and our culture would almost fade out. And then there would come a time when they begin to pay attention to the environment, there would be a day coming when, my grandmother said in my lifetime, I would see that they people would turn and begin to ask our Indian People about our teachings: about the land, and the sea, and the sky. And it's true, I have seen it.

Alright. My name is Delbert Miller. My family name is Smut-Koom and it means – as if you looked across a field or down a beach and seen heat waves rising up… and they fixed it to mean "that coming from within – right here"….the beloved…that kind of warmth. It's a family name and I was named after my father.

I had the good fortune to be around a number of elders growing up: great-uncle, Archie Adams, and my grandmother, Georgia Miller, Lee Kosh, Ida Kosh, Bennet Cooper, Catherine Cooper, Louisa Pulsifer, Emily…not as much as much Emily but I thought to spend time. So I treasure those memories and what I was told…I was taught - and over time in our culture I was taught very important things to remember.

I was told about the numerous villages on Hood Canal – the Tuwaduk villages – major villages…One of the things they told me to remember was about a village just north of Potlatch State Park, a place called Ts-hal-but and it means "A Place of Herring" – it was a herring spawning ground, there was also a longhouse right there – pretty significant …

I was told the way they use to fish there for herring and how important it was that these herring would spawn right at the place called Ts-hal-but, and that area has been destroyed by Tacoma City Light powerhouse and the boat launch they built; they destroyed the herring spawning ground that was so highly regarded and treasured by the Tuwaduk People. That beach is no longer there [it] has been covered-up and changed by the way they work the boat launch – they filled in that entire area now - covered the beach.

It's important to have these memories. I have seen these changes myself and heard the stories from our elders. I have seen, in my time, the change at the mouth of the Skok River, where growing up as a boy we would dig clams, geoducks. Now the silt has filled in so much that you can nearly walk across on a very low tide, all the way across to Ball Point, across from the Union. There is very little water there now; the silt is filling it all in. There is very little of any geoduck anymore, and it has interfered with the flounder that we used to enjoy gathering; twice a year we would go: in the middle of winter, and midsummer. There were different types of flounders. We had many members gathering flounders-those are almost gone too. And the crab is different. The cockles we used to gather, the way they were, have changed as well due to the bulkheads, the silt, the bark and the sawdust from the earlier mills. The cockles, we used to use a rake and get a lot of them-a couple of buckets and never over-harvesting. It was easy to get a lot of them. So, I have seen those changes…

Now, those kinds of areas have been disturbed by … bulkheads that people built and the sawdust, and the log dumps-the bark-and the people themselves poured gravel over or moved these large rocks, because they had to build the bulkhead; build up their beach. And if that wasn't enough, they had their open septic tanks that would pour from the drains septic system right onto the beaches. I have seen those myself - I walk the beach, quite often. So I have seen a decline in some areas of the beaches. The different types of clams-the types of horse clams, a lot of those beaches are gone, and a lot of types of muscles are fading away. And the kinds of grass, basket grasses, I've seen change on the shoreline.

This analysis is divided into four sections: 1) Habitat Utilization and Loss, 2) Changes in Species Abundance, 3) Management Approaches, and 4) History, Impacts, and Potential Causes of low dissolved oxygen events. In some passages the reader may feel that a portion of the information belongs in another section. For example, in Delbert's passage below while discussing river habitat alteration and a decrease in delta depth, Delbert describes a decrease in the presence of sturgeon. This passage is included in its entirety to provide the reader an example of the connectedness of the ecosystem. Placing the sturgeon portion in the 'change in species abundance' section of these results would exclude the cause and effect relationship Delbert alludes to.

8.1 Habitat Utilization and Loss

Rivers and Deltas

Land owners in the Hood Canal watershed have diked many of the rivers over the years in an effort to contain flood events and to reclaim flood lands for farming and other desires. These dikes have altered habitat as well as ecological processes essential to some organisms.

> Delbet Miller: We've seen the farmers up in the Skok[omish] valley dike and bulldoze everything they could and changing the course of the river in their efforts to stop the flooding as a result of the Tacoma dam. So they would build these big, long dikes, and they are still there today even though they were found and charged with this illegal building of dikes – changing the river's course – hydraulic violations. But [it] changed the course of the river and washed away some of our old village sites that run along the Skokomish River. And they also washed away some of the places that were seen as gathering areas. Certain plants, and even trees, were washed away because of the way they put the dike systems up. Some of these were specialized areas where [Skokomish] would gather for spears, bows, basket grasses, or medicines.

> I have seen the difference in the Belfair area – the rivers over there…Union River, Mission Creek.... And the bay – you can wade out a long way in there – can wade out far out in there. I believe it's filling in because of the way they have changed the course of the rivers. They've also seen the same thing in the Quilcene Bay. I was talking to some of the folks, Hood Canal Management, who say that if we don't take quicker actions, in 30 years that Quilcene Bay will no longer be there

because of silt will fill it all in. That was a large village site there – the Quilseit People. The kinds of clams I have seen change there, they were called Jack-knife clams. I haven't seen any there [in recent years]. Sturgeon – I don't see very many sturgeon in the Quilcene Bay like there use to be. Or in Twadoh Bay – when I was younger, I remember them. Those are fading away as well - ruining their spawning grounds. And that's a sad thing, these sturgeon seeing them disappear that way: 12-footers. There are 2 kinds … and I don't see very many of any of them. Once in a while a fisherman will catch one and there will be a lot of talk about them.

The Skokomish River was dammed in 1926 to provide light to the city of Tacoma. This event changed the rivers carrying capacity. Gary Peterson believes the rivers altered state negatively affects its ability to care for the Hood Canal.

Gary Peterson: On the Skokomish River for example when I grew up in the early fifties, the places we went to swim for example, at that time we could jump off of the bank down into the water maybe six or seven feet, hit the water and go down another maybe eight or nine or ten feet down to the bottom of the river. Today, the bank is gone, you can step off of the bank into the bed of the river and your feet come to the bottom of right away. So the river is *much* shallower than it used to be because it's filled up with the things coming out of the mountains as a result of the clear-cuts. So the river is less able to care for itself let alone contribute to a healthy canal so that would have happened probably from the time I was ten years old, eight or nine or ten, up until recent history, and I am sixty-two now.

Changes in Shoreline Habitat and shoreline associated species

Shoreline development has altered great stretches of shoreline along Hood Canal.

Gary Peterson: When I was a kid there used to be vast stretches of darkness along highway 106 and 101 where there just wasn't anybody, nobody lived there and we would drive at night on our way back home or going someplace it would just be dark. There wouldn't be any houses, but now it's just constant, it's almost the whole length of the either road of 101 or 106 there's houses build up along the hill which there never used to be when they started to appear it was along side of the road and gradually more and more they moved up the hills are now occupying the hillsides and the hilltops and right next to the [water].

With this development, many eel grass beds have receded or vanished altogether. Eel grass abundance changes are concerning to many. Its role in the ecosystem is imperative. Its diminishing abundance threatens many organisms as a variety of juvenile marine species depend on eel grass habitat for refuge and food. A map showing the change of eelgrass habitat in Puget Sound and the Hood Canal is in Appendix F.

Lalena Amiotte: Eelgrass is a huge, huge concern. The eelgrass is what I like to call the nursery for the babies. And if the eelgrass is gone, where are all the babies going to be reared up? It's a very, very important part of the Hood Canal ecosystem. And it's very disturbing to see…WDFW has been doing … surveys … for many years on what the distribution of eelgrass is in the Puget Sound. Hood Canal for the past three year has had the most consistent decline in eelgrass population as well as abundance and that's just the fact. Hood Canal, out of the entire Puget Sound is the number one impacted area for decline area for eelgrass. It's extremely disturbing when you're looking at the resources of the, you know, the salmon and the Dungeness crab. They need that to foster their babies. Without the babies we have no resource. So that's definitely an issue. I've definitely noticed changes.

Lalena develops this idea with several reasons she believes responsible for eel grass and beach reduction.

Lalena Amiotte: There's a lot of changes in the shoreline. A lot of it has to do with development. People are able to go to Mason County and get permitting to put in piers and bulkheads. Bulkheads are another reason why eel grass is declining. Bulkheads are concrete right up against the shoreline. I am sure you've seen them off of people's houses. When the waves come it changes the water movement, it changes the physical characteristic of the tidal influx; it smashes up instead of a flowing motion. Bulkheads have been linked to declining eel grass cause that motion changes. There's a lot more bulkheads and there are a lot more piers all along Hood Canal because there are more people moving here and buying property. Mason and Jefferson counties still allow through the permitting process these pieces of development to go in. So I would say the entire Hood Canal's changed in regards to that. Loss of sandy beaches, typically the entire Hood Canal is more of pebble area versus sandy. When I think of sandy beaches I think of Mexico or Southern California. The beaches here never really were sandy, mixed with sand definitely but more of a cobble pebble texture. The erosion, there's erosion all over the Hood Canal. Is that a natural occurrence or is that caused by man? That would be speculation. I can say that at the Potlatch State Park area the past 100 years where Potlatch State Park sits now which is in this little area right here off of the delta that used to be an area where logging, where they took the logs, put them on the barges and then send them out up the Hood Canal and then typically over to Tacoma or Seattle. So, that area that the park sits on right now, if you were to dig down 2 feet you're going to hit sawdust. It's basically just been filled over and that was a logging central area of Hood Canal. And there's several spots, Nally's which is at the very base of the river, that was another area where logs were shipped out the state park and then all along here, cause there was massive logging in the early part of the century, and they were just getting the logs out. Potlatch state park I've noticed in the past 2 years that when we have high tides and extreme weather events the shoreline is being eroded away and you can actually see that fill, the wood chips and you know all of that fill. So that is a real area where I've noticed some difference. Also, where the Skokomish fish hatchery is, which is at the very bottom of Hood Canal off of highway 101 just south of the Potlatch state park, that area we've actually filled in to stop erosion from occurring. And again that's the high tide and extreme weather events that are causing that. Some would speculate that the water is coming up. Is that global warming? Maybe. But, we've noticed that. Tom Gulley told me that, it must have been about a year ago, that he's noticed that, cause he's the one that literally built that hatchery… I don't know-40 years ago. He said that when that hatchery was built the water was much lower, and he was talking feet. So, he'd definitely seen some changes and I take what he says as probably true. Cause he's a lot older than me. So that's what I can say about erosion and what I've seen.

Attempts to restore eel grass beds in Hood Canal have met only limited success. Lalena links these complications to algal blooms.

Lalena Amiotte: My gut says algae [is responsible for the decrease in eel grass abundance], because eel grass, of course, is a plant and it needs the sunlight and if we're having this huge algae bloom that's blocking the sunlight from getting to the eel grass [eel grass will be unable to grow]. More nitrogen, like I said, going in causes these algae blooms to be bigger and bigger every year and that's more light that's being blocked for the eel grass.

Kelp has disappeared from the southern Hood Canal too.

Lalena Amiotte: And then kelp I remember when I was a girl, a teenager, kelp used to wash up on the shore on this delta area (showing map) we used to walk, my dad kind of lives up near Potlatch State Park and we used to walk down this delta everyday with our dogs and we used to ride our bikes. I remember kelp, cause we used to whip each other with them, across the face. So I definitely remember that I can't the last time I've seen it since I've been an adult. But I definitely remember whipping my sister with kelp when I was a kid.

Changes in forest cover

Logging decimated the forests in the Hood Canal watershed after European settlement. The impacts of logging the uplands were mentioned by several of the interviews I conducted as well as those interviews conducted by others in the Heritage program. Most often the impacts of forestry were related to an increase in sediment washing downstream and into the canal. Below, Lalena describes how forest regeneration has generated an altered tree species assemblage. Additionally, Lalena describes the impact of the Skokomish River Dams on local forests. The map she refers to is attached in appendix E.

Lalena Amiotte: Ok as far as the trees go this area used to be an Evergreen forest. This whole area was Evergreen and when the logging people came in a century and a half ago basically this area was clear-cut, this entire area was clear-cut. So the trees that we see now are second to third, some are even fourth growth, from the old growth forest. Right now we've got several companies that manage the forests and the private home owners shave a small share of what's going on with the timber industry as well as the national park system and the state and DNR. The changes have gone from evergreen trees to trees that shed their leaves and those were obviously were not originally here. The reason that those trees, such as the alders, alders have been planted following the old growth trees because they grow very quickly and they're of higher value. Long time ago cedars were worth a lot of value but the cedars aren't really worth that much [now] but the alders are. So when people go and replant they're planting alders it's kind of a mixed bag type thing. The state makes you plant a mixed forest. If we were to really get back to the way that the

geographical area looked it would all be evergreen. What changes have I seen? I've seen a dramatic disturbing change in the Skokomish valley, which is this area here. It runs along the Skokomish River. It starts up in the mountains, the Olympic Mountains and runs down. What I've seen in my lifetime is the trees that are in the Skokomish valley are dying. And, primarily it's the Evergreen trees that are dying; the cedar trees, the pine trees. The alders actually do very well in the area and the reason that the cedar trees and the pine trees are dying is because of a high ground water issue. The reservation is affected by the high ground water as well. What happened, you'll see on the map here Lake Cushman that Lake Cushman is not a natural lake. This is a dammed lake and there are power generators on 2 parts on the river. The north fork was dammed off completely and then this other outlet here that drains off into where the Potlatch area of Hood Canal is. When …the Skokomish River was dammed off it had major hydrological impact on the Skokomish valley and that caused the river to change its channel and direction and it also caused sediment cause the river used to just rage, rage, rage sediment really did not build up. Now the river is slower so we see sediment that over time has gotten higher and higher and higher. And with the logging, that I mentioned before, with clear cutting all that sediment washes down and when it washes down it goes into these channels here into the Skokomish valley. Now the river is higher cause there's more sediment, it's moving slower and when it rains there's flooding events. So the whole hydrological system that was in place 150 years ago is completely different and the end result is that we now have a high water table and the most frequently flooded river in the state. That's causing the trees to rot out from the bottom. The alder trees are able to maintain, a lot of them may fall over from flooding events or whatever, but the cedar trees and the pine trees they are just rotting from the bottom. So if you drive in the valley you'll notice that a lot of the evergreen trees are dying or are already dead and that's something I've seen in my lifetime. So that's what I know about trees.

8.3 Changes in Species Abundance

Fishes

The Skokomish have fished the Canal for many generations. During a couple of the interviews I participated in, a decrease in the number of fish present was mentioned as well as an overall decrease in the size of fish caught. Sturgeon is mostly gone according to Delbert and several people spoke of smelt disappearing. Smelt are culturally important to the Skokomish so I assume they have a heightened awareness of this fishery.

Lalena Amiotte: A long time ago smelt was as common as candy. Everybody was eating smelt…even 20 years ago every feast or everything there was always smelt. We don't see that now, and I don't know why. I tend to think that it's just not as abundant as it used to be and that's something that's I've witnessed in my lifetime. We used to eat smelt all the time and we don't anymore. And I don't know why. I just don't think the population is out there. The smelt schools used to be really big you could see them like if you were walking at Potlatch State Park you could see schools of smelt; we don't see that anymore. So I think that you know over time those populations have declined.

Two elders I interviewed remembered ling cod utilizing the intertidal zone. Fred Miller was one of them.

Fred Miller: The Cod – just north of the dock there, there's rocks there the Cod would go lay their eggs up in there, and we'd go get some, we ate some, use some for bait, you know. When the tide goes out – that's why the Cods laying like that so their eggs are protected half the tide, so they don't get ate up – and I don't know, I haven't seen that for a while, you know.

Shellfish

Nearly every person interviewed spoke of changes in the abundance of shellfish. The Skokomish people have always depended on these resources and the memories of past abundance and recent population declines were universal.

Lalena Amiotte: Well, again in this area, which would be the Skokomish River Delta the river feeds into the canal here, but this is all saltwater influenced and all shellfish beds. This area when I was a kid you could walk the entire beach and it was huge, huge abundance of clams, oysters, and muscles. And I would say probably in the past 7 years that area has been completely stripped down to hardly anything. There was a reseeding effort down there last year but we won't see the benefits of that, if any, for another 2 years. My theory on what changed that is illegal harvesting, it's right by the road so people will pull in and go out and get shellfish and I think a lot of illegal harvesting has been done down there.

Crabs

The availability of crabs has diminished too. Larry shared information gathered from a friend about crabs in the intertidal zone. Deeper water populations have declined too. Lalena's husband finds little payoff crabbing in the deeper waters of southern Hood Canal.

Larry 'Wong' Peterson: A friend of mine was telling me the other day that he's noticed that you used to be able to roll rocks down on the beach, and there would be all these itty bitty little crabs. As a kid we used to like to go down and catch these little crabs, but they're just not there anymore to speak of.

Lalena Amiotte: The crab… We have noticed in our family that the populations are declining. South of Ayock Point which is the exclusive area of the tribe, the crabbing is not very good, the numbers aren't good; commercially it's not a good situation. We aren't gonna make a whole lot of money if your setting your pots down here. But because the tribe has treaty rights up here (gestures towards the northern portion of Hood Canal) most of the guys are going in this area which would be south of Dabob Bay and into Dabob Bay.

Sea Cucumbers

Sea Cucumbers were previously found in the intertidal zone. Today, these organisms are found below eighty feet.

Fred Miller: There was places below the flats where there was probably thousands of sea cucumber, at that time we could see them, but they're not there any more, so everybody kinda harvested them out. They're there. I think they are more deep water now. I know my son, he does some scuba diving and goeducking and stuff and he says that he sees some, but you know, when I was a kid, like I say, on some of those flats, I'd drive over them and they were just all over. Even on the beach doing some clam digging we'd roll them up on the beach. You never see that anymore.

Lalena Amiotte: One thing that we have noticed is there is a real big interest in the Asian buyers in the sea cucumbers. Apparently that's some sort of delicacy in the Asian markets and there are a whole lot of Asian buyers that are trying to get our Geoduck divers to tap into that market. But the sea cucumbers that grow in the Hood Canal grow very very deep; they grow a lot deeper than most divers would want to go down. So I am not sure if that market will every open up. Maybe there are some people who would be interested in it but typically a divers not gonna go down below 60 feet. Typically where the real sea cucumber beds are is about 80 feet. Which a diver could do but it's a little bit more strenuous and more dangerous.

Marine Mammals

During one of the interviews marine mammals were mentioned. These mammals were porpoise and with this story came a story of the porpoise hunters. Porpoise hunters traditionally held a highly respected place in Skokomish society. These hunters along with the porpoise have ceased to exist in the southern portion of Hood Canal.

Delbert Miller: We also don't see porpoises in Hood Canal. We don't see porpoises anymore and I don't know if that was due to early gill netting or why it is that they don't return anymore. Every once in a while with an El Nino a couple will get blown into the mouth of the Hood Canal. But we don't get them anymore.

Birds

Noting an absence of pigeons due to sport hunting, Gary speculates that their loss coincides with an apparent decline in elderberry trees.

Gary Peterson: There used to be elderberry trees for example with purple berries on them that the birds ate and I don't know whether the birds disappeared first or the elder berry tree disappeared first but you don't see the elderberry tress around anymore. And there used to be pigeons, there used to be a large pigeon population and there was a point by the [inaudible] creek where there used to just be cars lined along the highway where they would stop and park their cars there and go in there and shoot pigeons and I think they managed to shoot them all which I think they were responsible

for the spread of the elderberry trees, the pigeon were, and once they were gone the trees couldn't survive anymore either.

Increases in abundance

Not all of the organisms in Hood Canal are diminishing. In response to the question "Are there any animals (fish, birds, mammals) that you used to see in the canal but no longer do?" Gary made reference to the abundance of several animals declining and one animal which has become more abundant. Of the two bird species which he believes were more common in years past, the "Red Headed Woodpecker" (*Melanerpes erythrocephalus*) is probably a Red Breasted Sapsucker (*Sphyrapicus rubber*) as *Melanerpes* is found in the Eastern United States and *Sphyrapicus* is similar in appearance and is found along the west coast.

Gary Peterson: No I cant think of anything except I think of things like Red headed woodpeckers that we used to see pretty often which you hardly see any more and its to the point now if you do happen to see one you think 'Hey, there's a Red Headed Woodpecker'. There were birds that we called wax wings, I don't know what the real name for them was, but there used to be a lot of those around and you don't see many of those any more. There are things like that I guess if you were to think about it …Skunk. Skunks, we used to see skunks around and get into trouble with them when I was a kid. You don't even see them smashed on the road anymore like it was at that time. So I think something like skunks are no longer as populous as they used to be. There are not as many of them. So I guess if you were to really probe your mind you'd probably think of quite a few things that aren't there anymore that used to be. Well one other, just along the lines of what aren't there any more, we may be interested in what is there that wasn't there before, thinks like opossums. We never had…I never saw them when I was a kid and now it seems like they are everywhere. So there are some things that have gone away and there are other things that have appeared like opossums.

8.3 Management Approaches

Changes in resource management

A primary difference in resource use was sifted out of the words of Delbert and Gary. Both men refer to changes in the fishing practices utilized today by both Indian and non-Indian fishermen. Gary describes how the year round fishery remembered

many years ago was a fishery that supported many fish species and he relates this to the comparatively limited fishery in existence today.

Gary Peterson: Well historically there would have been a year round fishery there would have been fish coming into the canal and streams in the canal year round so it would have been spring Chinook and fall Chinook and Sockeye salmon, chum salmon, silver salmon; over the years it dwindled so that by the time the commercial fishery had built up there was basically a silver run, a Coho salmon, and I guess the chum run, the dog salmon, and that had a lot to do with the state hatchery on the Skokomish River. They would release Chinook and silver salmon from that hatchery. So it was largely a hatchery run.

Cassandra Sharon: Has this changed?

Gary Peterson: Well yeah, it changed again because the state changed their hatchery management philosophy so basically they were just releasing chum salmon, dog salmon, and so this has become a giant chum run and not much of anything else.

Delbert explains how the fishery today has a greater impact on the marine ecosystem. Delbert explained how during red tide events many fish would swim up close to the shoreline. In earlier years these stressed fish, although an easy catch, were left unmolested. Below Delbert describes the resource impact from bycatch.

Delbert Miller: I have seen changes in the kinds of fishing. We mainly fished in the river when I was growing up. Some of the guys fished in the Canal – very little though - not like you see today. I have seen change in the types of fishing in the Canal, a lot of gill nets at first always drifted with their boats and then they began to tie off the beaches. I have seen the great numbers of crab and bottom fish and birds caught in … those nets. I have seen Indian and non-Indian fish like that. And I have seen Indian and non-Indian drift fishing – let your line out and just drift with the current. I have seen Indian and non-Indian having to cut their gear off because maybe there were too many sharks or they were hung-up on something on the bottom. Maybe they had caught too many fish, but they would have to cut them off. Out of sight, out of mind, but I know those nets are still there. So I have seen that change.

In recent times the resources have not been respected. Harvesting smelt while they attempt to spawn limits the sustainability of the population.

Delbert Miller: I have come across numbers of … people harvesting smelt in the spawning areas. I didn't understand why that was allowed but…; down near Twanoh State Park. I felt they should have been allowed to spawn, but they had their smelting seasons. In some of these areas, things like that were allowed.

The Skokomish way demanded a level of respect be given to the resources which they depended upon. Skokomish belief included the idea that resources would be taken

away if these resources were not respected. This is apparent in the practice of honoring the first salmon caught as well as where they built structures and in how they value ecosystem knowledge and understanding.

Delbert Miller: There were many places along Hood Canal that were seen as sacred in the old day. Nobody was allowed into the further reaches of the Hamma-Hamma area. They were holy grounds. Nobody was to live in there. Only at the mouth of the river, but nobody was to go up inside the hills and build. It was holy ground. The giant trees that were in there – the kinds of spirit lived in there. Now they are all covered in houses or logged off…It's important because some of these things need their purity in the place they live – their sacredness. Like many things, if they are not respected, then they will begin to be taken away.

Resources were managed more sustainably in years past. Earlier fishing practices exhibited a concern for the river and the resource.

Delbert Miller: in the early days, they use to build, all the way across the river, fish-traps. They would have names for every part of a fish-trap and river. And they had where they had to open these traps at a certain time of the night time – let fish go by. They were good managers of the resource in those days. We see remnants of those today in what we call "eddies". Dennis Allen built one of the last archer ones; it only went partially across the river and it was done to make deeper pockets because the river had begun to fill in – fill in with gravel and silt; no longer the deep holes or eddies in the river due to the Tacoma City Light dam. Everything began to fill-in where even the level of the water was higher than the surrounding land causing great floods year after year. So the People resorted to building these eddies to create these deeper pockets: some would fall trees, and some tried stakes to build deep pockets into the river and it was a great advantage. And it was done in a way of consideration for the fish who would have a place to rest, as well as for the fisherman [who] would be able to catch them. Now they don't allow building of eddies in the river like that – a wall type eddy to create deep pockets.

During Lalena's interview Cassandra, Lalena, and I discussed changes in fishing practices over time and whether or not Lalena believed the current practice of beach seining was sustainable.

Cassandra Sharron: What fish/shellfish were harvested and how? Have there been changes in fishing practices over time? Have fishing locations changed? Have you noticed or are there stories of changes in the harvest of herring, clams, and Dungeness crab?

Lalena Amiotte: Well (referring to the power point again to show specific species) there are several species here or natural resources that we're harvesting. Traditionally I think that's probably where we should start, with the fish. A long time ago, there was not, right now, the real main bread winner here is beach seining where people will set up nets; and they kinda go in like a purse string type thing. They stretch the net all the way out into the Hood Canal, they let the fish run into the net and then they come around with the boat and kinda trap em in there. Then the people are on the shore and they pull them out; that's beach seining. So a long time ago people did not do that. The

way that they did it a long time ago was they were on the river. And they had poles and they had nets and they were river people. River fishing now is it's different. Everything is different, everything has changed; the flow, the amount you can catch, and then there is money involved. People are out fishing because they are trying to feed their families basically. You can catch a whole lot beach seining vs. on the river. You can definitely make money on the river but certainly not what you would beach seining. For example my husband could spend the day out on the river and probably make 2 to 3 hundred dollars one day. Beach seining is 3 or 4 grand depending on what the market is. It's completely different. The amount of fish that are coming up the canal, you can catch a lot more. A long time ago that didn't make sense, cause they weren't doing it for commercial, they were doing it for sustenance. So you wouldn't go over harvest a bunch of things for sustenance, it wouldn't make sense. So that's the fishing thing.

Brian Cary: Do you think beach seining is sustainable?

Lalena Amiotte: It's sustainable in that we have co-management with the state hatchery system. If there were not state hatcheries and rearing of fish, that would certainly not be sustainable. Because the wild population versus the hatchery population is, it's not comparable. There are some issues with the issues, notably sea lice. Sea lice are fish lice and they attach to the fish and they're more common on hatchery fish than on a wild fish but what we are seeing now is that the hatchery fish and the native fish are you know, kinda swimming around together and just like kids at school, they brush up next to one another and then they end up with the sea lice too. So that's an issue. Sea lice if it's real bad infestation on the fish it will kill it. It's an issue that not only the state of Washington is dealing with but also in Canada and British Columbia and also Alaska. So that's an ongoing problem. But to answer your question as far as the sustainability of a wild fish problem for commercial purposes I don't see that as sustainable for very long if it were at all.

8.4 History, Impacts, and Potential Causes of low dissolved oxygen events

History

Most of the responses to questions about the history of hypoxic events spoke of the same events mentioned in the literature. New information regarding the impacts of these events on the organisms affected and the economic impact to the tribe were uncovered. Concerning the September 2006 hypoxic event in Hood Canal Lalena describes the enormous amount of mortality she witnessed.

Lalena Amiotte: O.k. So the only fish kills that I'm aware of would be in recent times going back into before the fifties I wouldn't know of any….The first fish kills that I think we had in Hood Canal in recent times was 2002. And every year since then we've had small events, last year however was a real large event. The event that occurred last year extended all the way from…when it occurred we sent all of our staff pretty much to comb beaches and see what the extent of it was. So we saw all the way from the Skokomish River Delta up to Hoodsport, past Hoodsport to Eagle Creek, Jorsted Creek, and to the Hama Hama. There was also documentation in Dabob Bay which is up by Quilicene, so we're looking at a 35 mile stretch of Hood Canal; where we saw real extensive mortality. What was really surprising to me in witnessing that was…the extent of species; it was like everything that was in the water died. There were jellyfish, and even up north where you would think that the oxygen would be much higher, um on the Hama Hama River we witnessed I

think three mud sharks which are, you know, four feet long and maybe a foot and a half wide, you know *huge* creatures that washed up on the shore. So this really covered everything, not just the bottom feeders, but just everything that was in that water column when that oxygen level hit um just washed up on the shore. It was a huge, huge event.

Impacts: biological and economic

Not every organism died during the 2006 hypoxia event. Many organisms were only severely stressed. Below Lalena describes the stress observed in schools of Rock Fish.

Lalena Amiotte**:** We saw fish, um Rock Fish. Rock Fish are definitely bottom fish, um, right at the surface. I mean within an inch of the surface and there was schools….all over at the surface. Then at some point the media came in and they were taking pictures and you know showing the footage of it all…um but that was really the only time. It's very strange to see that; a Rock Fish lives in very, very deep in the water and to be even at 30 feet, that's not very typical. So and then to have them just right at the top, and then you could see their little, you know, mouths kind of gasping at the surface it's very strange. It was kind of a surreal experience to see something like that.

Lalena describes the economic impact of red tide events in her community.

Lalena Amiotte: We see those all the time. The large algae blooms. Red tide…red tide hit the Hood Canal last year in August and it completely shut down the Oyster harvest in the Hood Canal. I think that what happened last year was the first year that anybody every knew of that red tide actually hit the Hood Canal. But what ever reason when the red tides hit, its always up in the straits of Juan De Fuca, last year was the first year that that ever happened here. So the Oyster harvesting, that supports a lot of people on this community… my family included cause my husband does oyster harvesting. Having a month of it being shut down…literally that's hundreds of thousands of dollars that impacted this community. And once one tide hits the public health comes, the department of health with the state of Washington, there absolutely can be no harvesting at all and no sales. So the whole fishery was completely shut down. There were a lot of people at that point that ended up going to general assistance programs through the tribe. And most people in this community there is a lot of resources so general assistance is a last; on a lot of reservations general assistance you have to, because of the situation and the economics and there are no jobs, but in this community there are a lot of resources that people are able to tap into and the unemployment is not very high. Last year in August when the red tide hit that was a real issue. And it tapped into that GA [general assistance] program and it certainly directly impacted native families here.

Causes

Algae blooms are not a new occurrence, however the intensity and frequency is apparently increasing.

Lalena Amiotte: Um as far as the algae blooms, Jennifer and myself and we always have a boat driver, we see those weekly; to say that that wasn't going on twenty years ago…that may be a stretch. Algae blooms, being little tiny plants in the water if it's sunny they're gonna grow. So that's a pretty common occurrence. But then some would argue that feeding all the nitrogen that's going into the Hood Canal from the fertilizers that people are using and the you know and water from failing

septic systems, that's pure nitrogen going in. The Skokomish valley being agricultural and there's a lot of livestock. I would guess probably seven to eight hundred head of cattle in the Skokomish valley. When it rains or it floods which the Skokomish River is the number one flooded river in the state of Washington. When it floods it [cattle waste] all goes into the river channel and the river empties into the Hood Canal. So that's more nitrogen going in and feeding those little tiny plants causing the algae blooms. So some would argue, which I tend to agree with, that there's more nutrients going in feeding these little plants causing bigger algae blooms and causing more impact onto the Hood Canal. So um you know human activities definitely are linked to you know what's going on with algae. But we see it weekly.

BC: Is that year round?

Lalena Amiotte: Yeah. The only months that I would say we really don't have algae issues would be during the ah, real heavy rainy season starting in October probably going to February, but February for some reason, it seems like we get like a week or two weeks of sun, that's been kinda what's been going on the past few years. We're seeing massive algae blooms in February, which historically we didn't have that. So why are we getting sun? Some would say its global warming, who knows.

Chapter 9: Conclusions

The objective of this study was to establish a better understanding of the declining health of Hood Canal and to inform restoration efforts. This objective and the legislature's assumptions concerning the possible insights attainable from long term residents of the region have been justified herein. The information provided by these six interviews provided detailed information related to various habitats, particular species, resource management, and low dissolved oxygen events both historically and in the present.

In Hood Canal the Skokomish are intimately familiar with the environment. This intimacy can benefit science. Since anthropogenic influence has apparently tipped the balance for Hood Canal's ability to sustain itself, reflections on past practices may illuminate the corrective actions required. While restoration efforts are currently underway, the rapid increase in anthropogenic forces in the region, and new concerns such as climate change, promise to test and possibly limit the PSP's attempts to restore this ecosystem. It is important that these histories are recorded before they are lost.

How Oral Histories Might Benefit Restoration Efforts

Analyzing these transcripts uncovered a couple of ways TEK may benefit restoration efforts. By identifying species assemblages in various portions of the ecosystem in years past a metric is provided to measure restoration success. This point is apparent when comparing the comments by Lalena and Fred regarding sea cucumbers (*Parastichopus* sp.) and their habitat. According to Doughton (2004) there are more than 30 species of sea cucumbers which inhabit Puget Sound's waters. These organisms inhabit waters ranging from the intertidal zone to 249 meters deep (Lambert 1997). Recognizing habitat preferences enabled this author to recognize the disappearance of one or more cucumber species. When Lalena mentioned a potential market for sea cucumbers she stated that cucumbers are only found below 80 feet. In these deeper waters divers are at greater danger and have more difficulty harvesting them. This prohibits the opening of this fishery in southern Hood Canal. However, tribal elders remember sea cucumbers living in the intertidal zone. The significance is that in recent years one or more intertidal sea cucumbers species likely has gone extinct at least locally. Information such as this could be useful to the PSP in establishing restoration reference conditions.

Another way in which TEK may benefit restoration efforts concerns the Skokomish River. This example illustrates how TEK derived from oral histories can enhance the knowledge derived empirically. This is apparent from Gary Peterson's interview. Gary's knowledge from living in the Skokomish River valley broadens the knowledge derived through scientific inquiry (Stover et al. 272) simply from a conversation. His knowledge is derived from "a lifetime of driving along the roads along

the canal and seeing the changes" and from childhood experiences. Gary recalls a decrease in Skokomish River channel depth of approximately 15 feet in places. Conversely, Stover et al (272) conducted research showing that the bed of the Skokomish River has risen by between 5 and 6 feet. Interestingly, a notable difference exists between Stover et al and Gary's recollection concerning how much the Skokomish River has risen. Stover et al (273) analyzed information from two gauging stations. One was located along the South Fork Skokomish and the other further downstream along the mainstem Skokomish. Gary spoke from the perspective of places he swam as a child. Both sources of information are credible yet they yield different results concerning the magnitude of aggradation. Utilizing both forms of knowledge provides a more complete picture of how the Skokomish River has changed over the past 60 years.

Study Limitations

This study explored the range of information attainable from the oral histories of the Skokomish people. It merely scratches the surface concerning how much information may exist. The Heritage program intended to identify 50 individuals. At the end of the project only 24 individuals were interviewed. Thirteen individuals who originally agreed to interviews later declined. Considering the 750 enrolled members of the Skokomish Tribe, the six individual voices heard within this analysis likely under represents the voice of the tribe as a whole. Additionally, of the six interviews analyzed herein included are two sets of brothers; Larry and Gary Peterson and Delbert and Fred Miller. Interviewing brothers likely limits the breadth of the perspectives depicted in this study. The analysis could be broadened by analyzing the other 18 interviews conducted by the

Heritage program. Additionally, although the Skokomish Tribal members represent the majority of long term residents in the Hood Canal region, other non tribal long term residents reside in the area and this analysis has not included them. Expanding the interview effort to other long terms residents is likely to provide additional information. Likewise, interviewing some of the other 744 Skokomish tribal members as well as the regions other tribes will increase the recorded TEK.

The potential for the future

The elders have knowledge attained over multiple generations that could likely save us many years of learning if we listen. The Skokomish recognize this and several of them expressed to me the lack of interest by the scientific community in the knowledge they possess. Advocates of TEK state that increasingly the scientific community is becoming more aware of the benefits of TEK and caution that valuable information is lost each time an elder goes to the other side. Augusta Blacketer sums up these thoughts well in her final statement and in response to the question, "is there anything you would like to add?"

> Augusta Blacketer: you know this is a good project, and so many people in our community, its so pushed on us that we learn from books, you know you got to get an education, you got to learn from books, you have to get books and read and read and read and I like to read I mean, of course I like to read, but when it comes down to this, like in our Skokomish community its not reading a book, its um oral history, we have to take time to, we have to listen to our elders, and I believe I listened to my grandpa a lot but when it comes to questions like this, you really miss your grandpa, you miss your grandma, so you know nothing can bring that oral history back once they're gone. So that's that I mean, its important that you do this but…like right now we did lose a lot of our elders...and I don't want to say it's too late, cause it's never too late, but it does make it, the struggle that much harder to find answers when they're gone. So just to keep that in mind.

The importance of restoring Puget Sound and the Hood Canal can not be over stated. Washington State's economy depends heavily upon its resources as do the cultures of this

regions tribal people. The fact that long term residents can provide historical information regarding ecosystem components and connections is obvious from the handful of interviews I analyzed. The legislature was correct in their findings regarding Hood Canal:

> a historical perspective is important in understanding Hood Canal's problems; tribal elders and other long-term residents of the Hood Canal area are a great source of knowledge regarding the history of Hood Canal; tribal elders and others [can] provide critical insight into the history, impacts, and potential causes of the low dissolved oxygen concentrations occurring in Hood Canal (HB: 1883).

The work initiated by the Heritage Program has enhanced the understanding regarding the history, ecology, and resource use within the Hood Canal watershed. The PSP is attempting a new approach to restoration. This approach is a holistic, ecosystem wide approach. The interviews analyzed herein support that this holistic vision should be incorporated into the research methodology for restoring the Sound. The information built upon since time immemorial is lost with the passing of every elder within the Skokomish Tribe and others. Additional interviews, well structured questions, and further analysis are likely to provide valuable insights into the ecosystem of the Hood Canal.

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Appendix A

H-1249.2
HOUSE BILL 1883

State of Washington 59th Legislature 2005 Regular Session

By Representatives McCoy, Pearson, Eickmeyer, Upthegrove and Haigh
Read first time 02/09/2005. Referred to Committee on Select Committee on Hood Canal.

AN ACT Relating to collection and preservation of oral histories about Hood Canal; amending RCW 43.07.365; adding a new section to chapter 43.07 RCW; creating a new section; and providing an expiration date.

BE IT ENACTED BY THE LEGISLATURE OF THE STATE OF WASHINGTON:
NEW SECTION. **Sec. 1.** (1) The legislature finds that Hood Canal is a marine water of the state in significant peril. The legislature also finds that low dissolved oxygen concentrations have occurred in Hood Canal for many years and that these conditions have created a serious environmental health concern. The legislature further finds that substantial fish kills have occurred in Hood Canal in recent years, and scientists and others report significant changes in marine species behavior in Hood Canal. (2) The legislature finds that the factors contributing to Hood Canal's low dissolved oxygen problems are complex and that investigation is needed to understand both the problem and its potential solutions. The legislature also finds that a historical perspective is important in understanding Hood Canal's problems. The legislature recognizes the tribal elders and other long-term residents of the Hood Canal area are a great source of knowledge regarding the history of Hood Canal. The legislature finds these tribal elders and others may provide critical insight into the history, impacts, and potential causes of the low dissolved oxygen concentrations occurring in Hood Canal. (3) The legislature intends to initiate a process for university students to interview tribal elders and others who have knowledge of the history of conditions along Hood Canal to collect information regarding the history and impacts of Hood Canal's low dissolved oxygen concentrations. The legislature further intends that these interviews and the information learned be preserved as part of the state's oral history program.

NEW SECTION. **Sec. 2.** A new section is added to chapter 43.07 RCW to read as follows:
(1) The secretary of state, with the assistance of the oral history advisory committee, shall administer and conduct a program to record and document oral histories of tribal elders of the tribes in the area surrounding Hood Canal and other long-term residents of the Hood Canal area who have similar knowledge of the history of the conditions along Hood Canal. The purpose of these interviews is to collect information and perspectives regarding the history of the conditions along Hood Canal, including but not limited to reports of fish kills, changes in marine species behavior, fishing and harvesting histories, and other conditions related to the environmental health of Hood Canal. (2) The secretary

of state shall contract with the state universities to have university students interview and record the oral histories specified in subsection (1) of this section. The tapes and tape transcripts shall be indexed and made available for research and reference through the state archives. The transcripts, together with current and historical photographs, may be published for distribution to libraries and for sale to the general public.

Sec. 3. RCW 43.07.365 and 2002 c 358 s 3 are each amended to read as follows:

(1) Except as provided in subsection (2) of this section, the secretary of state may fund oral history activities through donations as provided in RCW 43.07.037. The activities may include, but not be limited to, conducting interviews, preparing and indexing transcripts, publishing transcripts and photographs, and presenting displays and programs. Donations that do not meet the criteria of the oral history program may not be accepted. The secretary of state shall adopt rules necessary to implement this section.

(2) The secretary of state may fund the oral history activities specified in section 2 of this act through appropriations to the oral history, state library, and archives account.

NEW SECTION. **Sec. 4.** This act expires July 1, 2008.

--- END ---

Appendix B. Federal and Washington state listed species found within the Puget Sound region. Source: PSAT 2007.

State and federal listed species in Puget Sound
As of October 2006[1]

GROUP	COMMON NAME	STATE STATUS	FEDERAL STATUS
MARINE AND ANADROMOUS FISHES	Chinook Salmon (Puget Sound)	C	T
	Chum Salmon (Hood Canal/ E. Strait of Juan de Fuca)	C	T
	Coho Salmon (Puget Sound/ Strait of Georgia)		C
	Bull Trout (Coastal/Puget Sound)	C	T
	Pacific Hake	C	C
	Pacific Cod	C	
	Walleye Pollock (South Puget Sound)	C	Co
	Pacific Herring (Cherry Point/ Discovery Bay)	C	C
	Brown Rockfish	C	
	Copper Rockfish	C	
	Greenstriped Rockfish	C	
	Widow Rockfish	C	
	Yelloweye Rockfish	C	
	Quillback Rockfish	C	
	Black Rockfish	C	
	China Rockfish	C	
	Tiger Rockfish	C	
	Bocaccio Rockfish	C	
	Canary Rockfish	C	
	Redstripe Rockfish	C	
	Yellowtail Rockfish	C	
	Eulachon	C	
	River Lamprey	C	Co
	Pacific Lamprey		Co
	Coastal Cutthroat		Co
MARINE MAMMALS	**Northern Pacific Humpback Whale**	**E**	**E**
	Steller Sea Lion	T	T
	Orca	**E**	**E**
	Pacific Harbor Porpoise	C	
	Northern Sea Otter	**E**	Co
BIRDS	Bald Eagle	T	T*
	Canada Goose, Aleutian	M	Co
	Golden Eagle	C	
	Marbled Murrelet	T	T
	Tufted Puffin	C	Co
	Brandt's Cormorant	C	
	Cassin's Auklet	C	Co
	Common Murre	C	
	Western Grebe	C	
	Snowy Plover	**E**	T
INVERTEBRATES	Olympia Oysters	C	
	Newcomb's Littorine Snail	C	Co
	Pinto (Northern) Abalone	C	

State and Federal Status

E – Endangered
T – Threatened
C – Candidate
Co – Concern
M - Monitor

[1]This list includes marine-dependent species that live all or part of their life cycle in the waters of the Strait of Juan de Fuca, San Juan Islands, Hood Canal, and central and south Puget Sound. Not included are species that live in freshwater and upland of the shoreline.
*The federal government is proposing to de-list bald eagles.

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Appendix C Event timeline

Source: http://www.psat.wa.gov/News/press_info/images/PSI_brief_history.pdf

DATE Event

1983 Tacoma tide. flats added to the federal Superfund site list.
1985 Formation of Puget Sound Water Quality Authority.
1985 Decision to provide secondary treatment for sewage treatment plants discharging to Puget Sound.
1987 First comprehensive Puget Sound Water Quality Management Plan completed.
1988 Designation of Puget Sound as National Estuary Program.
1990 Growth Management Act approved.
1991 Adoption of sediment standards in Sound, as called for in 1987 Puget Sound Management Plan.
1991 Approval of 1991 Puget Sound Management plan as federal Comprehensive Conservation and Management Plan under Clean Water Act
1991 Local governments adopt development regulations
1992 Environmental Cooperation Agreement signed between Washington and British Columbia
1992 Ecology releases the region's first stormwater management manual. Ecology issues baseline permit for industrial and construction site stormwater discharges.
1992 Law passed requiring formation of local shellfish protection districts when pollution closes shellfish growing areas.
1993 Burley Lagoon shellfish upgrade, first significant shellfish restoration involving non-point sources.
1995Ecology reissues stormwater general permit for industrial activities; construction-site stormwater discharges covered under separate general permit. Ecology issues NPDES municipal phase I permits to cities of Seattle and Tacoma, King, Pierce and Snohomish counties, and WSDOT.
1995 Shoreline Management Act and GMA statutes were integrated and Best Available Science requirement added to GMA.
1995 Major updating of On-Site Sewage System rules, incorporating Puget Sound Management Plan elements.
1996 Creation of Puget Sound Action Team (from Puget Sound Water Quality Authority).
1998 Separate watershed planning systems established for water and for salmon recovery.
1998 Northwest Straits Marine Conservation Initiative authorized by Congress.
1999 Rescue tug stationed at Neah Bay (26 responses from 1999 to summer 2005).
1999 Puget Sound Chinook Salmon listed under the Endangered Species Act.
2000 State ballast water management program created.
2000 PBT Strategy completed and delivered to Legislature.
2000 Puget Sound Management plan updated with major rewrites of Stormwater and combined sewer overflow programs.
2001 Ecology published Stormwater Management Manual for Western Washington. Action Team begins active promotion of LID techniques.
2001 Formation of Shared Strategy to develop a watershed-based recovery plan for salmon.
2001 Puget Sound Nearshore Ecosystem Restoration Project launched.
2002 State creates the Ballast Water Work Group to study and recommend improvements to the state management program.
2002 Ecology reissues industrial stormwater permit and it is appealed. Action Team holds 3 regional training workshops on LID.
2003 New Shoreline Management Act guidelines adopted
2003 Marine Mammal Protection Act designation of Orca as "depleted."
2004 Invasive colonial tunicates reported in Puget Sound.
2004 Ecology issues "Beyond Waste" plan.
2004 Last Puget Sound county completed the basic GMA assignments.
2004 Hood Canal Dissolved Oxygen Program (HCDOP) launched.
2005 Delivery of Shared Strategy's Puget Sound salmon recovery plan to NOAA.
2005 The state Aquatic Nuisance Species Coordinating Committee develops and officially submits the state's Early Detection and Rapid
Response Plan for responding to new invasions.
2005 Ecology issues revised industrial stormwater general permit and preliminary drafts of municipal NPDES phase I and II permits.

Ecology issues draft general construction NPDES permit.
2005 HCDOP Integrated Assessment and Monitoring study launched with federal funding.
2005 Additional updating of On-Site Sewage System rules with special Puget Sound provisions.
2005 Environmental sampling indicates that PAH contamination has begun increasing while metals are decreasing.
2005 PBDEs recognized as environmental contaminant in Puget Sound.

Appendix D
Questions derived from The Evergreen State College Native American Studies "Heritage" Program and analyzed for information pertinent to my research question.

Questions for
The Evergreen State College Hood Canal Oral History Project

Were there any fish kills that happened in the past? How often? Where? When? (for all of the "when" questions it would be good to know not only the year or approximation, but the time of year e.g. Spring, Summer, etc.).

Do you recall or have you heard of any stories of seeing listless bottomfish in the Canal - fish that were alive but barely moving? When? Where?

Do you recall or have you heard of any stories of seeing schools of bottomfish in the shallow water- less than 10-20 feet deep? When? Where?

Do you remember or have you heard of any stories of red tides or large blooms of phytoplankton occurring in the canal in the past? When? Where?

What fish/shellfish were harvested and how? Have there been changes in fishing practices over time? Have fishing locations changed? Have you noticed or are there stories of changes in the harvest of herring, clams, and Dungeness crab?

Do you, or have you, fished in the deep water (deeper than 200 feet) of the canal? If so what did you used to catch and what do you catch now?

How has commercial fishing changed over time? What kinds of species were harvested? Has this changed? Were there fisheries in the past that are totally gone? (e.g. pollack, whaling, etc.)

Are there any animals (fish, birds, mammals) that you used to see in the canal but no longer do? Or that your ancestors used to see in the canal but no longer do?

Have you noticed changes in the abundance and distribution of eelgrass? Was kelp observed in Hood Canal previously?

What changes did you notice with the introduction of the Japanese oysters?

Do you know of any areas or have you heard of any stories of where smelt used to spawn but no longer do so?

Do you recall or have you heard of any stories of any spawning by smelt during the summer months? If so where?

Have you noticed changes (Declines? Distribution?) in the abundance of sea life on beaches? What kinds of changes? When? Where?

Have you noticed changes in the types of trees or other vegetation on the shorelines? In the upland forests? What kind of trees were the most common? What kinds of changes have you observed or have heard of? When? Where?

Have you observed changes in the shoreline? Loss of sandy beaches? Erosion? When and where did this occur?

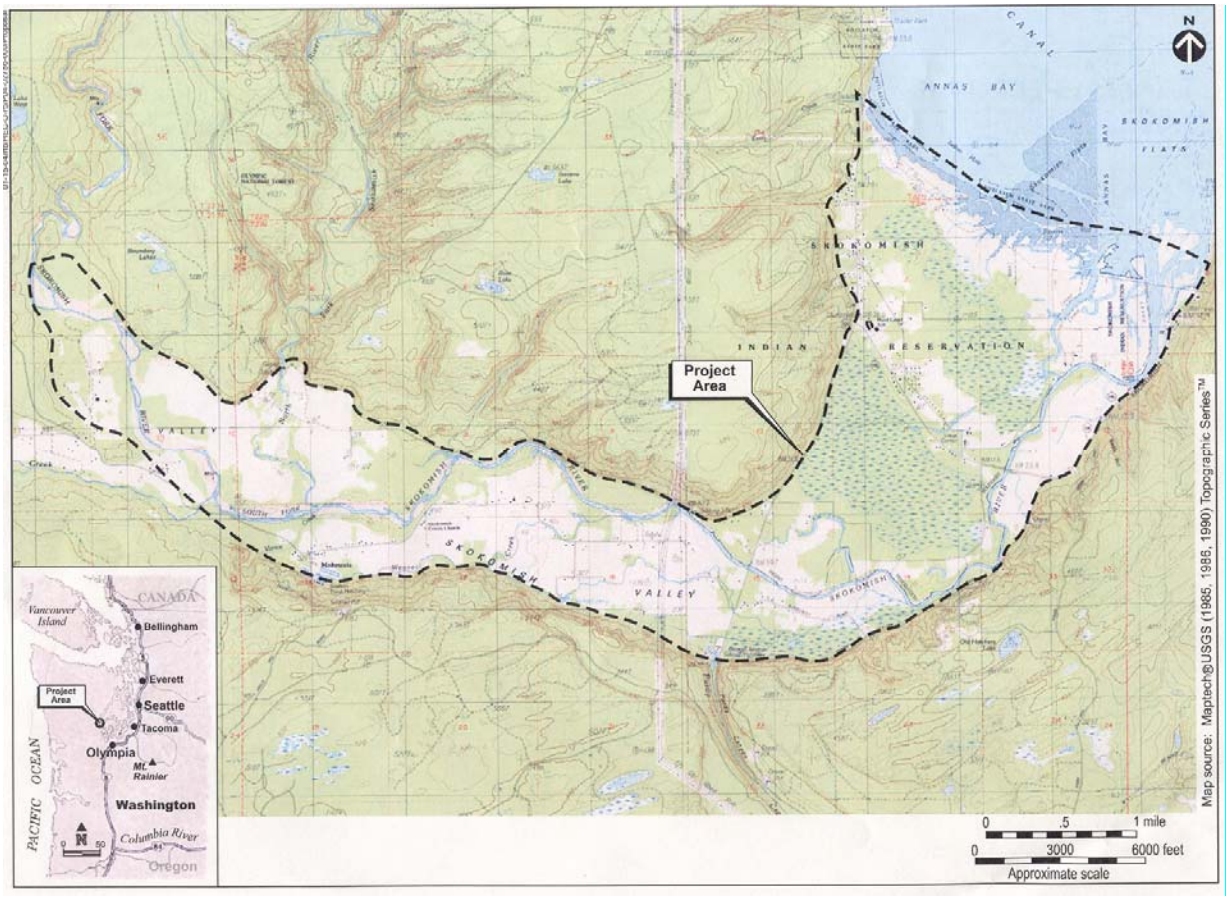
How have the populations of people changed? (numbers, distribution) Where did people used to live within the Hood Canal watershed vs. where they live now?

Did people talk about smelling sulfur?

How close were fire pits to the water?

Have you seen changes in farming practices over time? Locations?

Appendix E. Map showing the extent of the increased water table in the Skokomish River Valley. Source: provided by the Skokomish Natural Resource Department.



Appendix F. Source: provided by the Skokomish Natural Resource Department and the Puget Sound Action Team. Of interest is the Hood Canal regions where the large red circles depict declines in eelgrass habitat during the 2004-5 year.