Reconstructing Trends in Hypoxia Using Multiple Paleoecological Indicators Recorded in Sediment Cores from Puget Sound, WA

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Executive Summary

The impacts of coastal eutrophication range from economic and cultural losses to potential human health issues. The severity of these impacts are projected to increase with higher nutrient loadings from watersheds due to escalating urbanization, deforestation, agriculture, and atmospheric deposition (National Research Council 2000a). Symptoms of eutrophication include prolific production of algal biomass (sometimes toxic), loss of important habitats such as seagrass beds and corals, changes in marine biodiversity, and depletion of dissolved oxygen or hypoxia (National Research Council 2000a). Such symptoms comes with a very high economic price with a recent study placing a summed ecosystem services value of 16 billion per year on the Puget Sound estuary (Batker et al. 2008). Although research has focused on hypoxia issues primarily on the East Coast and Gulf of Mexico, there have been periods of hypoxia measured on the West Coast since the 1970s in Hood Canal, WA, a sub-basin of Puget Sound (Pew Oceans Commission 2003). These ecosystems are distinctly different from Puget Sound due to the inflow of nutrient-rich water masses from the Pacific Ocean that support high rates of primary productivity and are generally considered light-limited rather than nutrient-limited.

Based on the increasing presence, persistence, and distribution of hypoxia in Hood Canal during the 1990-2000's compared to 1930-60's, as well as, successive fish kills during the early 2000's, Newton et al. (2007) concluded that hypoxia conditions were becoming more severe in this basin. The factors driving the reduction in oxygen saturation within Hood Canal are not well understand and may include: 1) natural fluctuations in physical processes such as increased freshwater flow which reduces mixing by strengthening water-column stratification and reducing deep-water ventilation (re-oxygenation), and/or 2) eutrophication resulting in the over stimulation of primary productivity and deep water respiration supported by increasing nutrient and organic matter loadings from natural or anthropogenic sources.

This report summarizes the 19th to 20th Century (and older) reconstructions of a diverse set of paleoecological indicators preserved in sediment cores from central Puget Sound and Hood Canal. These data provide resource managers with scientific evidence to support informed decisions regarding hypoxia in Puget Sound by addressing the following questions.

1) **When did hypoxia begin in Puget Sound and how has the intensity varied over the last several hundred years?**
    - For most of the 20th Century, central Puget Sound and Hood Canal have been under a more oxygenated "stance" with respect to prior periods. Sedimentary reconstructions of redox-sensitive metal indicators suggest hypoxia has occurred to a greater degree prior to significant human alterations beginning in the 1900s, but does not resolve the timing of short-lived hypoxia events that led to fish kills in Hood Canal during the early 21st Century.

2) **How have the sources of organic matter, nutrients, and pollen changed as a function of increased human population, industrialization, wastewater discharges, and alterations in land-use and land-cover (LULC)?**
   - Anthropogenic forces throughout the 20th Century have had an unambiguous and substantial impact on the organic matter and nutrient fluxes entering Puget Sound. The paleo-indicators, collectively, record the intense land-clearing, urbanization, and industrialization that occurred beginning in the late 1800s in central Puget Sound and early 1900s in Hood Canal. Pollen records reflect the timing and significance of major LULC modifications with the abundance of Alder tree pollen ultimately exceeded the old growth coniferous trees in the 1950s as the dominate pollen in the marine sedimentary record.
   - These land-clearing and other industrial activities are clearly recorded in the inorganic priority pollutants and biomarkers reconstructions as increasing inputs around the early 1900s, peaks in the 1960s, and recovery back towards pre-industrial signatures following the passage of the initial environmental regulatory policies (1970s-1980s).
   - Collectively, the reconstructions show a strong shift from predominantly marine organic matter and lower oxygen conditions during the 18th to 19th Centuries to more terrigenous organic matter with more oxygenated conditions during the 20th Century.
3) **How have the assemblages of diatoms in the water column and foraminifera in the sediment changed with increased nutrient loading and LULC alterations?**
   - The microfossil reconstructions for diatom and foraminifera were too limited to provide statistically valid conclusions. However, overall abundance of diatom assemblages decline over time since circa 1900, with the most pronounced decline appearing after the 1950s. This trend is opposite to expected results related to eutrophication of the water column. However, the number of genera identified in the samples declines circa 1950s along with an overall increase in planktonic species (i.e. harmful algal species such as *Pseudo-nitzschia*) in the most recent sediments. These relationships may indicate a recent trending toward eutrophic conditions in the last several decades that is not resolved in the redox-metal reconstructions.
   - Alternatively, the decrease in diatom abundance may confirm other paleoecological markers (organic markers, biogenic silica, and redox sensitive metals) that indicate a decline in all proxies of water column productivity starting in the early 1900s and reaching a minimum in the 1950s.
   - Although the benthic foraminiferal assemblages are sparse, they suggest the observed alterations in assemblages may be coupled with large-scale climatic oscillations rather than human alterations, similar to the redox sensitive metal indicators. However, additional data are required to confirm this linkage.

In contrast to what was anticipated, the major land use changes in Puget Sound watersheds were not coincidental with low oxygen conditions (including Hood Canal). On the contrary, low oxygen conditions prevailed in a decadal pattern prior to the 1900s. The decoupling between the increase in anthropogenic factors and the low oxygen conditions in the deep waters of the basin is somewhat counterintuitive and opposite to what has been observed in other coastal systems, in which the onset of low oxygen conditions came as a result of a rise in land use changes (i.e. agriculture and deforestation). In fact, the paleo-ecological indicators suggest that climate oscillations, such as the Pacific Decadal Oscillation (PDO), may influence the ventilation of deep water in Puget Sound and particularly their least mixed regions such as the southern end of Hood Canal. Collectively, the reconstructions do not support the conclusions of increasing hypoxia in the 20th Century, as hypothesized. However, the reconstructions do not resolve the last decade, at a minimum, when the greatest frequency and intensity of hypoxia was measured. Coupling the historical record and the current water column monitoring data might support the hypothesis that if anthropogenic impacts (e.g. septic tank inputs of nutrients, increased organic matter flux from soil erosion and waste effluents) are added in phase with natural conditions that prevent deep water ventilation and support surface water primary productivity, an increasing trend in frequency and severity of hypoxia might occur in basins with long residence times (e.g. Hood Canal). Although, the process(es) supporting such a link is(are) not don't fully understand.

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1.0 Purpose

1.1. Overarching Project Goals

The impacts of coastal eutrophication range from economic and cultural losses to potential human health issues. The severity of these impacts are projected to increase with higher nutrient loadings from watersheds due to escalating urbanization, deforestation, agriculture, and atmospheric deposition (National Research Council 2000a). Excess nutrients drive the process of eutrophication within an ecosystem. Symptoms of eutrophication include prolific production of algal biomass (sometimes toxic), loss of important habitats such as seagrass beds and corals, changes in marine biodiversity, and depletion of dissolved oxygen or hypoxia defined as < 2 mg/L dissolved oxygen (National Research Council 2000a). Such symptoms have a very high economic price with a recent study calculating a summed ecosystem services value of 16 billion per year for the Puget Sound estuary, which includes beaches, salt marsh, seagrass beds, estuarine, and marine waters (Batker et al. 2008). Many of these symptoms of eutrophication are documented in coastal waters throughout the world (Nixon 1995; Boesch 2002) with a national focus on the Chesapeake Bay [see Kemp et al. (2005) and references therein] and Gulf of Mexico [see Rabalais et al. (2007a) and references therein]. Hypoxic conditions are among the most detrimental effects of eutrophication on aquatic organisms. Understanding the processes surrounding hypoxic episodes in coastal waters is complex, but critical for managing the continuing impacts of growing coastal populations (National Research Council 1993).

The general consensus is that the areal extent of hypoxia in the northern Gulf of Mexico and Chesapeake Bay has increased in the 20th Century primarily as a result of over-stimulated algal production [see synthesis by Turner et al. (2006) and Kemp et al. (2005), respectively]. In turn, this increased productivity is recognized to derive from substantial excess fluxes of anthropogenically-derived nutrients transported from the watersheds coupled to seasonal vertical stratification that restricts ventilation. The widespread usage of inorganic fertilizers after the 1950s accounts for more than half of the anthropogenic alterations to the nitrogen cycle (National Research Council 2000a). The extensive research into the ecological responses of a range of estuary types to coastal eutrophication suggests there are substantial differences in the magnitude and trajectory of an estuary's response driven by complex, non-linear, and estuary-specific ecological interactions (Cloern 2001). The biogeochemical and physical processes associated with the East Coast and Gulf of Mexico hypoxia zones have been linked to excess nutrient inputs from intensive agricultural practices and increased land–use, land-cover (LULC) changes in the watershed. However, there is growing concern among scientists that excess nutrients are not the only factors driving the spatial and temporal scales of hypoxic events (Bianchi et al. 2008).

Although hypoxia research has focused primarily on the East Coast and Gulf of Mexico, there have been periods of hypoxia measured since the 1970s on the West Coast in Hood Canal, Washington, a sub-basin of Puget Sound (Pew Oceans Commission 2003). Puget Sound is a fjord-type estuary with relatively strong tidal mixing that minimizes stratification in the main basin (Figure 1). In Puget Sound, a very high rate of primary production [~400 g carbon /m^2/y (Antoine et al. 1996)] is supported by the inflow of nutrient-rich water masses from the Pacific Ocean. As a result, most of Puget Sound is light-limited rather than nutrient-limited because of the vigorous tidal mixing at the sills located at the northern end of Hood Canal, northern end of the main basin at Admiralty Inlet, and the Tacoma Narrows (separating the central basin from the southern basin). The central basin of Puget Sound extends from Seattle to Tacoma and receives the majority of wastewater discharged into Puget Sound. However, the oxygen saturation of the central basin remains relatively uniform and high despite the urbanization. In contrast, the southern basin and the terminus of Hood Canal have a history of periodic oxygen-limitation in deep water. Based on the increasing presence, persistence, and distribution of hypoxia in Hood Canal during the 1990-2000's compared to 1930-60's, as well as, successive fish kills during the early 2000's, Newton et al. (2007) concluded that hypoxia conditions were becoming more severe in this basin. The factors driving the reduction in oxygen saturation within Hood Canal are not well understand and may include: 1) natural fluctuations in physical processes such as increased freshwater flow which reduces mixing by strengthening water-column stratification and reducing deep-water ventilation, and/or 2) eutrophication resulting in over stimulation of primary productivity and deep water respiration supported by increasing nutrient and organic matter loadings from natural or anthropogenic sources.

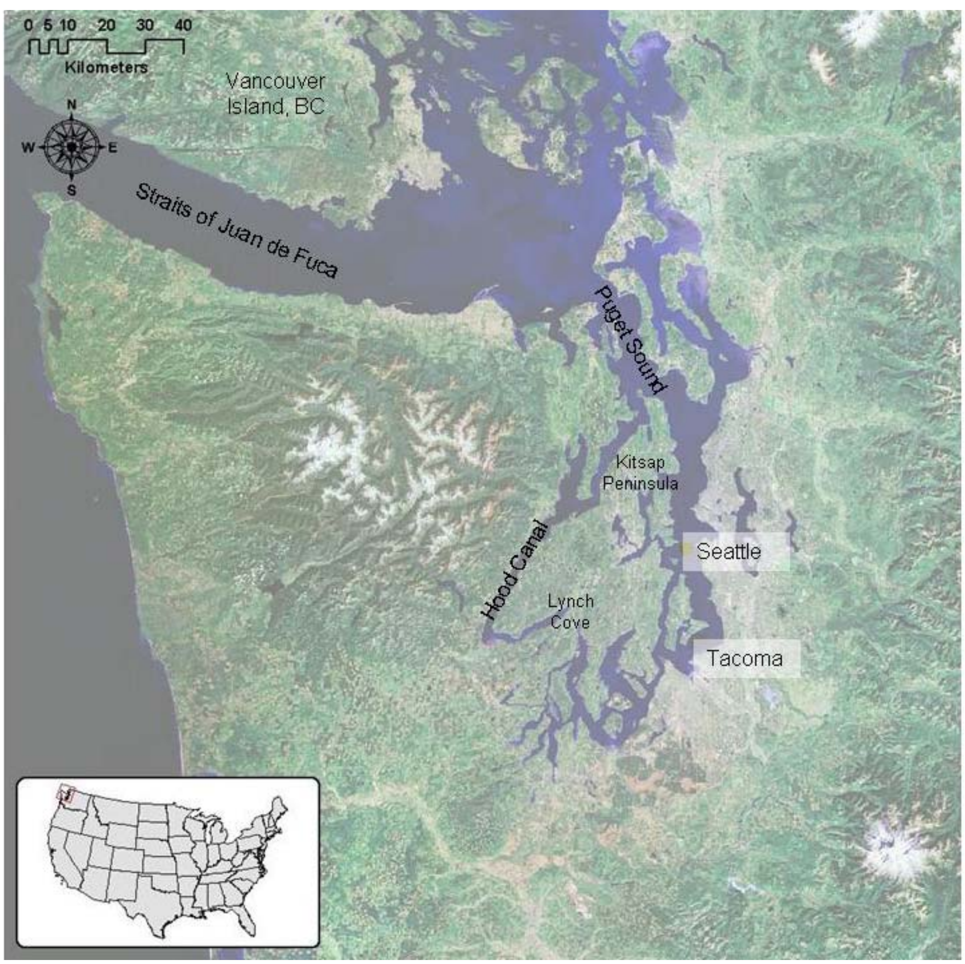


Figure 1. Puget Sound region in the Pacific Northwest.

This escalation in hypoxic conditions prompted the formation of the Washington State Hood Canal Dissolved Oxygen Program (HCDOP). In 2005, the HCDOP was funded to study the physical oceanography of Hood Canal, develop an analytical model that represents the hydrodynamic and biochemical processes, and monitor nutrients from the rivers and non-point sources. The research reported herein complements the HCDOP studies to understand the current processes in Hood Canal, by providing a historical reconstruction of ecological indicators spanning over 150 years in both Hood Canal and central Puget Sound. These records are valuable additions to environmental monitoring, and can suggest whether the causes of recorded changes may be linked to natural or anthropogenic factors (Charles et al. 1994).

Ecological indicators are required to inform the public and resource managers about the overall status of an ecosystem and it's response to anthropogenic or natural alterations. To develop and implement sound environmental policies, data must capture the essence of the dynamics of environmental systems and changes in their functioning over time or in response to known human alterations. The National Research Council (2000b) recognized the need for a robust set of ecological indicators and defined a set of indicators capable of informing decision makers and the public on ecological conditions and changes for three major reasons:

1) a long-term record of conditions is needed as a baseline reference to which current conditions and trends can be compared to,
2) detailed information on the ecological effects of various human activities and natural events – such as pollution, urbanization, agriculture, climate change, and geomorphological events – is essential for selecting and implementing management options to address problems successfully, and
3) long-term ecological data are needed for society to measure the effectiveness and efficiency of management interventions and to improve them.

Obtaining a long-term record of various paleoecological indicators over a temporal scale that extends back to pre-urbanization/industrialization in the ecosystem provides a means of evaluating natural cyclicity, as well as, a system's responses to human alterations. Paleoecological indicators incorporate geochemical and biological records to describe past ecological communities and their environments. Records of temporal change in the distribution of microfossils and of physical and chemical properties of the environment can provide a very useful background to asses the influence of diverse natural and anthropogenic disturbances. Coupling several indicators helps to elucidate the cause and timing of increases in primary productivity and oxygen limitations in these basins. In fact, a paleoecological approach makes it possible to define the naturally-occurring state of an ecosystem (and its variability), against which human influences can be measured (Smol 1992).

This report summarizes the historical reconstructions of a diverse set of paleoecological indicators preserved in sediment cores from the central basin of Puget Sound and Hood Canal. The results from this study provide resource managers with scientific data to support informed decisions regarding hypoxia in Puget Sound by answering the following questions.

1) When did hypoxia begin in Puget Sound and how has the intensity varied over the last several hundred years?
2) How have the sources of carbon and nitrogen changed as a function of increased human population, nutrient loading, wastewater discharges, and alterations in land-use and land-cover (LULC)?
3) How have assemblages of diatom in the water column and foraminifera in the surface sediment changed as a factor of increasing anthropogenic alterations (i.e. nutrient loading and freshwater discharges)?

1.2. Hypotheses and Objectives

Understanding the potential for natural cycles and/or the emergence of human related impacts on the overall conditions in a basin requires the use of the paleoecological record to understand historical ecosystems. The historical records preserved in age-dated sediment cores were used to reconstruct environmental conditions in both Hood Canal and central Puget Sound. Nine sediment cores were collected from depositional regions of each basin, age-dated using radionuclides, and appropriate sections analyzed for a large number of environmental tracers that have been successfully used to describe the evidence of human impacts in temperate coastal systems such as the Chesapeake Bay, the St. Lawrence and Hudson River Estuaries, Pamlico Sound, Long Island Sound, and the Gulf of Mexico. This multi-tracer approach included the determination of assemblages of diatom and foraminifera microfossils, pollen horizons, stable carbon and nitrogen isotopes ($\delta^{13}C$ and $\delta^{15}N$), biomarkers for terrestrial and marine carbon, biogenic silica (BSi), and oxidation-reduction sensitive metal tracers (RSM). Each paleo-indicator or proxy provides information on a specific set of ecological or anthropogenic conditions/processes, which were collectively used to infer the state of historical ecosystems. Table 1 summarizes each paleo-indicator measured and the condition or processes the indicator may be used to infer potential changes through time. Hence, each indicator has a separate set of hypotheses which all support the overarching goal of reconstructing ecological conditions on time-scales of at least 100-200 years. For example, the hypothesis related to the radioisotopes was “Have human alterations within the watersheds of each basin (i.e. land-use, land-cover changes) resulted in an increase sediment supply to the basins through the 20th Century recorded as a non-linear decay of the radioisotopes?”.

Table 1. A suite of paleo-indicators measured in Hood Canal and Puget Sound sediment cores and the changes in conditions or processes each indicator may reflect.

PALEO-INDICATOR	RECORDS CHANGES IN						
	**Dissolved Oxygen**	**Biodiversity**	**Urbanization**	**Industrialization**	**Terrestrial Organic Matter/Nutrients**	**Land Use/Land Cover Alterations**	**Sediment Supply**
Radioisotopes (^{210}Pb, ^{137}Cs)							✓
Redox Sensitive Metals (Mo, U, Re, Fe, Mn, Cd)	✓				✓		
Sediment Properties (Al, % moisture)						✓	✓
Inorganic Priority Pollutants (Pb, Cu, Ni, Zn, Cr, As)			✓	✓			
Nutrients (C, N, P)			✓	✓	✓		
Stable Isotopic Ratios (δ^{13}C, δ^{15}N)			✓	✓	✓	✓	✓
Organic Biomarkers (lignin, soil biomarkers)			✓	✓	✓	✓	✓
Biogenic Silica (BSi)	✓	✓					
Diatom Microfossils	✓	✓	✓				
Foraminifera Microfossils	✓	✓					
Pollen Rain			✓			✓	

1.2.1. Redox Sensitive Metals

Hypoxic conditions in the water column are one manifestation of a series of biologically driven oxidation-reduction (redox) reactions, resulting in the redistribution of redox-sensitive trace metals (RSM) due to phase changes. Several papers provide detailed reviews of the RSM geochemistry and address the concepts of their use as paleoenvironmental tracers (Calvert and Pedersen 1993; Crusius et al. 1996; Morford and Emerson 1999; Tribovillard et al. 2006). These along with other studies have applied such published methods to infer past changes in bottom water oxygen or productivity [e.g. (Emerson and Huested 1991; Piper and Isaacs 1995; Rosenthal et al. 1995b; Yang et al. 1995; Morford and Emerson 1999; Crusius and Thomson 2000)] and/or addressed the specific limitations of their usage under different geochemical conditions (Morford et al. 2001; Russell and Morford 2001; Crusius and Thomson 2003; Morford et al. 2007). Subsequently, the sedimentary records of RSMs, such as molybdenum (Mo), uranium (U), rhenium (Re), cadmium (Cd), vanadium (V), chromium (Cr), manganese (Mn), and iron (Fe), provide key pieces of information in the chronological reconstruction of oxygen saturation and biological productivity in the water column.

The geochemical behaviors of RSMs in oxic seawater varies from conservative for Mo, U, and Re (Colodner 1991; Crusius et al. 1996; Crusius and Thomson 2003), to partially conservative for V and Cr (Calvert and Pedersen 1993), to nutrient-like for Cd, copper (Cu), nickel (Ni), and zinc (Zn) (Rosenthal et al. 1995a; 1995b; van Geen et al. 1995; Tribovillard et al. 2006). The onset of reducing conditions results in a valence state change and subsequent reduction in the solubility of the conservative metals. Sedimentary redox reactions drive the authigenic enrichment of Mo, U, and Re in a chromatographic-type pattern as a function of each metal's reduction potential. This resulting enrichment has led to the usage of these metals as indicators of the intensity of past reducing environments (Calvert and Pedersen 1993; Crusius et al. 1996). In contrast, metals such as Cd, Cu, Ni, and Zn are not typical "redox sensitive" metals and do not change valence state under typical environmental reducing conditions. Instead they form insoluble sulfides, which drives their enrichment under suboxic-anoxic conditions (Rosenthal et al. 1995a; 1995b; Tribovillard et al. 2006). A brief geochemical synopsis of redox metal behaviors is provided in Section 3.1.

HYPOTHESES RELATED TO REDOX METALS:

1) Sediment core profiles record an increasing enrichment of all RSM during the 20^{th} Century as industrialization/urbanization occurs in the basins.
2) The RSM reconstructions are not significantly altered by diagenesis as the individual metals are collectively enriched or depleted in the same core segment.

1.2.2. Organic Tracers

A suite of molecular and isotopic signatures can be used to assess the impact of land clearance and forestry activities in the Puget Sound region. Large-scale disturbances in watershed basins (natural or man-made) lead to increased erosional fluxes of soil organic matter which in turn lead to substantial shifts in both the quantity and quality of terrigenous organic matter (TOM) reaching sedimentary deposits (Louchouarn et al. 1999; Farella et al. 2001; Houel et al. 2006; Hunsinger et al. 2008). Disturbances such as intensive industrial forestry practices (logging, saw mills, pulp and paper mills) have contributed massive amounts of TOM (ligneous and lignosulfonate by-products) to sedimentary deposits sometimes over vast coastal systems (Louchouarn and Lucotte 1998; Louchouarn et al. 1999). Because some biomakers of TOM are so source specific, their detailed study can help separate the sources of material coming from industrial effluents *vs.* surface or deep soils (Louchouarn et al. 1999; Farella et al. 2001; Houel et al. 2006). Moreover, studies of such biomarkers allow for a cross-validation of pollen data on vegetation changes (and thus deforestation/recolonization) at the basin-scale (Leopold et al. 1982; Hu et al. 1999).

Historical data show that from the onset of European settlement in the U.S., land clearance has favored increased runoff of freshwater and soil minerals into coastal zones resulting in increased sedimentation rates, turbidity, organic matter (OM) fluxes, nutrients, and biogenic silica (Bush et al. 2000; Bratton et al. 2003; Cooper et al. 2004). These changes seemed to have fueled the initial stages of eutrophication in receiving estuaries (Cooper 1995a; Swaney et al. 1996; Howarth et al. 2000; Cooper et al. 2004), which have been sustained and accelerated by further nutrient addition (agriculture, sewage, more land clearance) and increased stratification (Zimmerman and Canuel 2000; 2002; Kemp et al. 2005; Clarke et al. 2006). Because TOM can fuel the biogeochemical cycling of carbon both in the water column and in sediments of coastal systems (Hamilton and Hedges 1988; Cowie et al. 1992; Louchouarn et al. 1997a; Loh et al. 2008), increased inputs from watersheds may lead to an initial increase in oxygen demand in deep waters creating lower reduction potentials across the sediment-water interface. This should lead to the sedimentary enrichment of the RSMs. The preservation of such RSM enrichment events in sediment cores has indeed been used to determine past changes in reducing conditions over time linked to fluctuations in the quantity and quality of OM inputs (Schulte et al. 1999; Adelson et al. 2001; Pailler et al. 2002; Nameroff et al. 2004). The potential relationship between shifts in the source and quantity of OM and RSMs will thus serve as an indicator of condition changes in the system and provide a test for the hypothesis that changes in land use led to a switch towards low oxygen conditions in Puget Sound basins through enhanced urbanization in the 20th Century.

Subsequently, an increase in hypoxic conditions during recent decades should be observed in the sedimentary record as a result of shifts from land clearance inputs to more direct nutrient loadings (wastewater effluent). In particular, we focused on the stable isotopic signatures of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) to monitor the influence of primary producers in predominantly supplying OM to the sediments. If primary production has increased substantially due to increased nutrient loading, then both $\delta^{13}C$ and $\delta^{15}N$ should increase in recently deposited sediments indicating the increased contribution of autotrophic carbon to the sediment-water interface and high rates of nitrogen recycling in the water column, respectively. Alternative hypotheses for nitrogen enrichment need to be tested, however. For example, increased inputs of soil nitrates, which may be ^{15}N enriched (Schlesinger 1997), could generate similar nitrogen isotopic results if soil erosion is particularly important in the basins. If that is the case, however, soil biomarkers (Louchouarn et al. 1999; Farella et al. 2001; Houel et al. 2006) should also increase in recent times with either no change or a depletion in ^{13}C signatures reflecting increased inputs of light terrigenous organic matter.

HYPOTHESES RELATED TO ORGANIC MATTER TRACERS:

1) Historical changes in land use in the watershed have resulted in major shifts in both the quality and quantity of terrigenous organic matter inputs to Puget Sound.
2) Terrestrial plant biomarkers record the direct input of organic matter and occur concomitantly with the enrichment of redox sensitive metals in the basins.
3) Stable isotopic signatures of sedimentary organic matter preserved in the chronological record illustrate the shifts in the sources of organic matter reaching sediments (terrigenous *vs*. marine inputs).

1.2.3. Pollen

The reconstructions of watershed-scale LULC changes are essential to understanding the timing and impact of natural processes and human activities on watersheds draining into estuarine ecosystems. The reconstruction of pollen rain or palynology are frequently used in freshwater lakes/river [e.g. Leopold et al. (1982), Liu et al. (2007), and Li et al. (2008)], wetlands (Clark and Patterson 1985; Pederson et al. 2005), and occasionally used in marine ecosystems [e.g. Heusser (1985) and Hannon and Bradshaw (2000)] to hind-cast significant vegetation alterations within the surrounding watersheds. Wind-borne pollen from the forest deposits on the water surface, is preserved in the sediment record, and subsequently reflects the overall composition of the source forest trees (Davis 1973; Faegri and Iversen 1975). Changes in land-cover during significant European settlement, including logging, altered the forest composition and ultimately the distribution pollen types preserved in Puget Sound/Hood Canal sediment through time.

Coupling palynology with other paleoecological indicators provides an independent, time-constrained validation for both the radiological dating (Brush et al. 1982; Heijnis et al. 1987) and organic matter inputs, such as lignin and soil biomarkers (Cohen et al. 1999; Li et al. 2008). Pollen reconstructions can be compared to historical records for major disturbance and forest cutting in the Seattle area (Davis 1973). For example, mass production of lighter chainsaws in 1929 and then 1945 significantly altered the forest composition of Puget Sound watersheds (Kruckeberg 1991). These events should correspond with a drop in the percentages of conifer pollen and concomitant rise in Alder pollen and weeds. Sediment cores from lakes located within the watersheds of central Puget Sound have been used to reconstruct such records and identify these disturbance horizons. For example, the position of the significant deforestation horizon in Hall Lake was dated as 1914 associated with a saw dust layer (Tsukada, unpublished data, King County). Near Seattle, Lake Washington sediment cores record this disturbance as around 1900-1904 (Davis 1973). These dates were further confirmed by Department of Interior maps from 1897 showing that the lowlands surrounding Lake Washington and Seattle were already cut. Therefore, the "settlement horizon" can be judged to be about 1900 or slightly younger. The palynological reconstructions for Puget Sound sediments should reflect the timing and strength of microfossil zones recorded in Lake Washington (Leopold et al. 1982).

HYPOTHESES RELATED TO POLLEN HORIZONS

1) Increased land-use and land-cover changes during the 1900s resulted in an increase in Alder and weed pollen and concomitant decrease in total conifer pollen of the undisturbed forest.
2) The increase in Alder pollen ("the disturbance horizon") previously identified from Lake Washington and other fresh water bodies in King County, WA also occur in the marine cores at relatively similar time periods.

1.2.4. Microfossils of Diatoms

Diatoms are unique forms of algae, particularly useful for paleoecological research because they grow a silica shell or exoskeleton (frustules), the morphology of which is species specific. They are preserved, after the cell dies, as fossil evidence in the sedimentary record. Modern diatom taxonomy is based on frustule characteristics, and therefore a fossil diatom of good preservation can be identified as accurately as a living one. Diatoms are abundant in aquatic environments, generally cosmopolitan in distribution, and have a fairly well studied taxonomy and ecology (Reid et al. 1995; Stoermer and Smol 1999). The abundance and composition of diatom assemblages are determined by the interaction of many environmental factors, including light availability, temperature, salinity, nutrient availability, pH, and pollution (Patrick 1965; 1973; Brush and Davis 1984; 1990; Juggins 1992; Anderson et al. 1993; Nelson and Kashima 1993; Bennion et al. 1996; Cooper 1999; Cooper et al. 1999; Cooper 2000). Presence or absence of individual species and diatom assemblages can therefore be interpreted as indicators of eutrophication, climate changes (sea level and precipitation), land clearance (turbidity), pH, and salinity changes [e. g. (Cooper and Brush 1991; 1993; Cooper 1995a; Cooper et al. 1999; Cooper 2000; Cooper et al. 2004)]. Diatom assemblages can also be used to assess changes in benthic *vs*. pelagic environments, since different species indicate specific habitats. Responses of diatom communities to different land use patterns, pollution inputs, climate change, freshwater inputs, etc. can show which historical periods or events have shaped changes to estuarine ecosystems.

Diatom assemblage changes found in previous studies of Chesapeake Bay, Pamlico River and Neuse River estuaries are significant through time (Cooper and Brush 1993; Cooper 1995a; Cooper et al. 2004). Recent assemblages are composed primarily of small planktonic forms made up of species that are often found in large blooms in higher nutrient waters. Recent diatom assemblages show relatively low species richness and diversity compared to older samples, with higher number total counts being deposited to the sediments. Older assemblages are composed of more benthic and epiphytic species. Changes likely reflect eutrophication, increased turbidity and sedimentation, and freshwater flow to the estuaries, as well as, an increase in anthropogenic activities. Overall trends of the East Coast estuaries studied are similar, although the time frame of major changes is different.

HYPOTHESES RELATED TO DIATOM ANALYSES:

1) Increased anthropogenic nutrient inputs to Puget Sound will cause a decline in diversity of diatom species and increase the ratio of centric/pennate diatoms due to a suite of factors including: increased primary production in the upper water column (reducing light availability to benthic pennate species), blooms of less desirable phytoplankton, and competition related to changing nutrient conditions.
2) Increased anthropogenic nutrient loadings will cause an increase in diatom production, evident in total valves counted and BSi measurements.
3) Increased anthropogenic nutrient loadings and increased hypoxia/anoxia of bottom waters may contribute to a decline in benthic and epiphytic diatom species due to reduced habitat for these taxa (e.g. less submerged aquatic vegetation, and less light availability to deeper sediments).
4) Increased runoff from the watershed has caused increased stratification of the water column, resulting in an increase of estuarine and freshwater diatom taxa and a decline

in marine and benthic diatoms (due to less light availability to the bottom waters related to increased turbidity and productivity of the overlying fresher water).

1.2.5. Microfossils of Foraminifera

Benthic foraminifers are sensitive indicators of the chemical and physical properties of the water masses they occupy. Numerous studies have established the relationship between particular benthic foraminiferal species or assemblages with various physical properties such as depth, sediment type, or temperature, and chemical properties such as salinity or dissolved oxygen [see (Douglas and Heitman 1979; Ingle 1980; Douglas 1981) and references therein]. The end result of these studies is the ability to interpret the physical or chemical conditions under which sediments were deposited. The association between dissolved oxygen and benthic foraminifers is of particular interest to many researchers because of the need to understand the climate cycles, ventilation history, and water mass development that have led to intervals of hypoxia, locally and globally (Behl and Kennett 1996; van Geen et al. 1996; Gardner et al. 1997; Dean and Gardner 1998; Mix et al. 1999). Studies dealing primarily with foraminifers and dissolved oxygen content (Smith 1964; Douglas and Heitman 1979; Vercourtere et al. 1987; Kaiho 1994; Bernhard et al. 1997; Cannariato and Kennett 1999; Patterson et al. 2000) have identified species and assemblages that directly correlate with dissolved oxygen levels.

The purpose of using benthic foraminifers in Puget Sound would be to develop a history of climatic and dissolved oxygen variations over the last several hundred years and establish a baseline which can be used to separate natural climatic and human-induced dissolved oxygen changes. Analyzing the foraminiferal assemblages for alterations in abundance, diversity, and preservation help elucidate historical alterations of physical and chemical parameters at the sediment-water interface. Such physical and chemical parameters include water depth, temperature, down-slope transport, dissolution, salinity, and dissolved oxygen. This information will be useful for anticipating future conditions and predicting impacts of anticipated changes including identification of basins that are especially vulnerable to change.

HYPOTHESIS RELATED TO FORAMINIFERA ASSEMBLAGES

1) Foraminifera diversity decreased concomitantly with increasing redox-sensitive metal indicators or an increased frequency of low dissolved oxygen conditions during significant anthropogenic changes in Puget Sound during the 20th Century.
2) Foraminefera diversity decreased concomitantly with an increase in total organic carbon in sediment.

2.0 Approach

The main basin of Puget Sound and Hood Canal were selected for this sediment coring study for their similarities and differences. Both basins are fjord-type estuaries with similar bathymetries, basin orientation, general weather patterns, and nutrient-rich source waters from the Pacific Ocean through the Straits of Juan de Fuca. However, the basins have dramatically different water column residence times, basin geomorphologies, vertical mixing, watershed populations, industrial activities, wastewater inputs, and recorded hypoxic events. The collection of several cores from both the central basin of Puget Sound and Hood Canal allowed for a temporal comparison within each basin, as well as, between basins. Puget Sound serves as a basin receiving significant anthropogenic nutrients, but no recorded hypoxia, while Hood Canal, the long-deep axis, receives small quantities of wastewater through septic systems and has documented hypoxia at its southern end. Comparing historical reconstructions from the two basins provides a measure of change in response to the primary differences of anthropogenic forces and physical constraints.

2.1. Study Area

The Puget Sound Lowlands is a regional depression that lies between the Olympic and Cascade Mountains (see Figure 1). The shape results from regional glaciations with contemporary landscapes, primarily, from erosion and deposition associated with the incursion of the Puget Lobe during the ice-ages (Burns 1985). The largest subdivision of Puget Sound is the Main Basin, which is a U–shaped, fjord-type estuary (Baker 1984; Cannon et al. 1990). It extends ~100 km from Admiralty Inlet southward to the Tacoma Narrows where it enters the southern basin. The sub-basin of Hood Canal is also a glacially carved fjord and opens from Admiralty Inlet southward ~110 km to the southern terminus. It is separated from the main basin by the Kitsap Peninsula. The southern end of Hood Canal is called The Great Bend, which extends eastward into Lynch Cove. The axis of Hood Canal does not actually turn, but instead this is the intersection of the shallower (< 50 m) appendage formed by a glacial-meltwater distributary (similar to southern Puget Sound) that extended across the Kitsap Peninsula (Burns 1985). In contrast to other basins of Puget Sound, Hood Canal has limited tidelands, marginal bays, coves, and mudflats (Burns 1985). The only exception is the extensive mudflats in Lynch Cove. The bathymetry of both central Puget Sound and Hood Canal are characterized by controlling sills (~ 50 m) at the northern ends, deep central basins, and shallowing/sill at the southern end.

Southward of Admiralty Inlet is the central basin, which extends from Seattle south to Tacoma. The waters reach depths of 250 m compared to Hood Canal ranging from 150 m to < 50 m at The Great Bend. The two basins have very different circulation patterns with the sills and strong tidal currents of the central basin promoting vigorous mixing with residence times on the order of 49 days (Cokelet et al. 1990; Babson et al. 2006). While Hood Canal has a mixing zone at the northern end (Cokelet et al. 1990), the overall circulation is sluggish with residence times ranging from 52 to 99 days (Babson et al. 2006). Although, the circulation is sluggish, bottom waters in Hood Canal are usually not anoxic due to a seasonal intrusion of dense waters from the Straits of Juan de Fuca (Collias et al. 1974).

Both basins receive nutrient-rich Pacific Ocean water that supports a very high rate of primary production (Barlow 1958; Barnes and Collias 1958; Mackas and Harrison 1997). In general, most of Puget Sound is not nutrient-limited but rather light-limited due to vigorous tidal mixing at the sills (Collias and Lincoln 1977). However, several sub-basins with long-residence times, including Hood Canal, become nutrient-limited during the summer (Mackas and Harrison 1997). Most of the Puget Sound basins are well-ventilated with observed hypoxia events isolated to the sub-basins with the longest residence times (Hood Canal and portions of the southern basin).

These observations were somewhat consistent Rabalais et al. (1999; 2002a) that showed oxygen depletion occurs more frequently in estuaries with longer water residence times, higher nutrient loads, and a stratified water column.

The mean subtidal circulation of Puget Sound is primarily density driven by freshwater discharges and the salinity of the water masses entering from the Straits of Juan de Fuca (Cokelet et al. 1990; Babson et al. 2006). Upwelling and downwelling off the Washington coast is believed to control the salinity of the water entering the Straits (Barnes and Collias 1958). Freshwater discharges into Puget Sound peak in winter during peak runoffs and late spring due to snowmelt with a minimum typically recorded in September. The Whidbey Island Basin receives ~ 62% of the freshwater discharged to Puget Sound (Cannon 1983), whereas the central basin receives ~19 % and Hood Canal only around 8% (Burns 1985). The sediment supply to the region is generally newly eroded, fine-grained sediment (Carpenter et al. 1985).

Watersheds entering the central basin drain the western flank of the Cascade Mountains, the populated areas of Seattle and Tacoma, and the Kitsap Peninsula. The more densely populated coastal counties of the central basin (King, Pierce, and Kitsap Counties) have grown rapidly over the last 50 years compared to the sparsely populated counties surrounding Hood Canal [Figure 2; (State of Washington Office of Financial Management 2007)]. Since Kitsap County is located on the western shore of the central basin and eastern shore of Hood Canal, it is included in both population counts. The population of Kitsap County has also grown rapidly from containing only 50% of the Hood Canal basin population in the 1900s to a steady 90% since the 1960s. Hood Canal watersheds drain areas of the Kitsap Peninsula and the steep grades of the Olympic Mountains primarily located within the Olympic National Park. As a result, it experiences much lower anthropogenic influences than the central Puget Sound.

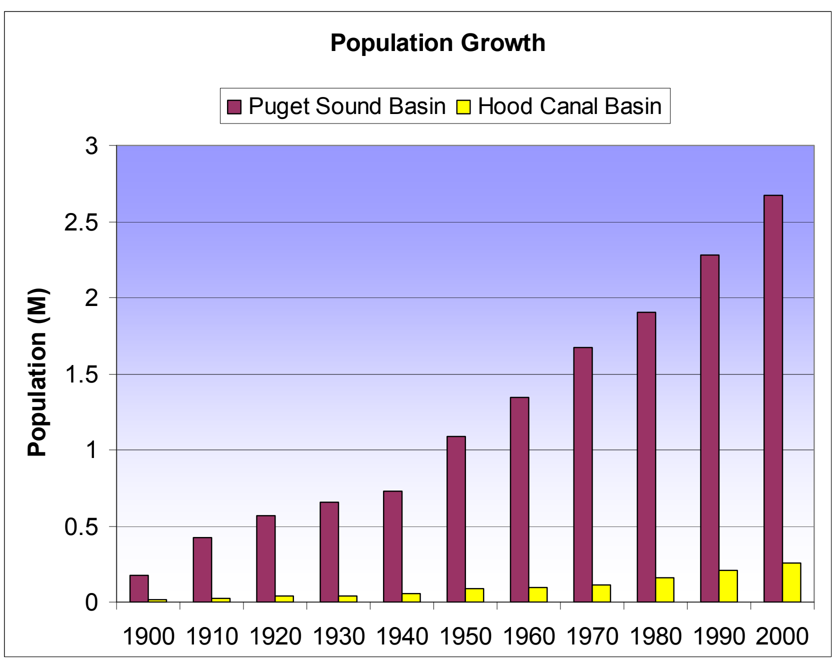


Figure 2. 20th Century population growth for coastal counties in central Puget Sound and Hood Canal.

2.2. Historical Timeline of Events

Euro-American exploration of the Puget Sound region began after Spanish explorer Juan de Fuca entered the Straits bearing his name in 1592. Detailed mapping of the abundant natural resources by Captain Charles Wilkes in 1841, prompted an increase in interest by the U. S. government towards establishing firm ownership and settlement of the Oregon Territory, later to become the states of Washington and Oregon (Buerge 1987). The development of industrial activities began in the 1850s with water powered sawmills established at Commencement Bay near Tacoma, and in Hood Canal at Port Ludlow and Port Gamble (Todd et al. 2006). The Northern Pacific Railroad was completed in 1853 linking the Pacific Northwest to other states followed by the first transcontinental railway in 1887, ending at Commencement Bay. This led to an exponential growth in the central Puget Sound population during the 20th century (Figure 2) and fueled major trends in the urbanization and industrialization. A synopsis of major events in Puget Sound provides documented events to compare with paleo-ecological reconstructions (Figure 3).

Tsunami records from Japan and radiocarbon dating, document a massive earthquake occurring in the early 18th Century (Figure 3) along the entire length of the Cascadia subduction zone off the Pacific coast causing sudden submergence and burial of wetland soils, rooted plants, and entombing tree stumps (Nelson et al. 1995; Satake et al. 1996). Other significant environmental events noted are minor eruptions of Mt. Rainier and Mt. St. Helens, heavy snowfall years, severe flooding, and notable wind storms (Kruckeberg 1991).

Historical changes in the logging practices were significant events due to the dense forests historically surrounding Puget Sound. Progress from the onset of clear-cut logging in the 1900s to mass production of the two-person, gas-powered chainsaw in 1927 and then single-operator chainsaws in 1945, altered the entire vegetation cover. This led to a marked shift in the pollen rain record (as discussed below). By this time automobiles were the popular mode of travel and roadways were under construction. Metal smelting activities established on Harbor Island (Seattle) and Commencement Bay (Tacoma) increased inputs of Pb, arsenic (As), Cu, and other metals during their operations (Crecelius et al. 1975; Bloom and Crecelius 1987; Brandenberger et al. 2008). Harbor Island was placed on the National Priorities List for volatile organic compounds and metal contamination (Department of Justice 2006). The ASARCO, Inc. metal smelter on Commencement Bay operated from 1890 to 1985. Approximately 15 million tons of slag from the smelter, containing other heavy metals such as As and Pb, were dumped along the shoreline and eventually used to create a 23-acre breakwater (USEPA 1995). These identified inputs provided a time event marker for sedimentary metal reconstructions in Puget Sound (Brandenberger et al. 2008).

Industrialization in Puget Sound was fueled by the U. S. participation in WWI and WWII. The U. S. Naval operations expanded with the largest and most diverse shipyard on the West Coast established at Bremerton, WA on the Kitsap Peninsula. Other Naval installations were located throughout Hood Canal and central Puget Sound. In the 1960s the first environmental protection acts were passed starting the movement of environmental awareness. This included the removal of Pb from gasoline, which began as a Pb reduction in 1973 and slowly progressed to 50% removal by 1980, and then the USEPA endorsed a total ban by 1995 (Needleman 2000).

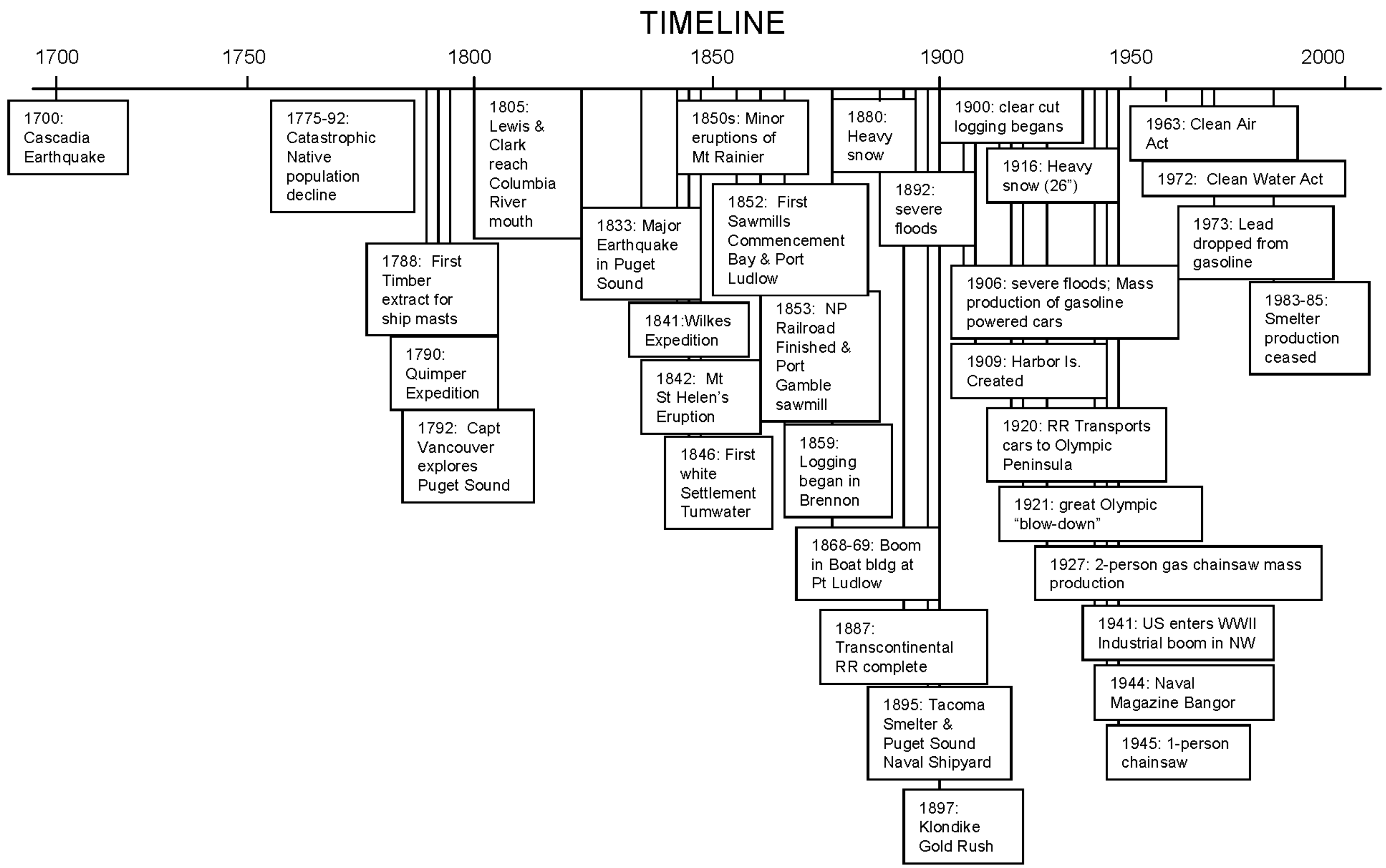


Figure 3. Historical timeline of significant events in the Puget Sound region.

The overall effectiveness of these laws are recorded in sediment coring studies conducted both in Puget Sound and other estuaries around the world [see (Bloom and Crecelius 1987; Van Metre et al. 2000; Santschi et al. 2001; Latimer et al. 2003; Brandenberger et al. 2008) and references therein]. These studies used sediment cores to reconstruct geochronologies reflecting watershed-integrated loads of metal and organic contaminants. They all showed similar trends with marked increases of metals during urbanization in the watershed, followed by decreasing concentrations around the middle of the 20th Century as environmental regulations began reducing point source inputs. In the case of metals, this method provides a means of separating anthropogenic from natural inputs and allows the calculation of the anthropogenic burden and its changes over time.

Although long-sediment cores have not previously been collected in Hood Canal, similar anthropogenic signatures should be recorded. The terrain within the Hood Canal watershed is generally rugged, sparsely populated, and not readily accessible. However, logging practices, river damming, and small population increases are expected to have altered the natural signatures of Hood Canal sediments through time. A vegetation cover loss analysis in sub-watersheds of Hood Canal was conducted to calculate the percent conversion from vegetated to non-vegetated land-cover. Vegetation cover loss was calculated by changes in Normalized Difference Vegetation Index (NDVI) between satellite data from 1975 and 2000, which only accounted for vegetated to non-vegetated changes and not changes in vegetation types. Figure 4 illustrates the percentage loss for each sub-watershed from 1975 to 2000. Of the total Hood Canal watershed (2668 km^2), around 148 km^2 or 18% of vegetation cover was lost during this period. The highest percent of change was calculated in the sub-watersheds of Kitsap County surrounding Lynch Cove. An aerial photo from 1939 confirms clear-cutting was occurring on the Kitsap Peninsula in the early 1900s (Figure 5).

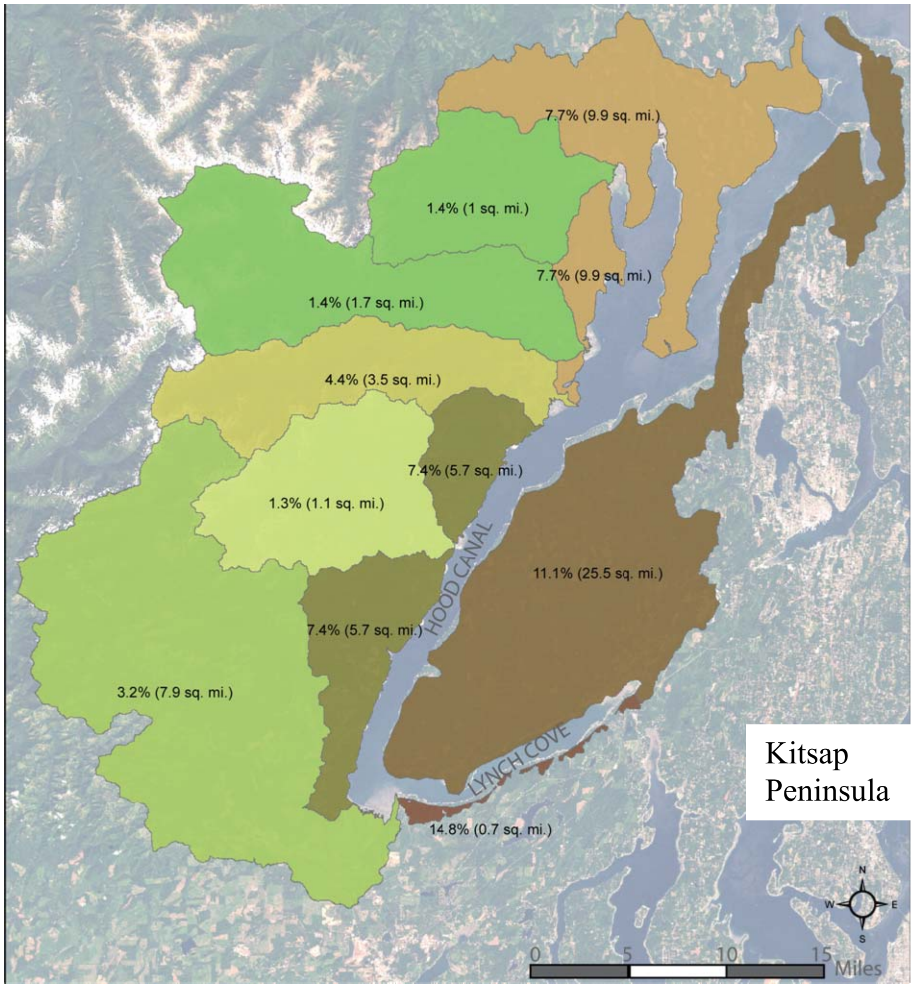


Figure 4. Percent vegetation loss by sub-watershed for the Hood Canal basin from 1975-2000.

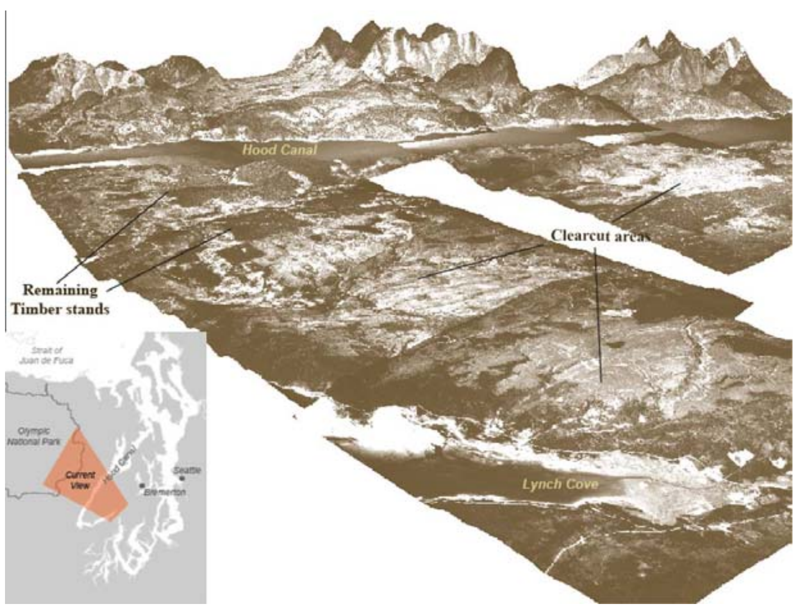


Figure 5. Aerial photograph from 1939 showing clear-cut areas on the Kitsap Peninsula. Original imagery source is U. S. Forest Service, distribution by University of Washington, Puget Sound River History Project.

2.3. Sediment Core Collection

Four coring locations in central Puget Sound (Figure 6, PS-1 to PS-4) were selected from previous coring studies conducted in 1982 (Bloom and Crecelius 1987) and 1991 (Lefkovitz et al. 1997). These areas were shown to have little sedimentary disturbances and good geochronological records to allow temporal comparisons (spanning 23 years), as well as, spatial comparisons from Seattle to Tacoma. Long-sediment cores have not been previously collected in Hood Canal; therefore, locations were selected based on anticipated depositional areas at five locations along the deep, north-south, long axis (Figure 6, HC-5 to HC-1).

Sediment cores were collected using a stainless steel, open barrel gravity corer (Kasten corer, see Figure 7) described in Zangger and McCave (1990). This technique provides more intact cores and minimizes shortening typically seen in conventional gravity corers (Lebel et al. 1982; Kuehl et al. 1985; Nevissi et al. 1989). The Kasten corer is 3 m long with a cross-sectional area of 15 cm^2. Coring was conducted from aboard the University of Washington research vessel, RV Barnes. The core barrels were rinsed and scrubbed with ambient seawater between coring and sediment in contact with the core barrel was removed prior to sample collect.

Figure 6. Sediment coring locations in central Puget Sound (PS-1 through PS-4) and Hood Canal (HC-1 through HC-5) and the Kasten corer (right).

The core barrels are designed with a removable piece the length of the core to allow segmenting without contamination or smearing. Each core was photographed and visually characterized for color change, texture, and/or anomalous horizons (Table 2). The cores did not contain distinct varves, with a few exceptions noted in some Hood Canal cores. The cores were generally uniform grey to dark olive in color and a fine-grained texture. The cores from Hood Canal tended to be more olive in color than those of Puget Sound with black and rust (Fe oxidation) bands and a few notable non-uniform (generally circular) black areas potentially indicating benthic invertebrate burrows. The northern most Hood Canal core (HC-5) contained a pronounced varve-like black band from 215-222 cm (Figure 7). The Hood Canal cores had a detectable to strong H_2S odor. Although, Puget Sound cores degassed and showed evidence of gas bubbles in the sediment at depth, there was not a strong H_2S odor. In addition, coal klinkers or sharp red fragments remaining from burned coal, were found in the two cores near Tacoma (PS-1 and PS-2). Visual inspection of all nine cores concluded they were relatively undisturbed and good candidates for age-dating and reconstructions. Only HC-1, from The Great Bend in Hood Canal, was coarser in texture and not considered the best representation of a depositional environment in this area.

The cores were subsectioned immediately upon collection using an acid-rinsed ceramic knife. Sediment in contact with the core barrel was removed prior to sub-sampling. The entire length of the cores were sampled at 2 cm intervals from 0-50 cm (or 0-100 cm) then at 5 cm intervals down to the core catcher. Two cores were sampled every 2 cm (HC-2 and HC-3). See Appendix A for a complete list of core segments intervals. Samples were collected in 8 oz. precleaned glass jars and stored in coolers until transport back to the Pacific Northwest National Marine Science Laboratory in Sequim, WA. Each core segment was homogenized and split for pollen counts, diatom assemblages, foraminifera assemblages, total elemental and stable isotopes of carbon and nitrogen, biomarkers, radioisotopes (^{210}Pb and ^{137}Cs), biogenic silica (BSi), total phosphorus (P), redox sensitive metals (Mo, U, Re, Mn, Cd), detrital metals (Al, Ti, Fe), priority pollutant metals used to bracket ages (Pb, As, Cr, Cu, Zn, Ni), and additional elements (Ba, V, Be, Ca, Mg).

Table 2. Coordinates for each coring location, water depth, core length, sediment texture, and descriptions of any anomalies for each core.

Core ID	Latitude [1]	Longitude [1]	Water Depth (m)	Core Length (cm)	Color/Texture and Noted Anomalies
PUGET SOUND CORES					
PS-1	47° 20.830	122° 24.580	174	255	- black to gray (64 cm) - crumbly, H_2S (50-56 cm) - coal and/or klinkers (94, 194 cm) - Shell fragments (115-120, 122, 154, 230 cm)
PS-2	47° 28.733	122° 24.238	193	250	- gray with black streaks (10-15, 28-32, 50 cm) - gas bubbles, no H_2S (196-250 cm) - coal klinkers (225 cm)
PS-3	47° 33.353	122° 26.326	222	205	- strong H_2S, olive/black (dominant <100cm) - shell/woody debris (95-100 cm)
PS-4	47° 36.898	122° 26.941	200	230	- grey/gas bubbles, no H_2S (80-230 cm)
HOOD CANAL CORES					
HC-1	47° 21.881	123° 05.390	49	205	- dark olive and coarser texture - shell fragments (78-86, 90, 138, 155, 170 cm)
HC-2	47° 23.327	123° 07.911	110	225	- gray/olive - black bands (0-16 cm) - black non-uniform (14-16, 42-44, 60-72 cm)
HC-3	47° 26.224	123° 05.938	129	215	- olive with Fe oxidation streaks (<18 cm) - black non-uniform (75-80, 92-94 cm) with strong H_2S (>150 cm) - small rounded pebbles (188-190 cm) - coarser/clay balls (210-215 cm)
HC-4	47° 29.225	123° 03.048	158	255	- strong H_2S and firm texture - Fe oxidation (0-2 cm), black bands (4-18 cm) - Black non-uniform (112-116, 176 cm)
HC-5	47° 36.995	122° 56.186	174	255	- gray/olive with heart urchin (0-10 cm) - Fe oxidation (0-10, 22-24 cm), plants (40 cm) - black bands (128, 198, 228-232 cm); non-uniform (100, 180-190 cm) - pronounced black band (210-230 cm)

[1] Coordinates are reported relative to Datum WGS84

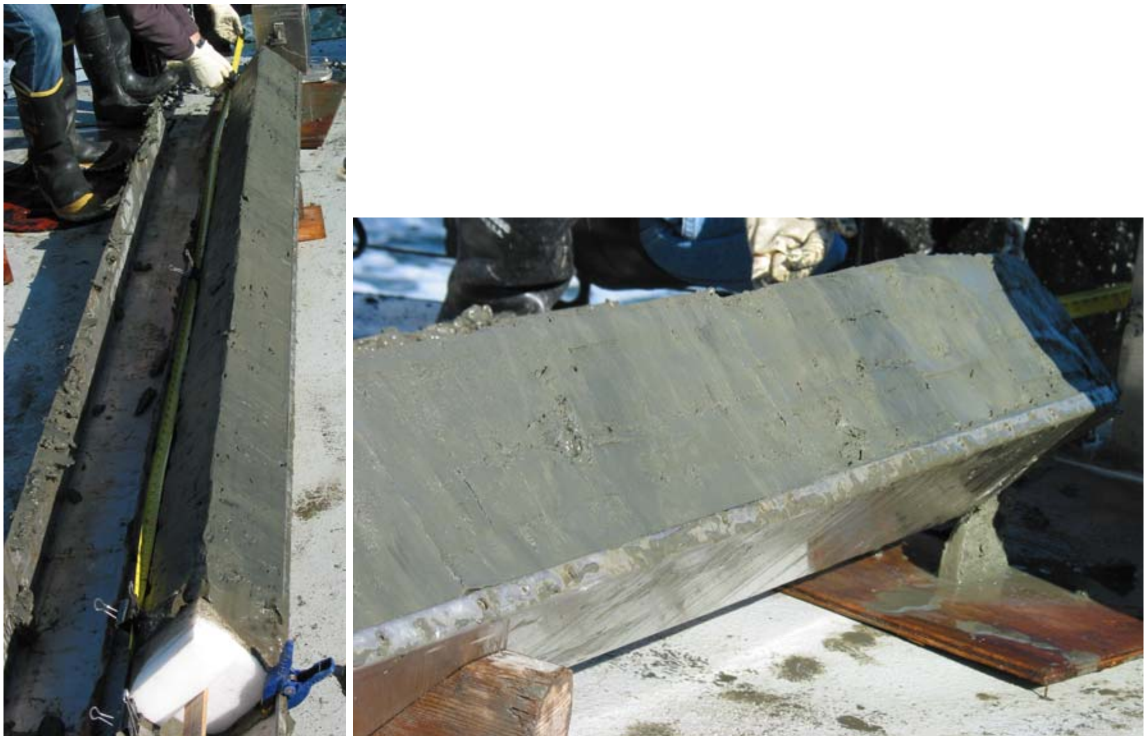


Figure 7. The northern most Hood Canal sediment core (HC-5) with the black band from 215-222 cm depth.

2.4. ^{210}Pb Geochronology

The geochronologies for all nine cores were established using radiometric dating methods previously described for sediment cores collected in Puget Sound (Lavelle et al. 1985; 1986; Bloom and Crecelius 1987; Lefkovitz et al. 1997; Brandenberger et al. 2008). Sedimentation (cm/yr) and sediment accumulation rates (g/cm^2/yr) were estimated using steady-state ^{210}Pb dating techniques (Koide et al. 1973; Lavelle et al. 1986). The naturally occurring isotope of ^{210}Pb ($t_{1/2}$ = 22.3 yr) is from the uranium-238 (^{238}U) decay series and results from the intermediate decay of radium-226 (^{226}Ra) to the noble gas of radon-222 (^{222}Rn) by alpha decay (Goldberg 1963). The ^{222}Rn isotope diffuses into the atmosphere, attaches to aerosols, and is scavenged during precipitation or falls as dry deposition. If ^{210}Pb is in equilibrium with the decay of ^{226}Ra, with minimal loss, and the highly particle reactive ^{210}Pb is readily scavenged from the water column by raining organic and inorganic particles; then the atmospheric supply of ^{210}Pb is in excess of the supported or background activity. This provides a means of estimating relative sediment ages up to 200 years before present (bp) or $<$ 10 half-lives.

The ^{210}Pb activity is radiochemically determined by measuring the alpha activity of the granddaughter product polonium-210 (^{210}Po). The direct measurement of beta activity from the decay of ^{210}Pb to bismuth-210 (^{210}Bi) is too weak to accurately measure. Since ^{210}Bi decays to ^{210}Po and subsequently to stable ^{206}Pb, the alpha activity of ^{210}Po can be determined and time-corrected to ^{210}Pb. The approach to this measurement was adapted from Koide et al. (1973) and Lavelle et al. (1985) and assumes that both ^{210}Po and ^{210}Pb remain in secular equilibrium in the post-depositional environment (Benoit and Hemond 1990).

Splits of each core segment were lyophilization for the determination of percent moisture and then homogenized using a sediment miller. Approximately 12-19 samples from each core were prepared for ^{210}Pb analyses following preparation procedures published in Carpenter et al. (1982). The yield tracer, ^{208}Po, was spiked into each sample prior to preparation. The Po isotopes were released from dried, homogenized sediment by successive digestion with concentrated acids and then spontaneously deposited onto silver disks. The alpha decay was counted using a silica-lithium barrier diode detector. The activity of ^{210}Pb was calculated as efficiency and time corrected disintegrations per minute per gram dry weight (dpm/g). Errors associated with the sediment accumulation rates were calculated using the sum a squares approach to error propagation and included error from the counting statistics, detector efficiency, chemical yield, and supported ^{210}Pb along with the 95% confidence intervals for the linear regression. The supported ^{210}Pb activity was defined as the average ± the propagated counting error for the core segments showing constant activity at depth. Progressing from the deepest core segment upward, the sample containing the first measurable excess ^{210}Pb was defined as an activity greater than the mean + 1 standard deviation (s). The supported ^{210}Pb activities for each core are listed in Table 3. The PS-2 core did not reach supported; therefore, the average and relevant errors from the other Puget Sound cores were applied to this core. The supported ^{210}Pb activities are in agreement with those reported by Lefkovitz et al. (1997) where the cores identified as 3 through 6 correspond with PS-4 through PS-1, respectively.

Table 3. The supported ^{210}Pb activity, mixed depth, sedimentation and accumulation rates, and overall quality of the geochronology for each core.

Core ID	Supported ^{210}Pb Activity ± 1σ (dpm/g)	Assumed Mixed Depth (cm)	Mean Porosity below mixed ± 1σ	Sedimentation Rate (cm/yr)	Sediment Accumulation Rate (g/cm^2/yr) [1]	Quality of Chronology
PUGET SOUND						
PS-1	0.825 ± 0.332	20	0.809 ± 0.016	1.2 ± 0.1	0.556 ± 0.052	Excellent
PS-2	0.965 ± 497 [2]	15	0.824 ± 0.020	2.6 ± 0.2	1.14 ± 0.065	Excellent
PS-3	0.747 ± 0.267	10	0.796 ± 0.022	1.8 ± 0.1	0.914 ± 0.042	Excellent
PS-4	1.10 ± 0.255	17	0.796 ± 0.015	2.1 ± 0.1	1.05 ± 0.048	Good
HOOD CANAL						
HC-1	0.535 ± 0.401	16	0.649 ± 0.023	0.90 ± 0.25	0.804 ± 0.42	Poor, coarse texture
HC-2	0.667 ± 0.37	6	0.797 ± 0.021	0.44 ± 0.1	0.222 ± 0.081	Poor, large slump
HC-3	1.07 ± 0.286	10	0.817 ± 0.033	0.49 ± 0.065	0.218 ± 0.030	Good, small slump
HC-4	0.977 ± 0.335	10	0.840 ± 0.017	0.43 ± 0.066	0.170 ± 0.027	Excellent
HC-5	0.851 ± 0.339	10	0.815 ± 0.019	0.73 ± 0.037	0.337 ± 0.018	Excellent

(1) Propagation of error as the sum of squares for counting, detector efficiency, chemical yield, and supported counting errors.

(2) Core did not extend to supported activity, value determined as the average of other Puget Sound cores.

The sedimentation and accumulation rates were calculated using the methods previously published for Puget Sound (Carpenter et al. 1985; Lavelle et al. 1986; Nevissi et al. 1989). The accuracy of this approach depends upon four basic assumptions: 1) sedimentation rate is relatively constant, 2) radioactive decay is the only process reducing the ^{210}Pb activity (i.e. no chemical mobility), 3) the mixed depth is confined to the surface layers, and 4) depositional times for core segments are well defined and compromise only a fraction of the overall dating period. Based on the previous studies, the current ^{210}Pb profiles, and the derived data from each core, these assumptions were not violated. Although there is evidence that ^{210}Pb can be diagenetically remobilized in reducing freshwater environments (Koide et al. 1973; Benoit and Hemond 1990; 1991), Brandenberger et al. (2008) found no significant remobilization of total Pb in the marine sediment cores from Puget Sound over the last 23 years. Meeting these assumptions defines the vertical distribution of excess $^{210}Pb_{xs}$ below the mixed depth as a function of the least squares fit of the natural logarithm of $^{210}Pb_{xs}$ versus total mass accumulation at depth (x).

The linear sedimentation rate has only limited significance due to the effects of compaction. Therefore, the total mass accumulation for each core segment was corrected for salt and used to generate the mass accumulation for each core segment. The salt correction assumed a constant salinity of 30 psu and density of 1.0229 g/cm^3. Lefkovitz et al. (1997) provides a detailed description of the calculations. In brief, the mass accumulation rate (w) in g/cm^2/yr is given by the formula in Equation 1.

Equation 1. Formula for mass accumulation (w).

$$w = -\frac{\lambda}{M}$$

Where M is the slope of the natural logarithm of $^{210}Pb_{xs}$ against total accumulation at the mid-point of each core interval and λ is the radioactive decay constant of ^{210}Pb per year (0.0311). The linear sedimentation rate (s) for each core segment is then related to w in Equation 2.

Equation 2. Relationship between mass accumulation and linear sedimentation rate (s).

$$w = s(1-\varphi)\rho_s$$

Where φ is the porosity and ρ_s is the sediment dry density (g/cm^3). Table 3 summarizes the sedimentation and accumulation rates ± error propagation, mean porosity ± 1σ below the mixed depth, and the overall quality of the chronology. Cores considered excellent have a good linear fit with r^2 values ≥ 0.98 and no evidence of significant disturbances in the bulk sediment properties. The PS-4 core (r^2 = 0.94) was considered good due to indications of small fluctuations in the sediment supply over time, but there was insufficient data to support the creation of two mass accumulation rates. The coefficients of variation (CV) for porosity (≤ 2%) are generally low for all cores; however, there are changes around 200 cm in HC-2, HC-3 and HC-5 (Figure 8). This is beyond the range of the ^{210}Pb chronology and did not impact the dating for the last 150 years. The chronology for HC-2 was disrupted by a large delta slump with ^{210}Pb anomalies in the upper portion of the core and HC-1 had low porosity with little $^{210}Pb_{xs}$. In addition, there were ^{210}Pb anomalies in HC-3 in segments 36-42 cm indicating a potential slump. These segments were assumed to deposit in a single event and were removed from the mass accumulation record.

The ^{210}Pb activities and natural logarithm of $^{210}Pb_{xs}$ with error propagation versus mass accumulations are plotted for Puget Sound (Figure 9) and Hood Canal (Figure 10) cores. The figures plot the linear regression with 95% confidence intervals (dashed lines). The ^{210}Pb data, mass accumulations per depth, statistical regression analysis, quality control data, and estimated ages for each core segment are summarized in Appendix A. Laboratory duplicates were analyzed with each core (relative percent differences 7.6 ± 5%) along with a check sample (percent recoveries 92 ± 7%).

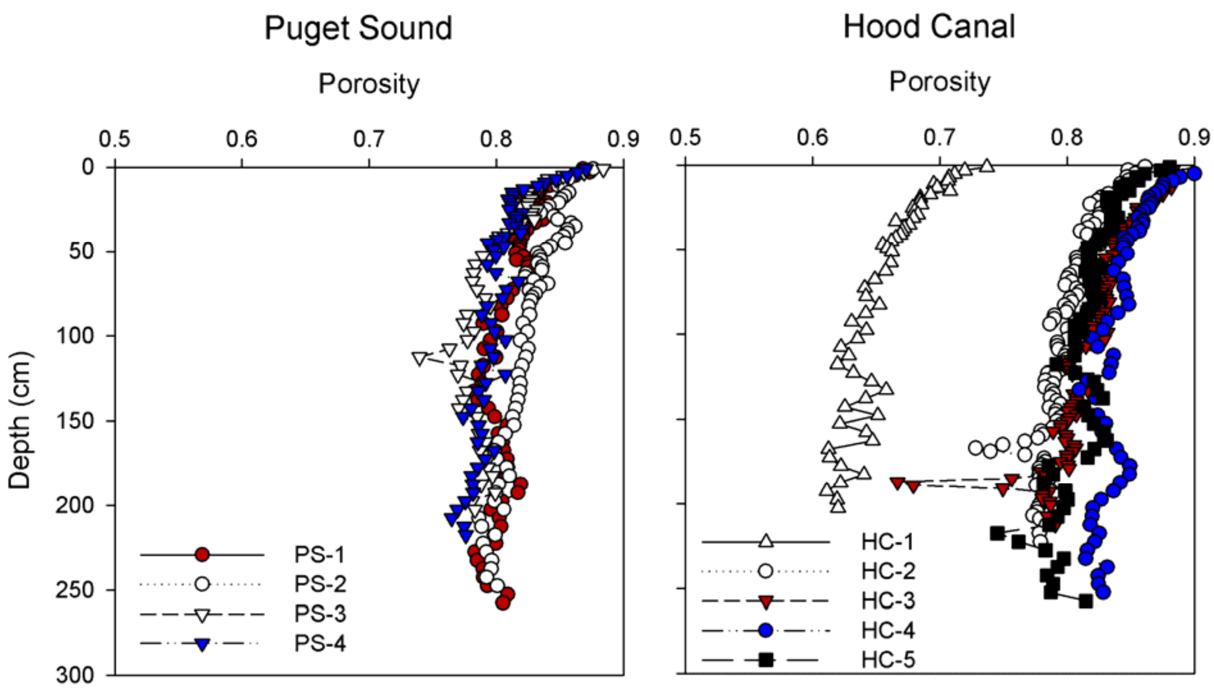


Figure 8. Porosity profiles for Puget Sound (left) and Hood Canal (right) cores.

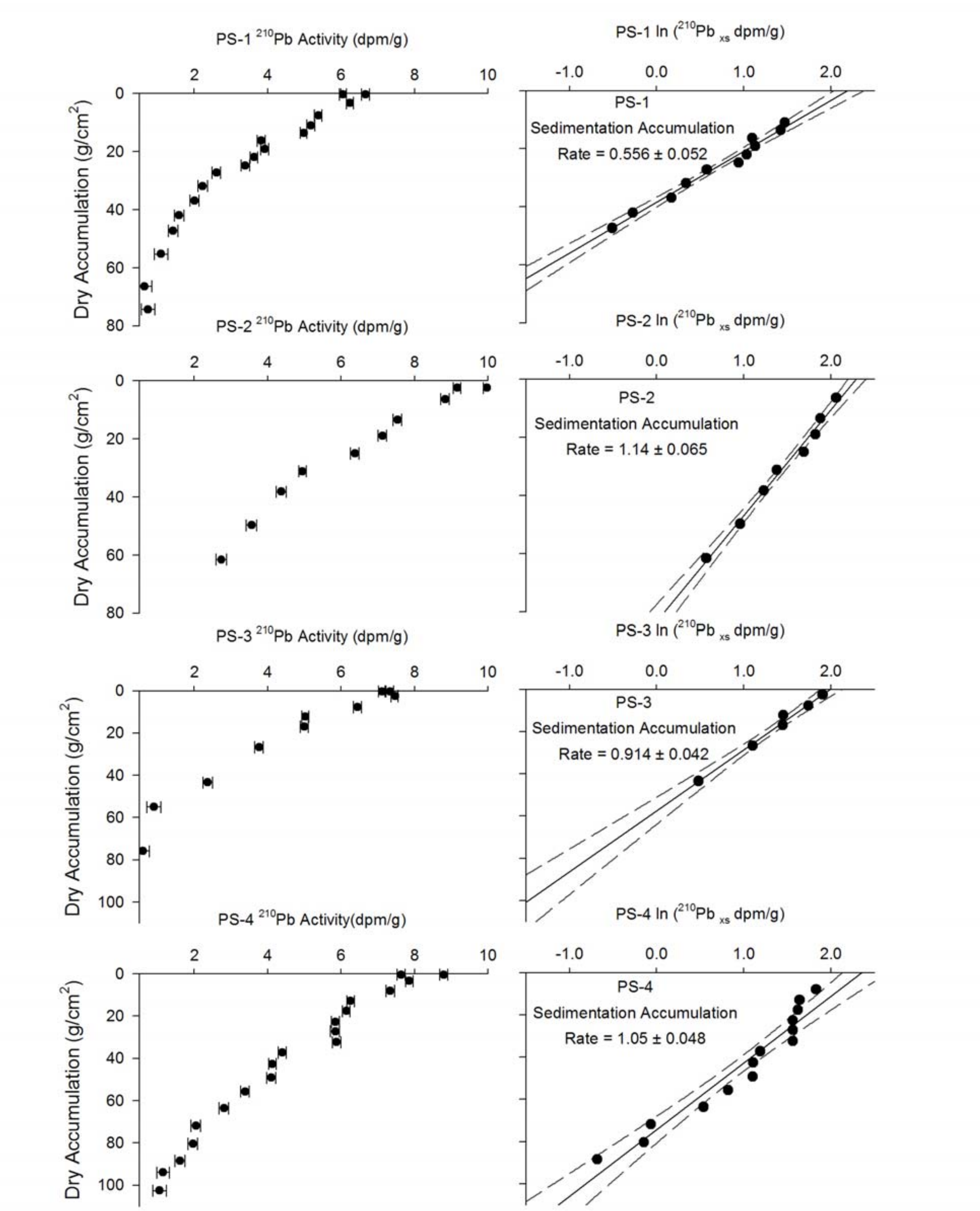


Figure 9. The ^{210}Pb activity profiles (left) with statistical error bars and linear regression of the natural logarithm of $^{210}Pb_{xs}$ (right) for Puget Sound cores PS-1, PS-2, PS-3, and PS-4, respectively. On the right, dashed lines represent the 95% confidence level of the solid linear regression line.

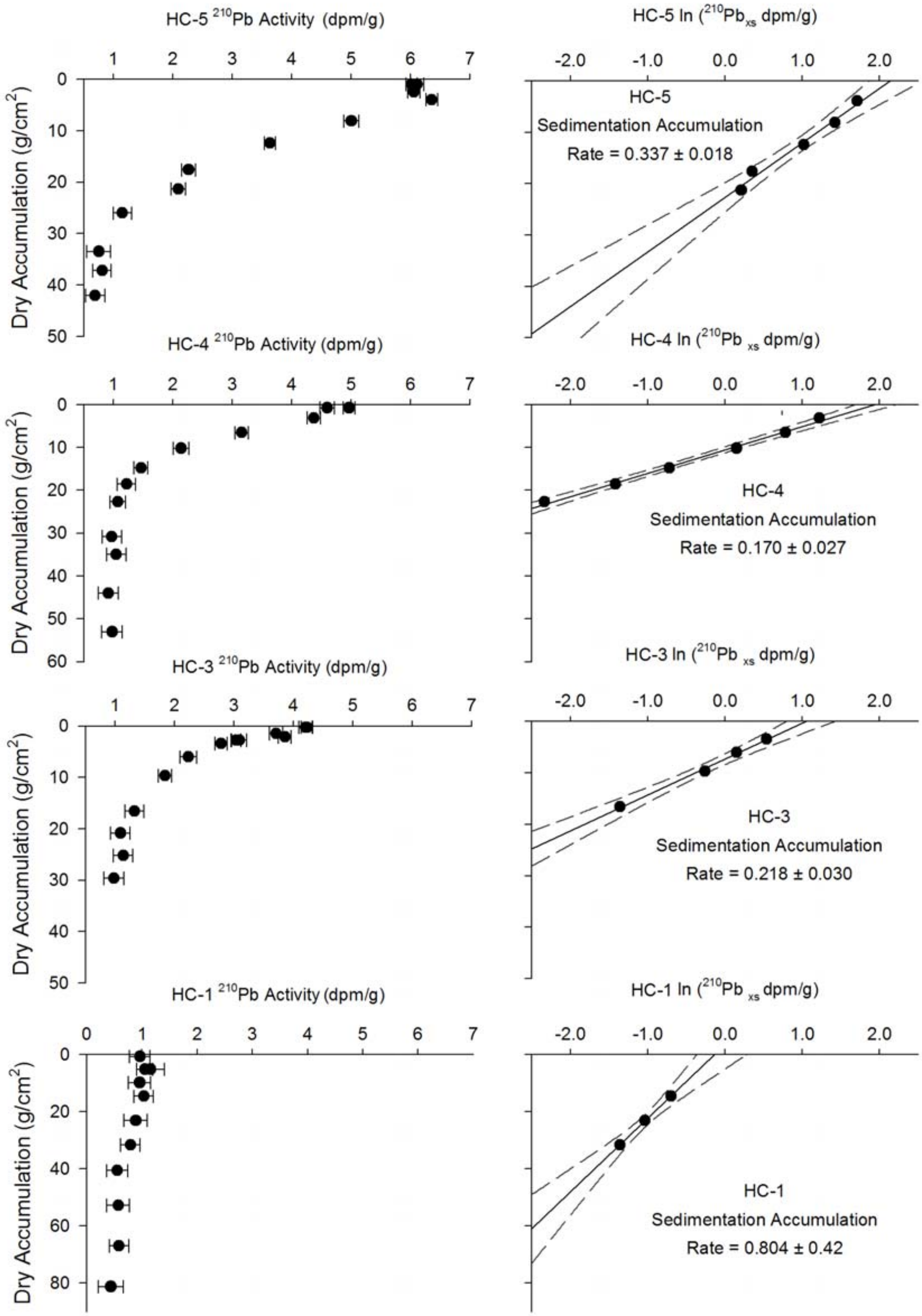


Figure 10. The ^{210}Pb activity profiles (left) with statistical error bars and linear regression of the natural logarithm of $^{210}Pb_{xs}$ (right) for Hood Canal cores HC-5, HC-4, HC-3, and HC-1, respectively. On the left, dashed lines represent the 95% confidence level of the solid linear regression line.

Many studies have incorporated these approaches for establishing geochronologies and rates of natural recovery. However, the application of these methods and other radiometric sedimentation models has recently come under criticism for over simplification or inappropriate assumptions (Smith 2001). The methods applied to Puget Sound coring studies were recognized as perhaps simplistic and potentially underestimated the effect of mixing on the ^{210}Pb profiles, which would lead to overestimating sediment accumulation rates (Bloom and Crecelius 1987). Smith (2001) proposed that ^{210}Pb geochronology be validated using at least one independent tracer that separately provides an unambiguous time-constrained stratigraphic horizon. Brandenberger et al. (2008) used the three separate coring studies at the same locations in central Puget Sound to provide such an *in-situ* independent marker incorporating all diagenetic processes. The tracer was the peak in total Pb observed in cores collected in 1982 (Bloom and Crecelius 1987), 1991 (Lefkovitz et al. 1997), and this coring study (see Figure 11 for the PS-1 coring location). A regression of the depth of the peak-Pb horizon versus elapsed time gives burial rates for PS-1 and PS-4 of 1.3 ± 0.1 cm/yr and 2.8 ± 0.5 cm/yr, respectively (Brandenberger et al. 2008). These rates fall within the error of the linear sedimentation rates determined using ^{210}Pb and serve as one confirmation tool for the Puget Sound cores. This marker was not available for Hood Canal cores and required additional verification tools.

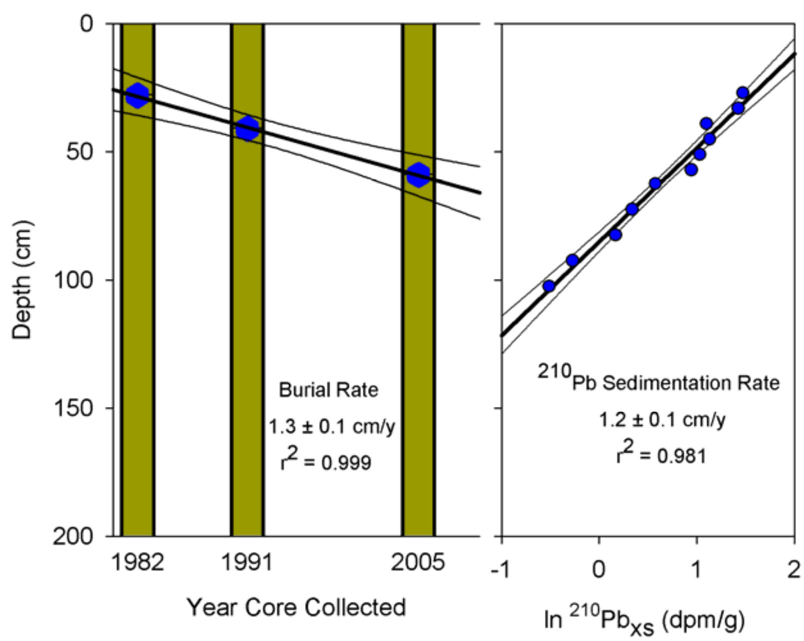


Figure 11. On the left, burial rate at PS-1 determined as the linear regression of the peak in total Pb, with 95% confidence intervals, for cores collected in 1982, 1991, and 2005. On the right, sedimentation rate determined at PS-1 by the linear regression of the natural log of excess ^{210}Pb, with 95% confidence intervals, for the 2005 core. Adapted from Brandenberger et al. (2008) with permission.

A down-core peak in cesium-137 (^{137}Cs) is often used as an independent time-marker (Wan et al. 1987). The maximum input of ^{137}Cs into the environment from weapons testing is usually taken to occur around 1963. The activity of ^{137}Cs was determined by counting gamma ray emissions directly from the sediment on a lithium-drifted germanium diode detector. Problems with the instrument allowed only a few segments to be counted; therefore, the data provide only limited bracketing of the ages for cores PS-1, HC-3, HC-4, and HC-5. The certified reference material (SRM) IAEA-135 was counted in triplicate with average ^{137}Cs activity of 42.6 ± 0.40 dpm/g and percent recovery of 87.3 ± 1.2 %. All data are reported in Appendix A. The ^{137}Cs activity shows good bracketing for PS-1 with the peak occurring in the core segment dated 1960-1968. The segment in the HC-3 core dated 1957-1965 contained detectable ^{137}Cs with no detectable ^{137}Cs in deeper segments. The peaking of ^{137}Cs in HC-4 occurs in a segment dated 1962-1972. The HC-5 core data was inconclusive as the core segment with no measurable ^{137}Cs was not counted, but the segments dated 1966-1977 contained activities similar to the peaks in the other Hood Canal cores indicating the relative ages may be reasonable estimates.

The ^{137}Cs data did not provide a powerful confirmation tool; therefore, other independent markers were used to further constrain the estimated dates of the core segments. These markers are discussed in the following sections and include the total Pb profiles, pollen horizons, lignin profiles, and $\delta^{13}C$ profiles. All the independent markers are summarized in section 3.6.

2.5. Methods for Paleoecological Tracers of Hypoxia

2.5.1. Metal Analyses (Redox, Trace, and Major Elements)

Core subsections were lyophilized and homogenized using a sediment miller. The sediments were digested using an adaptation of the total dissolution methods developed for the National Oceanic and Atmospheric Administration (NOAA) Status and Trends (S&T) program (Laurenstein and Cantillo 1996). In summary, approximately 400 mg of each sample was combined with HNO_3, HCl, and HF (1.5:3:3, respectively) in a Teflon digestion vessel, sealed to 18 foot-pounds of pressure, and heated in an oven at 130ºC (±10ºC) for a minimum of eight hours. The modification occurs with the addition of 30 mL of 5% supersaturated boric acid solution to the digested sample, which effectively results in the binding of the HF (Wu et al. 1996). After addition of the boric acid, the vessels were sealed and returned to the oven for two hours and then diluted with 20 mL of deionized water to a final volume of 60 mL. With every 20 core samples, the following quality control samples were analyzed: method blank, laboratory control sample, SRMs from the National Institute of Standards and Technology (Mess-3) and National Research Council Canada (2702), matrix spike, and laboratory duplicate. The sample concentrations and quality control data are available in Appendix B.

Samples were analyzed for Al, Ti, Fe, Mn, Zn, Ni, V, Cr, Cu, Ba, Be, Ca, and Mg by inductively coupled plasma optical emissions spectrometry (ICP-OES) using a Perkin-Elmer 4300 Dual View instrument. The data were corrected for several types of interferences, which in brief included spectral interferences with corrections based on guidance from Winge et al. (1985), interference check samples, physical interferences addressed using internal standards, chemical interferences addressed using matrix matching, and serial dilution to address multiple interferences.

Molybdenum, U, Cd, and Pb were analyzed by inductively coupled plasma mass spectrometry (ICP-MS) using a Perkin-Elmer DRC-e employing peak hopping mode with a 100 ms dwell time and a 1000 ms integration time. Isobaric interferences were corrected using established correction equations and evaluated by matrix spike additions. Table 4 summarizes the overall all means for the quality control data including the SRMs, their certified or reference values, percent recoveries, and relative percent differences (RPD) for duplicate preparations. The accuracy for trace elements was 91% or better for certified values except Cd for the SRM 2702 (17%) and overall precision was 1-4% difference.

Table 4. Average measures of accuracy and precision for elemental analyses.

	SRM MESS-3 (n=18)		Cert. Value	% Recovery	SRM 2702 (n=18)		Cert. Value	% Recovery	Avg. RPD
	Mean	**s**			**Mean**	**s**			
Units: %									
Al	7.85	0.24	8.59	91 %	7.71	0.27	8.41	92 %	1.5 %
Ti	0.41	0.01	0.44	93 %	0.82	0.027	0.884	92 %	1.7 %
Fe	4.08	0.12	4.34	94 %	7.17	0.21	7.91	91 %	1.8 %
Ca	1.41	0.037	1.47	96 %	0.32	0.009	0.34	93 %	3.8 %
Mg	1.65	0.039	1.6 [r]	97 %	0.90	0.032	0.99 [r]	91 %	1.7 %
Units: µg/g dry wt.									
Mn	296	6.8	324	91 %	1580	42	1760	90 %	2.3 %
Mo	2.67	0.13	2.78	96 %	9.75	0.30	10.8 [r]	90 %	3.8 %
U	3.65	0.12	4 [r]	91 %	8.26	0.31	10.4 [r]	80 %	2.2 %
Cd	0.224	0.014	0.24	93 %	0.677	0.052	0.817	83 %	6.3 %
Pb	21.9	0.57	21.1	96 %	126	4.3	133	95 %	1.9 %
As	19.7	1.4	21.1	94 %	41.6	3.0	45.3	92 %	4.3 %
Zn	146	5.9	159	92 %	443	20	485	91 %	1.7 %
Ni	44.1	1.8	46.9	94 %	68.4	2.8	75.4	91 %	1.8 %
V	234	5.1	243	96 %	344	7.3	358	96 %	1.7 %
Cr	98.8	2.2	105	94 %	312	6.9	352	89 %	2.2 %
Cu	31.3	0.72	33.9	92 %	110	2.3	118 [r]	94 %	1.8 %
Ba	984	29	NC		375	18	397	94 %	1.9 %
Be	2.27	0.14	2.30	99 %	2.70	0.23	3.0 [r]	90 %	1.3 %
P		Spikes (n=15)		98 %					4.0 %

[r] = Reference Value

A comparison of three different digestion methods was conducted to determine the optimal method for Re quantification due to its low (ppb) abundance. The methods were 1) total dissolution with boric acid addition (described above), 2) aqua regia with evaporation and reconstitution (adapted from Uchida et al. (1993)), and 3) total dissolution with preconcentration using Biorad AG1-X8 following Morford et al. (2005b). Core segments with anticipated high and low concentrations based on the Mo and U data were selected for these preparations. For each method, the results were 16.1, 11.8, and 12.6 ng/g, respectively for the high range, and 2.80, 1.93, and 1.60 ng/g, respectively for the low range. The relatively good agreement between the three methods allowed all the samples to be quantified using the first method with analysis by ICP-MS with ^{189}Os correction on ^{187}Re, low-level verification standards at 10 ng/L (10.2 ± 0.75 ng/L, n=11), correlation coefficients for calibrations of ≥ 0.99995, and internal standard correction. The 10 ng/L standard confirmed instrument accuracy at the sample concentration range (± 7%). Although the third method along with isotope dilution would be preferable, it would not be feasible for the analysis of each segment in these long cores. An operationally-defined method detection limit (MDL) of 1 ng/g was determined by analyzing six replicates of a core segment (Equation 3). Although this MDL is not sufficiently low for lithogenic Re quantification, the core segments were, on average, greater than the MDL.

Equation 3. Rhenium method detection limit (MDL).

MDL = 1σ * 3.365 (student t's value for n-1 at p = 0.01).

Although there are no marine sediment SRMs certified for Re, the SRM PACS-2 was prepared (n=5) to compare this approach to published values using isotope dilution (Morford et al. 2001). The PACS-2 results were 4.0 ± 0.39 ng/g and are lower than those determined by isotope dilution [5.21 ± 0.19 ng/g, (Morford et al. 2001)]. Based on these results, our data may be biased low by 16%. However, the goal was to allow down-core and within core comparisons and was accomplished with a precision level of 20%, which was sufficiently precise to identify periods of the highest down-core authigenic enrichment.

Total phosphorus was determined by Columbia Analytical Laboratory following EPA Method 365.3M. This method converts all forms of phosphorus to orthophosphate, which reacts with molybdate and ascorbic acid to form a blue complex. The samples were quantified using a spectrometer. Accuracy was determined using certified standards (mean = 98%) and laboratory duplicates yielded a precision of 4% (Table 4).

Biogenic silica (BSi) concentrations in sediment provide a marker for the burial of siliceous organisms and in turn an indirect proxy for water column productivity. Silica may become the limiting nutrient for diatom growth during periods of eutrophication as increased sedimentation leads to a reduction in the regeneration of silica (Conley and Malone 1992; Dortch and Whitledge 1992; Conley et al. 1993). Methods for determining amorphous silica solubilize fossils of diatoms, phytoliths, radiolarians, silicoflagellates, and sponge spicules (Conley 1998). Estimates of BSi concentrations are most often used as an index of the amount of siliceous microfossils (primarily diatom) abundance in sediments (DeMaster 1981; Conley 1988). Sediment samples from three of the cores (HC-5, HC-3, and PS-1) were freeze dried and ground. Samples were prepared and analyzed according to Conley (1988), which was adapted from the method published by DeMaster (1981). Approximately 30 mg of each sample was leached with 1% Na_2CO_3 for 4 hours at 85°C. Aliquots were removed at 3, 4, 5, and 6 hours and analyzed for dissolved Si by ICP-OES. The dissolved Si concentrations were sufficiently high and did not significant change between the 4th, 5th, and 6th hours; therefore the weight percent of dissolved Si was directly converted to SiO_2. Two Chesapeake Bay samples used in the interlaboratory comparison for BSi published by Conley (1998) were obtained and analyzed with the core segments. The samples were identified as Still Pond sample (No. 1) and R-64 (No. 2) by Conley (1998). The published concentration for R-64 was closer to those anticipated for Puget Sound and included in all BSi preparation batches. Figure 12 plots the results obtained from each batch relative to the intercomparison range (Conley 1998). All data are provided in Appendix B including the results from the lower concentration reference material Still Pond sample with 91% accuracy relative to the published intercomparison value.

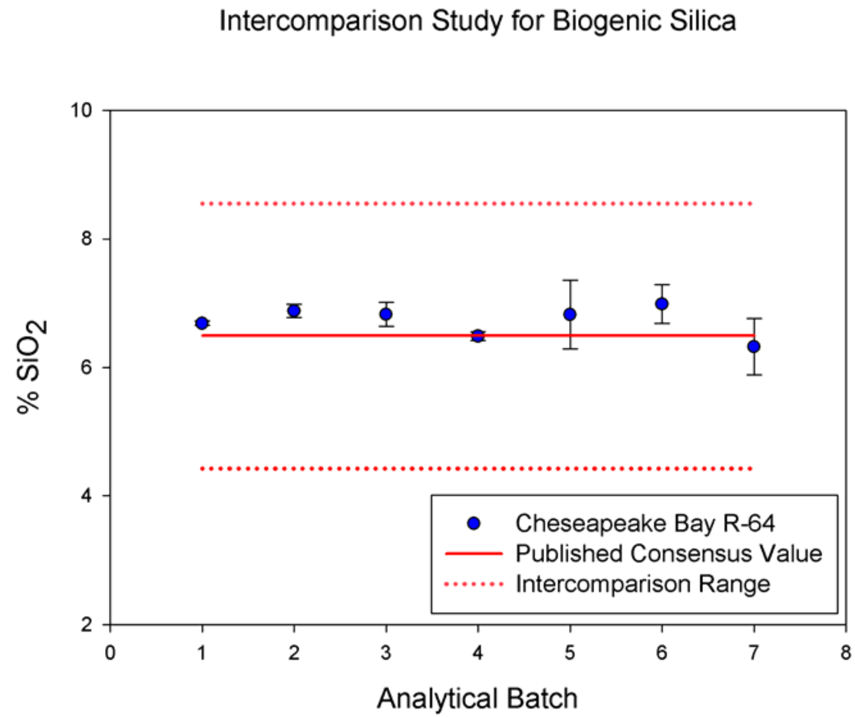


Figure 12. Measured biogenic silica (BSi) concentrations for each analytical batch prepared in this study compared to the interlaboratory comparison range for sample R-64 (Conley 1998).

2.5.2. Elemental and Stable Isotopic Analyses

Total carbon (TC) and nitrogen (TN) were determined on freeze-dried sediments by combustion using a Eurovector elemental analyzer. Another set of samples previously decarbonated with concentrated HCl were analyzed to estimate the organic carbon (OC) content. The instrument is calibrated with acetanilide, while a series of NIST SRMs (1944, 1941b, 1679) are used regularly (i.e. every 10 samples) as verification standards (Louchouarn et al. 2006). The mean analytical variability determined from replicate analyses of selected samples was ±2% for both OC and TN.

Carbonates were removed prior to OC determination and stable isotopic analyses by vapor-phase acidification with HCl for 24 hours followed by drying at 40ºC for 24 hours (Hedges and Stern 1984). The results are reported as $\delta^{13}C$ and $\delta^{15}N$ values relative to the Pee Dee Belemnite limestone standard (PDB) and air, in the usual parts per thousand (‰) notation as shown in Equation 4 where R = $^{13}C/^{12}C$ or $^{15}N/^{14}N$. Analytical reproducibility at 1σ of replicate measurements is ±0.1‰ and ±0.2‰ for $\delta^{13}C$ and $\delta^{15}N$, respectively. All data are available in Appendix C.

Equation 4. Ratios for carbon and nitrogen isotopes.

$$\delta^{13}C \, or \, \delta^{15}N = \left[\frac{R_{spl} - R_{std}}{R_{std}}\right] \times 1000$$

2.5.3. Organic Matter Biomarkers

Molecular analyses were performed according to the CuO oxidation method (Hedges and Ertel 1982; Goñi and Hedges 1992), with slight modifications (Louchouarn et al. 2006). Briefly, a sediment amount providing 2-4 mg C_{org} (Louchouarn et al. 2000a) is oxidized under alkaline conditions with CuO at 155ºC for 3 hrs in pressurized stainless steel mini-reaction vessels (3 mL; Prime Focus Inc.). The aqueous solution is then acidified with 6N HCl and extracted three times with ethyl acetate. Extracts are dried with Na_2SO_4 and then evaporated to dryness using a LabConco™ solvent concentrator. The CuO reaction products are re-dissolved in a small volume of pyridine (200-500 µL). After further dilution, a sub-sample is derivatized with bis trimethylsilyl trifluoroacetamide (BSTFA) containing 1% trimethylchlorosilane (TMCS). Separation and quantification of trimethylsilyl derivatives of CuO oxidation by-products were performed by gas chromatography-mass spectrometry on a Varian Ion Trap GC/MS system (3800/4000L) fitted with a fused capillary column (VF 5MS, 60 m x 0.25 mm inner diameter; Varian Inc.). Each sample was injected, under splitless injection mode, into a straight glass liner inserted into the GC injection port and helium was used as the carrier gas (~1.3 mL/min). The GC oven was temperature-programmed from 100°C, with no initial delay, to 300°C at 4°C/min and held constant at the upper temperature for 10 min. The GC injector and GC/MS interface were both maintained at 300°C. The mass spectrometer was operated in the electron impact mode (EI, 70 eV), in full scan mode. Compound identification was performed using column retention times and by comparing the full spectra of each sample to those produced by commercially available standards. Quantification was performed using relative response factors adjusted to trans-cinnamic acid (CiAd) as the internal standard. Replicate analyses of standard estuarine sediments (i.e., NIST SRM 1944; n=12) showed that the analytical precision of the major CuO-oxidation products and related parameters averaged ~5%. The yields and composition parameters produced in this study match those obtained with both microwave digestion (Goñi and Montgomery 2000; Houel et al. 2006) and with larger reaction vessels and conventional oven procedure (Louchouarn et al. 2000b). The average standard deviation obtained from replicate analyses of Puget Sound samples was in the same range (5-10%). All data are available in Appendix C.

2.5.4. Pollen Horizons

Homogenized aliquots from three Hood Canal cores (HC-3, HC-4, and HC-5) and three Puget Sound cores (PS-1, PS-2, and PS-3) were processed in the Pollen and Seed Laboratory at University of Washington by means of standard analysis procedures (Faegri and Iversen 1975; Doher 1980; Heusser 1985). Approximately 1-1.5 cc of sediment was found to provide sufficient counts for the microfossils. A total of 123 samples were treated with 10% cold HCl to remove carbonates, then heated in 10% KOH if the sediments contained organics. After these steps 60%

HF was added to remove silicates. Sieves with apertures of 10 µm were used to remove tiny inorganic clay particles then pollen residues were mounted with glycerin jelly.

For calculating pollen concentration and influx rate, a tablet of *Lycopodium* spores was added to every sample at the beginning of preparation as a spike in order to calculate absolute numbers of pollen grains per cc. All slides are stored at the Pollen and Seed Laboratory. Pollen was identified and counted with an Ernst Leitz GmbH Wetzlar microscope. Generally, no less than 400 grains and as many as 700 grains were counted and identified per sample. A few samples with low pollen concentrations yielded small counts, e.g. 250-400 grains. Non-pollen types including algae, fungi and foraminifera were qualitatively recorded but not included in percentage calculations.

The sum of the conifers, woody dicots, herbs, and ferns were used to determine total pollen rains and calculate the percent composition of each major pollen type. Percentages are based on the total pollen and fern spores. Fungal spores, algae and foraminifera are shown as numbers per 100 pollen grains and spores. All data are available in Appendix D.

2.5.5. Diatom Assemblages

Diatoms were extracted from wet sediment using a modification of the method published by Funkhauser and Evitt (1959), using H_2O_2, HCl, and size fractionation. Permanent slides were prepared from extracted diatom/silica material by diluting the original extraction material by 1/2500 or 1/1250 and using a measured volume (0.1 mL) of diatom residue mounted onto glass slides using Naphrax® mounting medium. At least 400 diatoms were identified for each sample counted. For statistical purposes, a minimum of 300 valves identified per sample is recommended (van Dam 1982). Identifications were done using light microscopy (Leitz DM RB with Nomarski optics at 1000X), according to available taxonomic references, including Hustedt (1927-1930), Hendey (1964), Krammer and Lange-Bertalot (1986-1991), Snoeijs (1993; Snoeijs and Vilbaste 1994; Snoeijs and Potapova 1995; Snoeijs and Kasperovîĉienė 1996; Snoeijs and Balashova 1998), Cooper (1995b), Tomas (1997), and Witkowski et al. (2000). Low resolution digital images of diatoms are archived for each sample.

The diatom counts were converted to relative abundances of each species present. Total number of species, number of genera, and planktonic:benthic diatom ratios are recorded for each sample. Diatom assemblage diversity was calculated for each sample using Shannon's H′ (Shannon and Weaver 1949). The number of valves per wet volume of sediment was also calculated for each sample analyzed. Centric diatoms are generally planktonic forms in estuarine waters, and pennate diatoms are generally benthic, including epiphytic forms. These data have been used to calculate the centric:pennate (c:p) ratio (Cooper 1995b). This ratio is somewhat less useful in Puget Sound and Hood Canal, as three dominant taxa in these cores do not fit these descriptions. *Paralia sulcata* (Ehrenberg) Cleve, present in over 5% abundance in several samples, is a centric marine to brackish diatom that is characterized as tychoplanktonic, epontic (Denys 1991/92), which means that it is often found in the plankton component, but originates as a benthic life form. For the planktonic:benthic ratio, this species is considered benthic. Additionally, *Thalassionema nitzschioides* Grunow, present in over 10% abundance in one sample, is a pennate, marine to brackish, euplanktonic form (Denys 1991/92). This species is considered planktonic, as are *Pseudo-nitzschia* species (Snoeijs and Balashova 1998). Both of these taxa were included in the ratio as planktonic species.

Principal components analysis (PCA) using CANOCO for Windows 4.5 (ter Braak and Šmilauer 2002) was performed on the diatom species data to summarize major trends. Detrended correspondence analysis (DCA) was used to provide a measure of the gradient length present within the assemblage data. A short gradient length (<2) suggests that a linear method of ordination such as PCA is suitable (McCure et al. 2002; ter Braak and Šmilauer 2002). Input for the CANOCO program included the percent abundance of diatom taxa that were present in at least 1% abundance in a sample. This reduced the diatom list from more than 440 taxa to 56 taxa. Scaling was focused on intersample distances and the species data were square-root transformed. The data were centered and standardized by species. This method approximates Euclidean distance between samples, similar to a cluster analysis. The PCA was also run separately with supplemental data, including Shannon's H' for each sample, the date assigned to each sample, total number of diatoms calculated per volume of sediment, and planktonic:benthic ratios for each sample. All data are available in Appendix E.

2.5.6. Description of Dominant Diatom Taxa

Achnanthes delicatula (Kützing) Grunow in Cleve & Grunow and ssp. *hauckiana* (Grunow) Lange-Bertalot &Ruppel 1980. References: Hustedt (1927-1930): fig. 834 and 836, Krammer & Lange-Bertalot (1986-1991):fig. 39/6-14 and 40/1-13), Snoeijs (1993): fig. 3, Cooper (1995b): figs. 34&51, and as *Planothidium delicatulum* & *Planothidium haukianum* in Witkowski et al. (2000) Pl. 46 & 48, figs. 28-29 & 1-2,18-30, and 39-41.

These *Achnanthes* taxa are grouped, including two subspecies of similar life-forms and distribution (see above). They are primarily epipsammic (found on sandy sediments) and epilithic (Snoeijs 1993), therefore categorized as benthic species. They are common taxa, found with world-wide distribution in marine and brackish-water coasts, but most often living in brackish water (Witkowski et al. 2000). These taxa are listed as mesohalobous, euryhaline, often found in eutrophic water with moderate preservation potential (Denys 1991/92). These taxa show a declining trend through time in HC-1 and possibly PS-4 (where no valves were seen in the surface sediments). Otherwise it is a fairly common taxa, with >1% abundance in 14 samples.

Chaetoceros Ehrenberg, species and spores - These extremely abundant valves and spores were found in the highest abundance (>10%) of any diatom taxon in all samples. This genus may well be the largest genus of marine and coastal plankton with approximately 400 species described (Tomas 1997). There were at least six species included in these counts. Specific identification was difficult due to poor preservation of whole valves and spores, but probably included *C. debilis* Cleve, *C. septentrionalis* Østrup, *C. diadema* (Ehrenberg) Gran, *C. affinis* Lauder, *C. danicus* Cleve and *C. holsaticus Schütt*. For the quantitative study these are grouped together since indistinctive specimens were most common. *Chaetoceros* species are all pelagic (planktonic) forms, found in marine and brackish waters. They are weakly silicified and dissolve quickly, so are not always found in sediment cores (hence the poor preservation of whole valves in these sediment cores). *Chaetoceros* was extremely abundant in the sediment core samples, and may be the most common genus in the phytoplankton of northern Pacific waters (Sancetta 1982). High concentrations of *Chaetoceros* spores may indicate high productivity and upwelling (Sancetta 1982). Surprisingly, these valves and spores are found in abundance in older samples, indicating relatively good silica preservation in these Puget Sound and Hood Canal sediment cores.

Cocconeis scutellum Ehrenberg - References: Hustedt (1927-1930):figs.790-792, Hendey (1964):fig. 27/8, Snoeijs (1993):fig. 25, Cooper (1995a): fig. 39, Witkowski et al. (2000): figs. 36/1-7 &38/11. *C. scutellum* is described as a cosmopolitan epiphyte of marine and brackish-water coasts (Witkowski et al. 2000). It is polyhalobous and euryhaline with moderate preservation and high oxygen requirement (Denys 1991/92). This species shows a trend of declining abundance in HC-1 over time (with no valves seen in the surface sediment sample) but otherwise appears to increase between ca. 1960-1990 in Puget Sound. *C. scutellum* lives firmly attached to seagrasses and algae, and is not strongly affected by grazers. It has been shown to respond positively to nutrient enrichment (Nicotri 1977; Hillebrand et al. 2000). It is found in >1% abundance in eight of the samples analyzed.

Nitzschia af. frustulum (Kützing) Grunow in Cleve & Grunow - References: Krammer & Lange-Bertalot (1986-1991) 1988:fig. 68/1-19, Snoeijs (1993): fig. 76, Cooper (1995a): fig. 54, and Witkowski et al. (2000): fig. 209/13-17. This taxa is one of several apparently independent species that are difficult to distinguish, so there may be more than one species represented. *N. frustulum* is a cosmopolitan brackish water species, listed as eiplithic (Snoeijs 1993), benthic, oligohalobous halophilous, with moderate preservation, and found in eutrophic waters with low oxygen requirement (Denys 1991/92). This species is found in all but one sample counted (>1% abundance in 11 samples), with apparent declines in HC-1 and PS-1.

Paralia sulcata (Ehrenberg) Cleve - References: Snoeijs and Vilbaste (1994):fig. 175, Cooper (1995a:fig. 12 & 53). Hendey (1964) describes this species as a “true bottom form”, while it is listed as tychoplanktonic epontic (attached) or benthic origin by Denys (1991/1992). This species is considered polyhalobous, mesoeuryhaline and marine to marine-brackish (Cooper 1995a). This species is common and widespread, but there is no precise information on its actual niche. In Chesapeake Bay sediments, this species was found to decline over time with eutrophication and increasing freshwater input and turbidity of the water column (Cooper 1995a). In Puget Sound and Hood Canal cores it is relatively abundant, showing >5% abundance in at least three samples. This species appears to show a declining trend through time with lowest abundance in the surface sediments of all four cores analyzed.

Pseudo-nitzschia H. Peragallo in H. & M. Peragallo - References: Hustedt (1955): fig. 6/1-2, Tomas (1997): fig. 70-73, Snoeijs and Balashova (1998): fig. 477-478. The genus *Pseudo-nitzschia* (*Ps-n*) is a widely distributed marine plankton genus (Tomas 1997), but has delicate valves and poor preservation (Parsons et al. 2002). No whole valves of this species were found, so counts were based on pieces (counted when >half of a valve, or enough pieces equal to one whole valve were seen). The species counted may include *P. australis* and *P. multiseries*. Several species of this genus are known to produce the neurotoxin, domoic acid, which is responsible for amnesic shellfish poisoning. Research has shown that *Ps-n* produces domoic acid when nitrogen is abundant but silica or phosphorus is limiting (Mann 2000). Other studies link Fe and nitrogen interactions with an increase in domoic acid production by *Ps-n* (Anderson et al. 2002). Trainer et al. (2002) found blooms of *Ps-n* and high domoic acid concentrations originating in the Juan de Fuca eddy in 1997-98. Ocean currents and large wind reversals brought high concentrations of toxic *Ps-n* in near-surface waters to the coast of Washington, resulting in toxification of razor clams. Recent studies also show evidence of increasing abundance of *Ps-n* with anthropogenic nutrient inputs to coastal waters in the past 50 years to the Gulf of Mexico and elsewhere (Parsons et al. 2002, Anderson et al. 2002). This genus is showing increased abundance in Puget Sound and Hood Canal sediment core samples through time, especially in the most recent sediments. *Ps-n* was found in all samples analyzed, with >1% abundance in 9 samples.

Rhizosolenia Brightwell, species including *R. hebetate* - References: Cooper (1995a:fig. 23), Snoeijs and Kaperoviĉienė (1996): fig. 389, Tomas (1997:fig. 26-30). Only isolated apical spines of *Rhizosolenia* were counted. Whole valves of the relatively long, planktonic, marine genus were not seen in the sediments of Puget Sound and Hood Canal. This was also true of sediment samples from Chesapeake Bay (Cooper 1995a). These taxa are listed as euplanktonic, polyhalobous and euryhaline, with moderate preservation potential (Denys 1991/92). Sancetta (1982) finds that *R. hebetata fo. semispina* is weakly silicified and not often preserved in sediments. Other forms are heavier. Valves of this genus are common and fairly abundant, with >5% abundance in 3 samples. *Rhizosolenia* spp. shows an increasing trend with time in the sediments of Puget Sound and Hood Canal. Whether this is due to poor preservation in older sediments, increasing abundance with upwelling and current or wind movement inshore, or increasing nutrient availability, is not known.

Skeletonema costatum (Greville) Cleve - References: Hustedt (1927-1930:Fig. 149), Hendey (1964:fig. 7/3), Snoeijs (1993:fig. 83), Cooper (1995a:fig. 5 & 47). This species and *Detonula confervaceae* (valves and resting spores) appear similar under the light microscope in valve view, and there may be some overlap in identifications. *Skeletonema costatum* is an abundant cosmopolitan pelagic diatom found throughout brackish and marine waters. It is often associated with coastal floras (Cooper 1995a). Denys (1991/1992) lists this species as tychoplanktonic epontic, marine to brackish, polyhalobous and pleioeuryhaline with moderate preservation potential. This species is very abundant in Chesapeake Bay and Long Island Sound on the east coast, as well as in these cores from Puget Sound and Hood Canal (>10% abundance in 20 samples). No clear trends through time were evident.

Thalassionema nitzschioides (Grunow) Hustedt - References: Hustedt (1927-30:fig. 725), Snoeijs and Vilbaste (1994): fig. 194, Cooper (1995a:fig. 36). *T. nitzschioides* is a cosmopolitan marine to marine-brackish euplanktonic diatom with moderate preservation potential (Sancetta 1982, Denys 1991/1992). In Puget Sound and Hood Canal core samples, it was observed to account for 2.5-10.7% of the diatoms counted. *T. nitzschioides* shows an increasing trend through time in Hood Canal cores, but the trends are less clear for Puget Sound cores. This diatom was also very abundant in Long Island Sound, the lower Chesapeake Bay and inner continental shelf of the east coast. It was also found to be common in more saline waters of the Baltic Sea (Snoeijs and Vilbaste 1994).

Thalassiosira decipiens (Grunow) Jørgensen - References: Hustedt (1927-30;fig. 158), Cooper (1995a:fig. 2). The taxonomic and morphologic literature on *T. decipiens* presents some interesting problems that have been discussed in Hasle (1979). This species is listed as planktonic marine to estuarine (Hustedt 1927-30), but it has alternatively been described as a littoral, epiphytic, probably benthic species in variable salinity. Denys (1991/1992) lists *T. decipiens* as tychoplanktonic, epontic, polyhalobous and euryhaline. (Marshall 1984) found this species in the lower Chesapeake Bay with greatest abundance on the continental shelf outside the mouth of the Bay. In Hood Canal and Puget Sound this diatom species shows an overall declining trend in the two Puget Sound cores analyzed, but variable abundance over time in HC cores. It is common, and present in >1% abundance in 18 samples. It is possible that this species should be listed with the benthic component of diatoms.

Thalassiosira guillardii Hasle - References: Snoeijs (1993:fig. 96), Tomas (1997:fig. 10/a-b and 11/d-f). *T. guillardii* is listed as a common pelagic species found in the Baltic Sea in waters of variable salinity (fresh to brackish) (Snoeijs 1993). Hasle (1978) lists this species as a brackish water species. Weckström (2005) found *T. guillardii* in high abundance in sediment cores collected at hypereutrophic urban sites in the Gulf of Finland, Baltic Sea. They were most abundant at the time of increasing urbanization (ca. 1915-1975). Weckström (2005) attributes the abundance of this weakly silicified *Thalassiosira* species to prolonged nutrient enrichment that caused silica limitation to other species. In Hood Canal and Puget Sound cores, this species was found from 0-3.5% abundance, with highest abundance in Puget Sound between ca. 1850-1980. HC-1 shows no evidence of *T. guillardii* in the one sample analyzed that was dated prior to 1800 whereas HC-5 shows >2% abundance in one sample dated ca. 1760.

Thalassiosira levanderi Van Goor - References: Sneoijs (1993:fig. 98). This small *Thalassiosira* species is very common in the Baltic Sea in variable salinity (Snoeijs 1993). Denys (1991/1992) lists this species as tychoplanktonic epontic, brackish, polyhalobous mesoeuryhaline (prefers brackish water) and eutrophic conditions. It is common in Puget Sound and Hood Canal with highest abundances between ca. 1900 to 2000. It was found with >5% abundance in six samples. Smaller valves of this species may be confused with *T. proschkinae*, another small *Thalassiosira* species that is known to bloom under high nutrient conditions. *T. proschkinae* was also identified in Puget Sound and Hood Canal cores. *T. proschkinae* has been used as an indicator of eutrophic conditions in other estuaries and coastal areas (Cooper et al. 2004).

Thalassiosira oestrupii (Ostenfeld) Hasle - References: Fryxell & Hasle (1980), Cooper (1995a:fig. 9), Snoeijs and Kaperoviĉienė (1996:fig. 397), Tomas (1997:plate 12). This *Thalassiosira* is considered to be a cosmopolitan marine species occasionally found in coastal areas (Fryxell & Hasle 1980). Denys (1991/1992) lists this species as euplanktonic, marine and polyhalobous (euryhaline). It was found in most samples of Puget Sound and Hood Canal, with >1% abundance in nine samples. It was also found to be common in Chesapeake Bay sediments.

2.5.7. Foraminifera Assemblages

Previous microfossil studies in Puget Sound are limited and many were primarily reconnaissance studies which provide little ecological information. The only geographically broad study was that of Cockbain (1963) which included the distribution of foraminifers in the Straits of Juan de Fuca and the Georgia Straits. Additional smaller published studies primarily from the Straits of Georgia include studies by Williams (1989), Patterson (1990), Blais-Stevens and Patterson (1998), and Patterson et al. (2000), although a few studies were based in the Washington portion of Puget Sound (Scott 1974; Jones and Ross 1979). Unpublished studies include the work of Robert Harman (personal communications, 2005-2006) and Smith (unpublished report on paleoceanographic survey of past bottom water oxygen conditions in Hood Canal, Washington).

For this study, 213 samples from all nine cores were examined for benthic foraminifers. Microfossil samples were taken from each of the cores at roughly 10 cm intervals. These samples were processed with water, washed on 250 and 400 µm screens, and dried at low temperatures (<40°C). Foraminiferal specimens were picked from the residues and identified. Slides are on file in the U.S. Geological Survey Micropaleontology Laboratory, Flagstaff, Arizona. Foraminiferal assemblages were analyzed to determine abundance, diversity, preservation, and the physical and chemical parameters of the environment in which they lived. Physical parameters considered were depth, temperature, down-slope transport and dissolution. Chemical parameters included salinity and dissolved oxygen. Both physical and chemical parameters are interpreted based on previous foraminiferal studies of climate and dissolved oxygen variability. All data are available in Appendix F.

2.5.8. Foraminifera Taxonomic Notes

Ammontium planissimum (Cushman) - - (Lankford and Phleger 1973) p.114, pl. 1, fig. 6.

Alveolophragmium columbiensis (Cushman) = *Alveolophragmium columbiense* (Cushman) - - (Uchio 1960) p. 52, pl.1, fig.22. = *Alveolophragmium columbiensis* (Cushman) - - (Lankford and Phleger 1973) p.114, pl. 1, fig. 8.

Astrononion incilis Lankford, 1973, *in* (Lankford and Phleger 1973) p. 115, pl. 3, fig. 11.

Bolivina pacifica Cushman and McCulloch - - (Walton 1955) p. 1002, pl. 102, fig. 4.; (Bandy 1961); (Phleger 1964) p. 382. = Brizalina pacifica; (Lankford and Phleger 1973) p. 115, pl. 4, fig. 7. Along the Eastern Pacific Margin, *Bolivina pacifica* is found in the outer neritic and upper bathyal biofacies associated with the shallow oxygen minimum zone (Bandy 1961; Phleger 1964; Smith 1964; Ingle 1980; Ingle and Keller 1980). Patterson et al. (2000) refer this species to *Bolivinellina pacifica* and consider it a typical dweller of dysoxic environments in the California Borderland.

Buccella frigida (Cushman) = *Eponides frigidus* (Cushman) - - (Bandy 1953) p. 177, pl. 23, fig. 5. = *Buccella frigida* (Cushman); (Blais-Stevens and Patterson 1998) p. 215, pl. 2, fig. 8. The upper depth limit of *Buccella frigida* is in the inner neritic biofacies (Ingle 1980).

Buccella frigida ranges from the Aleutian to the California provinces of Buzas and Culver (1990). *Buccella frigida* is indicative of normal, temperate marine conditions (Blais-Stevens and Patterson 1998).

Buliminella elegantissima d'Orbigny - - (Walton 1955) p. 1004, pl. 102, fig. 17; (Bandy 1961) p. 16; (Phleger 1964) p. 382; (Smith 1964) p. B33; (Lankford and Phleger 1973) p. 116, pl. 4, fig. 12; (Haller 1980) p. 244, pl. 6, figs. 12a-b. Along the Eastern Pacific Margin, the upper depth limit of *Buliminella elegantissima* is in the inner neritic biofacies (20 m, Smith 1964; Ingle 1980). In the Gulf of California, *Buliminella elegantissima* is a dominate species in the inner neritic biofacies at depths of 18-37 m (Walton 1955; Bandy 1961; Phleger 1964). It is also found in the Salton Sea (Culver and Buzas 1986).

Cibicides fletcheri -- (Galloway and Wissler 1927) p. 64, pl. 10, figs. 8-9; (Walton 1955) p. 1005, pl. 104, figs. 11, 12; (Bandy 1961) p. 15; (Lankford and Phleger 1973) p. 117, pl. 6, fig. 11. *Cibicides fletcheri* is a cosmopolitan species (Culver and Buzas 1986; Buzas and Culver 1990). Its upper depth limit is in the inner neritic biofacies along the Eastern Pacific Margin (Lankford and Phleger 1973; Ingle 1980).

Dyocibicides perforata -- (Cushman and Valentine 1930) p. 31, pl. 10, fig. 3. = *Dyocibicides* cf. *D. perforatus* Cushman and Valentine; (Lankford and Phleger 1973) p. 119, pl. 6, fig. 13-15. Along the East Pacific Margin, *D. perforatus* has an upper depth limit in the inner neritic biofacies (Lankford and Phleger 1973).

Eggerella advena (Cushman) - - (Lankford and Phleger 1973) p. 114, pl. 1, fig. 6. *Eggerella advena* tolerates slightly brackish water conditions and dominates the low-diversity assemblages in areas with sewage discharge along with *Trochammina pacifica* (Murray 1991; Alve 1995; Blais-Stevens and Patterson 1998). When waters become too brackish *Miliammina fusca* will dominate especially close to a freshwater source (Blais-Steven and Patterson 1998).

Elphidiella hannai (Cushman and Grant) = *Elphidium hannai* (Cushman and Grant 1927) p. 77, pl. 8, fig. 1. = *Elphidiella hannai* (Cushman and Grant); (Lankford and Phleger 1973) p. 119, pl. 3, fig. 26. Along the East Pacific Margin, *Elphidiella hannai* is common from Point Conception north (Culver and Buzas 1986). *Elphidiella hannai* migrated south during cooler periods and north during warmer periods of the late Neogene.

Elphidium clavatum Cushman - - (Loeblich and Tappan 1953) p. 98, pl.19, figs. 8-10; (Feyling-Hanssen et al. 1971) p. 273, pl. 11, figs. 10-13, pl. 20, figs. 5-8. *E. excavatum* forma *clavatum* most commonly occurs in high northern latitudes and colder climates (Feyling-Hanssen et al. 1971; Scott et al. 2001); it is also know to be extremely tolerant of dysoxia and even anoxia (Olsson 1975); it is common in coastal areas subject to pollution (Alve 1995; Filipsson and Nordberg 2004).

Elphidium frigidum Cushman - - (Loeblich and Tappan 1953) p. 99, pl. 18, figs. 4-9. = *Cribrononion frigidum* (Cushman) - - (Lankford and Phleger 1973) p.118, pl. 3, fig. 22.

Elphidium magellanicum Heron-Allen and Earland - - (Feyling-Hanssen et al. 1971) p. 279, pl. 12, figs. 15-16. *E. magellanicum* ranges from brackish to low salinity environments (Filipsson and Nordberg 2004).

Epistominella exiqua (Brady) = *Epistominella exiqua* (Brady 1884) p. 696, pl. 103, figs. 13-14. Upper depth limit varies but is usually near the shelf-slope break or ~150 m (Ingle 1980).

Fursenkoina seminuda (Natland) = *Virgulina seminuda* (Natland 1938) p. 145, pl. 5, fig. 12; (Walton 1955) p. 1017, pl. 102, fig. 19; (Bandy 1961) p. 17. = *Fursenkoina seminuda* (Natland) - - (Phleger 1964) p. 383; (Smith 1964) p. B34, pl. 2, fig. 9; (Lankford and Phleger 1973) p. 120, pl. 4, fig. 6. In the Gulf of California, living specimens of *Fursenkoina seminuda* are reported in the upper bathyal and upper middle bathyal biofacies between 200 and 800 m in Todos Santos Bay (Walton 1955) and in the upper bathyal fauna (366-610 m; Bandy 1961). Similar upper depth limits are reported in the Gulf of Mexico (Phleger and Parker 1951) and off Central America (Smith 1964).

Globocassidulina globosa (Hantken) = *Cassidulina globosa* Hantken (Phleger and Parker 1951) p. 27. pl. 14, figs. 11-13. Along the East Pacific Margin, the upper depth limit of *G. globosa* is in the outer shelf biofacies, 50-150 m (Ingle 1980).

Lagena elongata (Ehrenberg) - - (Martin 1952) p. 121, pl. 18, figs. 2a-b. *Lagena elongata* is found commonly in the California borderland and south (Culver and Buzas 1986).

Lagenammina atlantica (Cushman) - - (Lankford and Phleger 1973) p. 123, pl. 1, fig. 1.

Miliolinella oblonga (Montagu) - - (Lankford and Phleger 1973) p. 123, pl. 2, fig. 9.

Nonionella basispinata (Cushman and Moyer) - - (Bandy 1953) p. 177, pl. 21, fig. 9, 13; (Uchio 1960) p. 61, pl. 4, fig. 13,14. = *Florilus basispinatus* (Cushman and Moyer) - - (Lankford and Phleger 1973) p.119, pl. 3, fig. 15. *Nonionella basispinata* is a cosmopolitan species (Culver and Buzas 1986) which ranges from the Aluetian to the Panamanian provinces along the East Pacific margin (Buzas and Culver 1991). Its upper depth limit is in the inner neritic biofacies (Ingle 1980; Ingle and Keller 1980). *Nonionella basispinata* is a dominant species in the outer shelf assemblages of the nearshore basins of the California continental borderland (Douglas and Heitman 1979).

Nonionella stella Cushman and Moyer = *Nonionella miocenica* Cushman *stella* Cushman and Moyer - - (Walton 1955) p. 1010, pl. 101, figs. 13, 14 = *Nonionella stella* Cushman and Moyer (Bandy 1953) p. 177, pl. 22, fig. 2; (Uchio 1960) p. 61, pl. 4, fig. 15,16; (Bandy 1961) p. 16; (Phleger 1964) p. 383; (Lankford and Phleger 1973) p. 123, pl. 3, figs. 13,14. *Nonionella stella* is a cosmopolitan species (Culver and Buzas 1986; Buzas and Culver 1991). Its upper depth limit is in the inner neritic biofacies along the East Pacific Margin and Gulf of California (Walton 1955; Bandy 1961; Lankford and Phleger 1973; Ingle 1980; Ingle and Keller 1980). Ingle and Keller (1980) associate this species with the shallow oxygen minimum zone. This species thrives in most oxygen-depleted sediments of the Santa Barbara

Basin (Bernhard et al. 1997) but in Saanich Inlet, B.C. it occurs with less tolerant species suggesting other factors (Patterson and Kumar 2002).

Quinqueloculina akneriana d'Orbigny - - (Haller 1980) p. 231, pl. 2, fig. 8. The upper depth limit of Quinqueloculina akneriana is in the inner neritic biofacies (Ingle 1980).

Recurvoides turbinatus (Brady) - - (Loeblich and Tappan 1953) p. 27-28, pl. 2, fig.11.

Reophax scorpiurus Montfort - - (Phleger 1964) p. 383; (Lankford and Phleger 1973) p. 109, pl. 1, fig. 2. In the Gulf of California, *Reophax scorpiurus* has an upper depth limit in the inner neritic biofacies (Walton 1955).

Rosalina columbiensis (Cushman) - - (Uchio 1960) p. 66, pl. 8, fig. 1,2; (Lankford and Phleger 1973) p. 127, pl. 5, figs. 10-12; (Smith 1964), p. B44, pl. 5, fig. 2a-b. *Rosalina columbiensis* is a cosmopolitan species (Culver and Buzas 1986) which is dominant in the inner neritic biofacies (Ingle and Keller 1980) and in the bank assemblages of the offshore basins of the California continental borderland (Douglas and Heitman 1979). Off Central America the upper depth limit of *R. columbiensis* is near the inner neritic/outer neritic biofacies boundary (50 m; Smith 1964; Lankford and Phleger 1973).

Stainforthia feylingi -- (Knudsen and Seidenkrantz 1994) p. 5-7, pl. 1, figs. 1-32; pl. 2, figs. 1-6, 8; (Blais-Stevens and Patterson 1998) p. 217, pl. 2, fig. 19. *S. feylingi* can persist under dysoxic conditions (0.1-0.3 mL/L [4.4-13.3 μM](Patterson et al. 2000; Patterson and Kumar 2002). This species normally occurs in arctic to boreal environments (Knudsen and Seidenkrantz 1994). *Stainforthia feylingi* indicates deep water and probably low oxygen conditions (Blais-Stevens and Patterson 1998).

Stainforthia fusiformis (Williamson) (Scott and Vilks 1991) p. 30, pl. 4, fig, 11.

Spiroplectammina biformis (Parker and Jones) (Lankford and Phleger 1973) p. 128, pl.1, fig. 11.

Trifarina angulosa (Williamson) = *Angulogerina angulosa* (Williamson) - - (Bandy 1953) p. 176, pl. 25, fig. 13; (Bandy 1961) p. 16 = *Trifarina angulosa* (Williamson) (Lankford and Phleger 1973) p. 129, pl. 3, figs. 29, 30. *Trifarina angulosa* is a cosmopolitan species (Buzas and Culver 1990). Its upper depth limit is transitional between the outer neritic and upper bathyal biofacies along the East Pacific Margin (Ingle 1980).

Trochammina charlottensis Cushman - - (Uchio 1960) p. 58, pl. 3, fig. 13,14; (Lankford and Phleger 1973) p. 130, pl. 3, fig. 3,4.

Trochammina inflata (Montagu) - - (Phleger 1960) pl. 5, p. 20, 21, pl.8, fig. 28a. Upper depth limit in the inner neritic biofacies (0-50 m). This species is also common in closed inlets at depths up to 21 m, temperatures of 12.9-17.5° C, brackish environment and a muddy substrate (Annin 2001).

Trochammina kellettae Thalmann - - (Uchio 1960) p. 58-59, pl. 3, fig.20-21; (Lankford and Phleger 1973) p. 130, pl. 3, fig. 5.

Trochammina pacifica Cushman - - (Uchio 1960) p. 59, pl. 3, fig. 26, 27.

Uvigerina hispida Schwager - - (Martin 1952) p. 136, pl. 25, figs. 1a-b; (Bandy 1953) p. 177; (Haller 1980) p. 249, pl. 8, fig. 1; (Boersma 1984) p. 74-76, figs. 1-4. Along the East Pacific margin, the upper depth limit of *Uvigerina hispida* is in the upper middle bathyal biofacies, although it is most frequently associated with the lower middle bathyal biofacies (Ingle 1980; Ingle and Keller 1980). *Uvigerina hispida* is typical of intermediate to deep water sites in areas of high surface productivity and very little detrital sedimentary input (Boersma 1984).

Uvigerina peregrina Cushman - - (Phleger and Parker 1951) p. 18, pl. 8, figs. 22, 24-26; (Bandy 1953) p. 177, pl. 25, fig. 10; (Walton 1955) p. 1016, pl. 102, figs. 22; (Bandy 1961) p. 17, pl. 4, fig. 3; (Haller 1980) p. 250. The upper depth limit of *Uvigerina peregrina* is given as in the upper bathyal biofacies (Ingle 1980). The upper depth limit of this species has, however, been noted at a variety of depths along the East Pacific Margin (Smith 1964; Ingle and Keller 1980). The abundance of *Uvigerina* is usually related to low oxygen and high organic carbon (Streeter and Shackleton 1979; Douglas 1981; Miller and Lohmann 1982). In the California borderland, abundant *Uvigerina peregrina curticosta* are found in environments with low oxygen values (< 1.0 mL/L, not dysaerobic) and sediments rich in organic matter (Douglas 1981). *Uvigerina peregrina* and variants are most abundant during the Pleistocene glacials and tend to disappear during the interglacials which are associated with lower surface productivity decreased carbonate sedimentation and increased oxygen (Boersma 1984).

Uvigerina peregrina dirupta Todd - - (Bandy 1961) p. 17, pl. 5, fig. 8. Along the East Pacific margin, the upper depth limit of *U. peregrina dirupta* is in the upper middle bathyal biofacies (Ingle 1980) associated with the cool, high salinity oxygen-rich North Pacific Intermediate Water or the Antarctic Intermediate Water masses (Ingle and Keller 1980).

2.6. Project Management: Individuals and Organizations

The strength of this project was the combined resources of multiple scientists with expertise in a specific field that collectively created the historical reconstructions of multiple tracers of biological, geological, and chemical conditions both within the water column and the surrounding watershed. The roles and responsibilities within the team for specific paleo-indicators are listed in Table 5.

Table 5. List of tasks and analyses used to generate the reconstructions and the scientists and laboratories conducting the analyses.

Tasks/Analyses	Individual and Organization
Project Coordination	Jill Brandenberger, M.S., Senior Research Scientist, Pacific Northwest National Marine Science Laboratory, operated by Battelle Memorial Institute, Sequim, WA
Core Collection and Sediment Properties	Dr. Eric Crecelius, Laboratory Fellow & Jill Brandenberger, M.S., Senior Research Scientist Pacific Northwest National Marine Science Laboratory, operated by Battelle Memorial Institute, Sequim, WA
Sedimentation rates and Radioisotopes	Dr. Eric Crecelius, Laboratory Fellow & Jill Brandenberger, M.S., Senior Research Scientist Pacific Northwest National Marine Science Laboratory, operated by Battelle Memorial Institute, Sequim, WA
Redox Sensitive Metals	Dr. Eric Crecelius, Laboratory Fellow & Jill Brandenberger, M.S., Senior Research Scientist Pacific Northwest National Marine Science Laboratory, operated by Battelle Memorial Institute, Sequim, WA
Priority Pollutant Metals	Dr. Eric Crecelius, Laboratory Fellow & Jill Brandenberger, M.S., Senior Research Scientist Pacific Northwest National Marine Science Laboratory, operated by Battelle Memorial Institute, Sequim, WA
Biogenic Silica (BSi)	Dr. Eric Crecelius, Laboratory Fellow & Jill Brandenberger, M.S., Senior Research Scientist Pacific Northwest National Marine Science Laboratory, operated by Battelle Memorial Institute, Sequim, WA
Elemental C, N & Isotopic $\delta^{13}C$, $\delta^{15}N$	Dr. Patrick Louchouarn, Associate Professor Texas A&M University, Department of Marine Sciences/Oceanography, Laboratory for Oceanographic and Environmental Research, Galveston, TX
Organic Biomarkers	Dr. Patrick Louchouarn, Associate Professor Texas A&M University, Department of Marine Sciences/Oceanography, Laboratory for Oceanographic and Environmental Research, Galveston, TX
Diatom Microfossils	Dr. Sherri Cooper, Associate Professor Bryn Athyn College, Department of Biology, Bryn Athyn, PA
Foraminiferal Microfossils	Dr. Kristin McDougall, Research Scientist Western Region, Earth Surface Processes Team United States Geological Survey, Flagstaff, AR
Pollen Rain	Dr. Estella Leopold, Professor Emeritus University of Washington, Department of Biology, Seattle, WA Dr. Gengwu Liu, Academia Sinica Nanjing Institute of Geology and Paleontology, Nanjing, P.R. China

The sediment cores were collected by Battelle scientists and students from aboard a University of Washington vessel. The collection methods were discussed in section 2.3. Sample analyses conducted by each member of the team of scientist are listed in Table 5 and methods are discussed in Sections 2.3 through 2.5. Tasks conducted by the Marine Science Laboratory were carried out in the radioisotope laboratory and trace metal laboratories with assistance from the following key scientists: Nikki Sather, M.S.; Gary Gill, Ph.D.; Brenda Lasorsa, M.S.; Key-Young Choe, Ph.D.; Jordana Wood, M.S., and Linda Bingler, M.S. Splits of the core samples were sent to the other laboratories listed in Table 5. The elemental analyses (C and N) and organic biomarkers were quantified in Dr. Patrick Louchouarn's lab at Texas A&M University with assistance from Mr. Ron Lehman. Samples for isotope analyses were prepared for analysis in Dr. Louchouarn's laboratory and quantification was performed, for services, by the University of California, Davis Stable Isotope Facility (http://stableisotopefacility.ucdavis.edu/). The sample preparation and analyses for diatom microfossils were conducted by Dr. Sherri Cooper in her laboratory at Bryn Athyn College. Ms. Martha Hyatt Odhner and Ms. Annika Fitzpatrick assisted with diatom extraction and slide preparation tasks. The sample preparations and analyses for foraminifera microfossils were conducted by Dr. Kristen McDougall in her laboratory at the U.S. Geological Survey. Samples for pollen analyses were sent to Dr. Estella Leopold at the University of Washington. Preparations were conducted by and Alecia Spooner and Gary Yetter and analyses by senior post-doctoral student Dr. Gengwu Liu.

3.0 Findings

Historical reconstruction must define the period of history they cover, as discussions can range from geologic time-scales (1000s of years), to human settlement (100s of years), to environmental program scales (10s of years). Large-scale climatic alterations are clearly defined on the geologic time-scale within sediment cores collected in Saanich Inlet, British Columbia (Pacific Northwest fjord) recording shifts from anoxic conditions throughout most of the Holocene to generally more oxic conditions during the late Pleistocene (Morford et al. 2001). The following sections discuss the results of the paleo-reconstructions in Puget Sound on the time-scale of human settlement and more specifically western migration and urbanization in the Pacific Northwest beginning in the late 1800s.

3.1. Redox Sensitive Metals

Sedimentary redox reactions drive the authigenic enrichment of Mo, U, and Re in a chromatographic-type pattern as a function of each metal's reduction potential. This, in turn, results in the enrichment of these metals and their usage as indicators of the intensity of past reducing environments (Calvert and Pedersen 1993; Crusius et al. 1996). The interpretation of individual RSM sediment profiles and the coupling of multiple RSM to infer past geochemical conditions are complicated by many factors; therefore, the current understanding of their geochemical behaviors and limitations are provided.

3.1.1. Geochemistry

Manganese is a non-conservative metal in the water column nor effectively preserved in the sediment; therefore, Mn has limited use as a paleo-redox tracer (Calvert and Pedersen 1993). However, the geochemical cycling of Mn potentially entrains other metals adsorbed onto the oxyhyroxides [Pb, Mo, V, Co, and Cr; e.g. (Paulson et al. 1988; Viollier et al. 1995; Brandenberger et al. 2004; Morford et al. 2007)]. In oxic marine systems, Mn is present as oxyhyroxides with Mn enrichment recorded in the surface sediment down to the redox boundary. Below this boundary, the reduction of oxyhyroxides releases Mn (II) into pore waters, which subsequently diffuses upward to the depth of oxygen penetration or into overlying waters resulting in depletion from anoxic sediment. A subsurface peak in Mn results from oxygen penetration from overlying waters and diffusion into reduced pore waters containing Mn (II) which is then re-oxidized (Calvert and Pedersen 1993). The only known mechanism for potential preservation of Mn in anoxic sediment with sulfide rich pore waters is coprecipitation with FeS (Emerson et al. 1983).

In contrast, Mo, U, Re, V, and Cr are present as stable oxyanions in oxic waters (Emerson and Huested 1991; Colodner et al. 1993). Thus changes in their authigenic concentrations in sediments are due to variations in the effectiveness of removal processes, primarily related to the redox states at or near the sediment-water interface (e.g. Tribovillard et al. (2006) and references therein). Marine sedimentary respiration involves a series of oxidants generally consumed in the order of oxygen, nitrate and Mn, then Fe and sulfate [see Brandes and Devol (1995) for Puget Sound and references therein]. Porewater profiles collected in northern Puget Sound indicate the depth of oxygen and nitrate penetration is generally < 1cm (Brandes and Devol 1995). Therefore, the depth of this redox boundary and the authigenic enrichment of these metals may be related to the oxygen concentrations of the bottom waters with highly enriched sediment found underlying anoxic bottom waters [e.g. (Colodner 1991; Emerson and Huested 1991; Calvert and Pedersen 1993; Colodner et al. 1993; Piper and Isaacs 1995; Crusius et al. 1996; Morford and Emerson 1999; Adelson et al. 2001; Morford et al. 2001; Pailler et al. 2002; Sundby et al. 2004; McKay et al. 2007; Morford et al. 2007)]. Tracing redox conditions requires that authigenic enrichment is sufficiently elevated relative to detrital concentrations, which is true for Mo, U, and particularly Re with detrital concentrations in sub ng/g (parts-per trillion). This is not the case for V and Cr, which have high detrital concentrations (Emerson and Huested 1991; Colodner et al. 1993) and thus not effective in estuarine systems with high detrital fluxes.

Molybdenum, U, and Re have slightly different reduction potentials allowing U and Re to be enriched in sediments under mildly reducing conditions (suboxic in the water column) where the redox boundary penetrates a few centimeters into the sediments (Klinkhammer and Palmer 1991; Rosenthal et al. 1995a; 1995b; Crusius et al. 1996; Morford et al. 2001). Uranium is reduced at approximately the same depth as Fe (Klinkhammer and Palmer 1991) followed by Re and then Mo with strongly reducing conditions (Crusius et al. 1996).

The sedimentary enrichment of Re appears to be independent of sulfide formation (Colodner et al. 1993) with values of ~5-130 ng/g in anoxic sediment relative to < 0.1 ng/g in oxic sediments (Koide et al. 1986; Ravizza et al. 1991). The enrichment of Re is not associated with Fe and/or Mn cycling (Colodner et al. 1993; Crusius et al. 1996; Morford et al. 2007) and Morford et al. (2007) found no evidence of Re release to pore waters by diagenesis of solid phases. These geochemical properties make Re an ideal tracer for mildly reducing conditions compared to the highly reducing conditions required by Mo (Morford et al. 2005a).

Unlike Re and U, authigenic Mo is not enriched under mildly reducing conditions except when scavenged by Mn (Crusius et al. 1996; Morford and Emerson 1999) and Fe oxyhydroxides (Morford et al. 2007). Therefore, evaluating Re and Mo authigenic enrichment factors could distinguish between suboxic and anoxic conditions in the water column. In Saanich Inlet, an anoxic fjord located on Vancouver Island in the Georgia Basin/ Puget Sound region, Mo was shown to be associated with Mn oxyhydroxides in more ventilated regions (Berrang and Grill 1974). The mildly reduced sediment were near detrital values for Mo [~0.6 µg/g (Morford et al. 2001)], while sediment supported by an anoxic water column were highly enriched [~90 µg/g Mo (Russell and Morford 2001)]. Molybdenum precipitation is not generally related to MoS_2, except when the diffusion of molybdate (MoO_4^{-2}) from the overlying water is converted to a thiomolybdate (MoS_4^{-2}) in the presence of > 11 µM H_2S (Helz et al. 1996; Erickson and Helz 2000). Although in some basins Mo has limited use due to the "basin reservoir effect", where Mo removal exceeded resupply rates in basin's with significant sill restrictions (Algeo and Maynard 2004), this is not the case for Puget Sound or Hood Canal.

Cadmium, Zn, and Cu are unique from other "redox sensitive metals" in that they have a nutrient-type distributions in the open ocean and are delivered to the sediment by biological debris in estuarine ecosystems (Bruland et al. 1991; Tribovillard et al. 2006). The mechanism for enrichment in estuaries occurs when they are released to pore waters during organic matter diagenesis (Gobeil et al. 1997) and then immobilized by the formation of insoluble metal sulfides under anoxic conditions (Emerson et al. 1983; Huerta-Díaz and Morse 1992; Morse et al. 1992; Rosenthal et al. 1995a; 1995b; Gobeil et al. 1997; Tribovillard et al. 2006). However, the use of Zn, and Cu as paleo-tracers is limited in estuarine systems receiving significant anthropogenic loads through storm water, industrial/municipal wastewater, and atmospheric deposition, such as Puget Sound (Brandenberger et al. 2007; 2008). The sediment cores from this study illustrate this relationship of increasing Cu and Zn during the 20^{th} Century due to anthropogenic activities, but Cd concentrations actually decrease during this time period (Figure 13). This suggests that sedimentary Cd concentration were not significantly altered by anthropogenic activities and may be useful as a paleo-indicator.

The reducing potential for authigenic Cd formation occurs after U and appears to require nanomolar levels of H_2S (Rosenthal et al. 1995b). Therefore, Cd, similar to Re and U, maybe enriched in sediment supported by mildly reducing (suboxic) waters where the redox boundary occurs within the upper few centimeters of the sediment. The relationship between productivity, bottom-water oxygen concentrations, and Cd enrichment are contentiously discussed within the literature [see (Rosenthal et al. 1995a) and references therein].

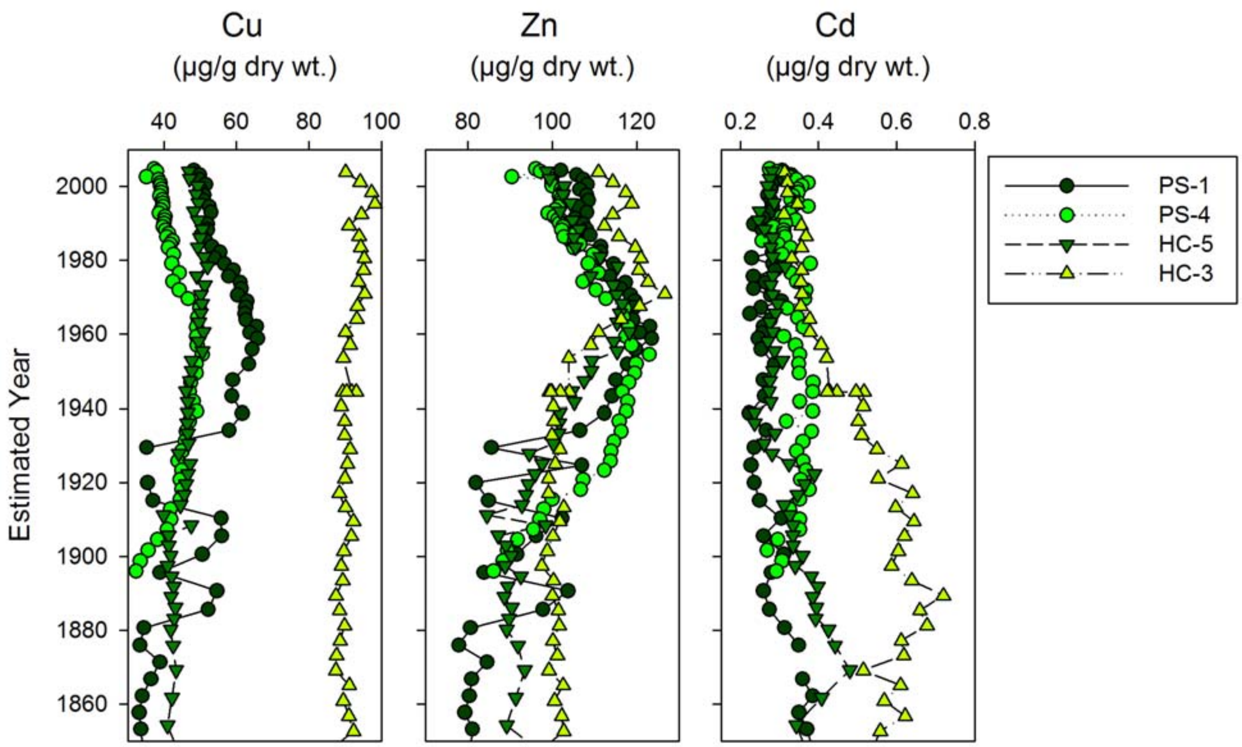


Figure 13. Core profiles for Cu, Zn, and Cd (µg/g dry wt.) show increasing Cu and Zn during the 20th Century, but decreasing Cd concentrations beginning around the mid-1900s.

Comparative analysis of multiple RSM indicators provides a tool to better reduce the uncertainty surrounding post-depositional oxidation and redistribution. For example, Rosenthal et al. (1995a; 1995b) suggest the $(Cd/U)_{authigenic}$ ratio could be evaluated to determine redistribution of one of the metals as they are strongly coupled under steady-state conditions and not likely to vary. Crusius et al. (1996) proposed that Re (ppb)/Mo (ppm) ratios greater than 0.77 (seawater ratio) were likely deposited beneath oxygenated waters with minimal penetration into the sediment, whereas ratios ≤ 0.77 resulted from deposition under anoxic bottom waters. Therefore, the enrichment of each of these RSM in the same core segment supports discussions on the redox-state during relative depositional times within the resolution of the coring method.

3.1.2. RSM Concentrations and Ratios

The down-core concentrations of Al, Ti, and Fe changed very little with the CVs $\leq 5\%$ (see Appendix B). Metal to Al ratios were calculated (Appendix B) to normalize the data relative to detrital metal concentrations (Brown et al. 2000). This adjusts for variations in sediment grain size allowing for a comparisons between different depositional environments. Metal concentrations in sediments are typically normalized with respect to Al because it is an abundant crustal element associated with detrital minerals (primarily aluminosilicates) and minimally affected by diagenesis (Calvert and Pedersen 1993; Morford and Emerson 1999). Tribovillard et al. (2006) summarized potential errors associated with Al normalization including a large variability for Al compared to the RSM metals. This particular caveat, however, was not observed in this study.

The Ti/Al ratio may be used as an indicator of bulk grain size (Spears and Kanaris-Sotiriou 1976) or shifts in detrital sources (Turekian and Wedepohl 1961). Figure 13 provides a comparison of Ti/Al among cores and indicates Puget Sound and the northern Hood Canal core (HC-5) fall closer to the ratios for global average shale (Turekian and Wedepohl 1961) than the mean detrital ratios for Cowichan River suspended sediment (Russell and Morford 2001). Cowichan River is located on Vancouver Island and was used for evaluating detrital metal concentrations in Saanich Inlet, British Columbia. Vancouver Island is across the Strait's of Juan de Fuca from the Olympic and Kitsap Peninsulas surrounding Hood Canal and is similar in geologic composition. This provides a regional detrital metal concentration, which may be more representative of the study area than global average shale.

The Ti/Al ratios at HC-1 indicate coarser grain size (also noted in the porosity and % moisture) and this core was not used for further RSM discussion. Although the Ti/Al values at HC-3 and HC-4 are greater than the shale ratios, the sediments are primarily silt/clay and the higher Ti/Al ratios are not related to a grain size effect. The southern Hood Canal cores have a slightly different sediment chemistry than the northern most core (HC-5), which typically falls closer to the central Puget Sound cores in metal composition.

The overall concentrations of Fe (HC: 4.1-6.8%; PS: 3.4-4.1%) vary spatially while the Mn concentrations (HC: 564-6174 µg/g; PS: 460-656 µg/g) vary both spatially and down-core. The Fe/Al and Mn/Al profiles for HC-5 and both Puget Sound cores fall closer to global shale ratios, while the southern most Hood Canal cores are comparatively more enriched in Fe and Mn and trend closer to the Cowichan River ratios (Figure 14). This gradient is consistent with the water column data published by Paulson et al. (1993) which demonstrated a gradient in dissolved Fe and Mn within Hood Canal. The highest values are recorded in the waters of Lynch Cove and decrease seaward. This suggests that the relatively oxygen-depleted bottom waters of Lynch Cove transport soluble-reduced Mn and Fe out to The Great Bend region until they encounter more oxygenated waters resulting in precipitation of the oxyhydroxides leading to a sedimentary gradient in Mn and Fe concentrations.

The upper few cm of HC-3,-4, and -5 contain elevated concentrations of Mn suggesting the redox boundary penetrates down to 24, <10, and 4 cm, respectively. Not all segments of HC-4 were analyzed, so a definitive depth could not be determined. Similar patterns, but with overall lower concentrations are recorded in PS-4 and PS-1 with the redox boundary occurring at around 14 and 10 cm, respectively. Combining the redox boundary depth with the mixed depth estimated from the radioisotopes (Table 3), provides the limits of resolution for each core, also briefly discussed in Section 2.4. As annual laminations are not preserved, the data will be further discussed within the determined resolution of ~ 20 years in Hood Canal and 5-10 years in Puget Sound.

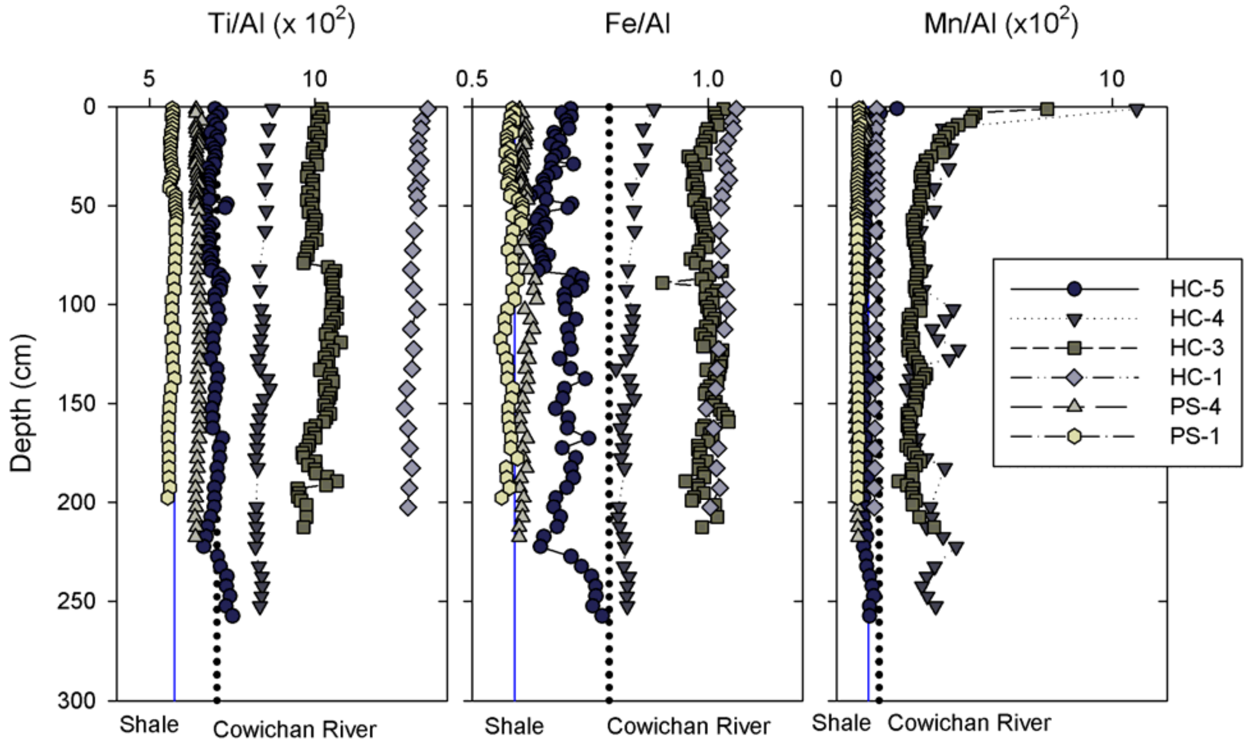


Figure 14. Core profiles for Ti/Al, Fe/Al, and Mn/Al for Hood Canal (HC-5, HC-4, HC-3, HC-1) and Puget Sound (PS-4 and PS-1) sediment cores collected in 2005. The blue lines represent world average shale ratios (Turekian and Wedepohl 1961) and black dotted lines Cowichan River ratios (Russell and Morford 2001).

The concentrations of Pb, As, Ni, V, Cr, Cu, Ba, Be, Zn, Ca, Mg, and P were determined along with the RSM metals. The data are summarized in Appendix B, but not generally discussed below as the high detrital fractions (Cr, V, Ba) or potential anthropogenic sources (Cu, Ni, Pb, Zn) hindered the ability to use them for paleo-reconstructions. The Pb, As, and Cu reconstructions are reported for Puget Sound cores by Brandenberger et al. (2008) and used within this report for independent time-constrained markers to bracket the estimated ages (see section 3.6).

In Hood Canal, concentrations of Mo (0.837-18.1 µg/g), U (1.40-5.02 µg/g), Re (2.00-20.3 ng/g), and Cd (0.236-0.756 µg/g) were spatially variable and in some cases highly variable down-core (HC-3). The down-core CVs ranged from 17-64% for the various metals and cores (Appendix B). The concentrations of Mo, U, Re, and Cd with 1σ error bars versus core depth (cm) are plotted for Hood Canal cores HC-5, HC-4, and HC-3 (Figure 15). The vertical dashed lines represent the mean concentrations within each core, with RSM concentrations generally higher in southern Hood Canal cores, note the scale changes. Each core segment was analyzed for HC-5 and HC-3 to provide detailed reconstructions. Selected segments of HC-4 were analyzed to evaluate periods of interest in the detailed profiles. Again, there is a gradient within Hood Canal with the highest RSM concentrations recorded at HC-3 and decreased seaward.

The pronounced black band in HC-5 is contained within four core segments from 210-230 cm and corresponds with concentrations greater than the average for all RSM metals. In addition, HC-3 contains peaks at ~ 75, 93, and 170-174 cm. Although the analytical precision of Re somewhat hinders the interpretation, the periods of high Re concentrations are separated from the overall core mean by at least 1σ and the patterns are supported by other RSM profiles.

In Puget Sound, concentrations of Mo (0.994-3.73 μg/g), U (1.63-3.22 μg/g), Re (1.76-7.34 μg/g), and Cd (0.222-0.397 μg/g) showed some spatial variability with PS-1 generally higher than PS-4, as well as, down-core variability recorded only in PS-1. The down-core CVs were generally half of those reported for Hood Canal with ranges of 7-30% (Appendix B). Again, all core segments were analyzed in PS-4 and PS-1 to facilitate a detailed reconstruction. The concentrations of Mo, U, Re, and Cd with 1σ error bars versus core depth (cm) are plotted in Figure 16.

To interpret the authigenic metal concentrations between cores in the same basin and across basins, the data must be normalized with respect to two factors. The first is estimated age of deposition, as the sediment accumulation rates differ between both the basins and the cores. The second is detrital metal concentrations. The authigenic fraction was determined as the metal to Al ratio and plotted against estimated age for Hood Canal (Figure 17) and Puget Sound (Figure 18). The ratios are displayed relative to global average shale ratios (Turekian and Wedepohl 1961) and the mean Cowichan River ratios (Russell and Morford 2001). The normalized profiles have similar patterns to the concentration profiles indicating normalizing does not result in significant changes to the profiles and potentially anomalous correlations.

The three most striking features of these cores are 1) the overall higher RSM/Al ratios (and concentrations) in Hood Canal compared to Puget Sound, 2) the relatively lower ratios in the 1900s with respect to earlier times, and 3) the general cyclic pattern, through time, for the RSM in Hood Canal. Before a more detailed interpretation of the RSM patterns can occur, their behavior during diagenesis, reoxidation, and long-term burial must be considered.

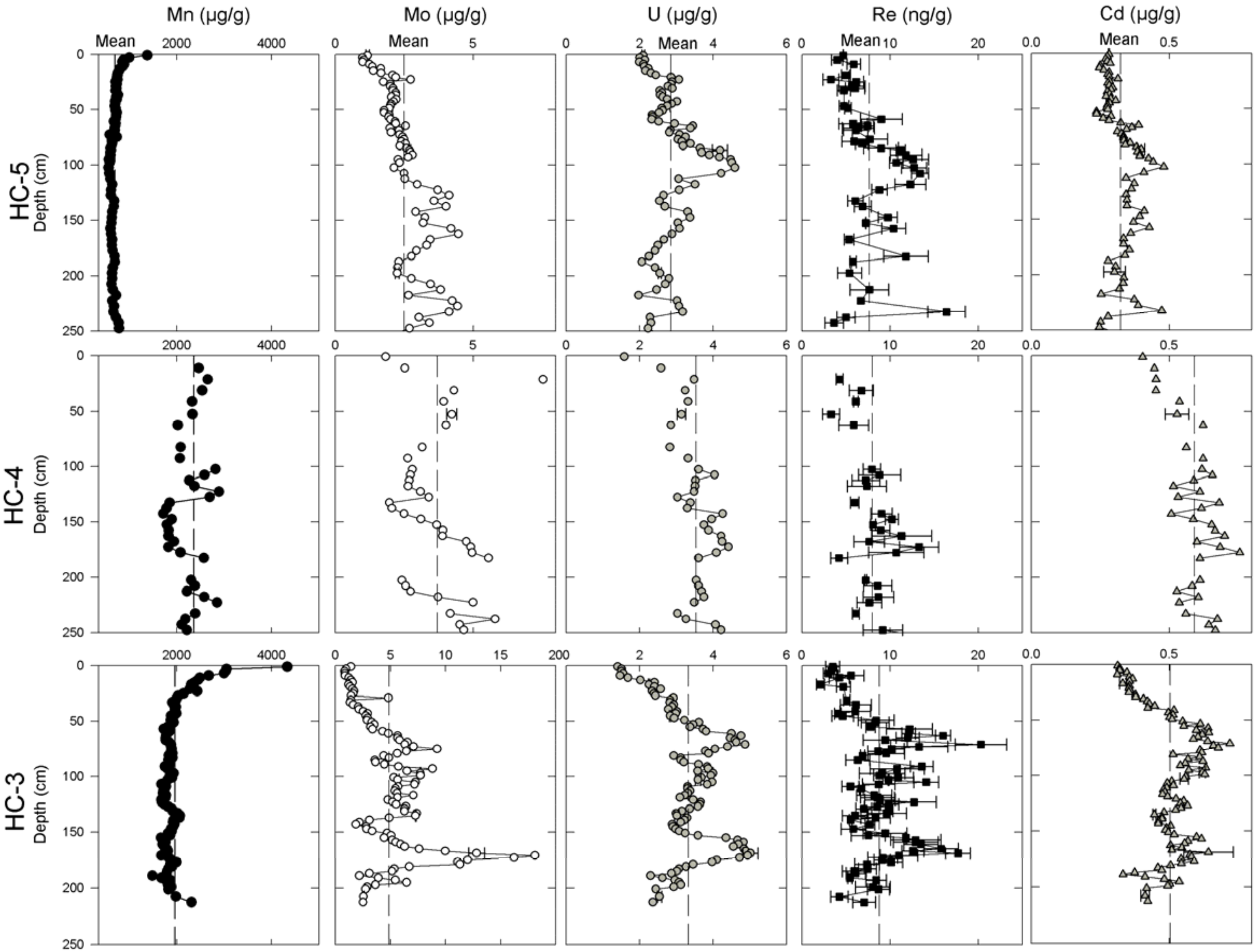


Figure 15. Concentrations for Mn, Mo, U, Cd in µg/g and Re in ng/g for Hood Canal cores HC-5 (top panel), HC-4 (middle), and HC-3 (bottom) plotted against core depth (cm). Dashed vertical lines represent the core mean and error bars are at 1σ.

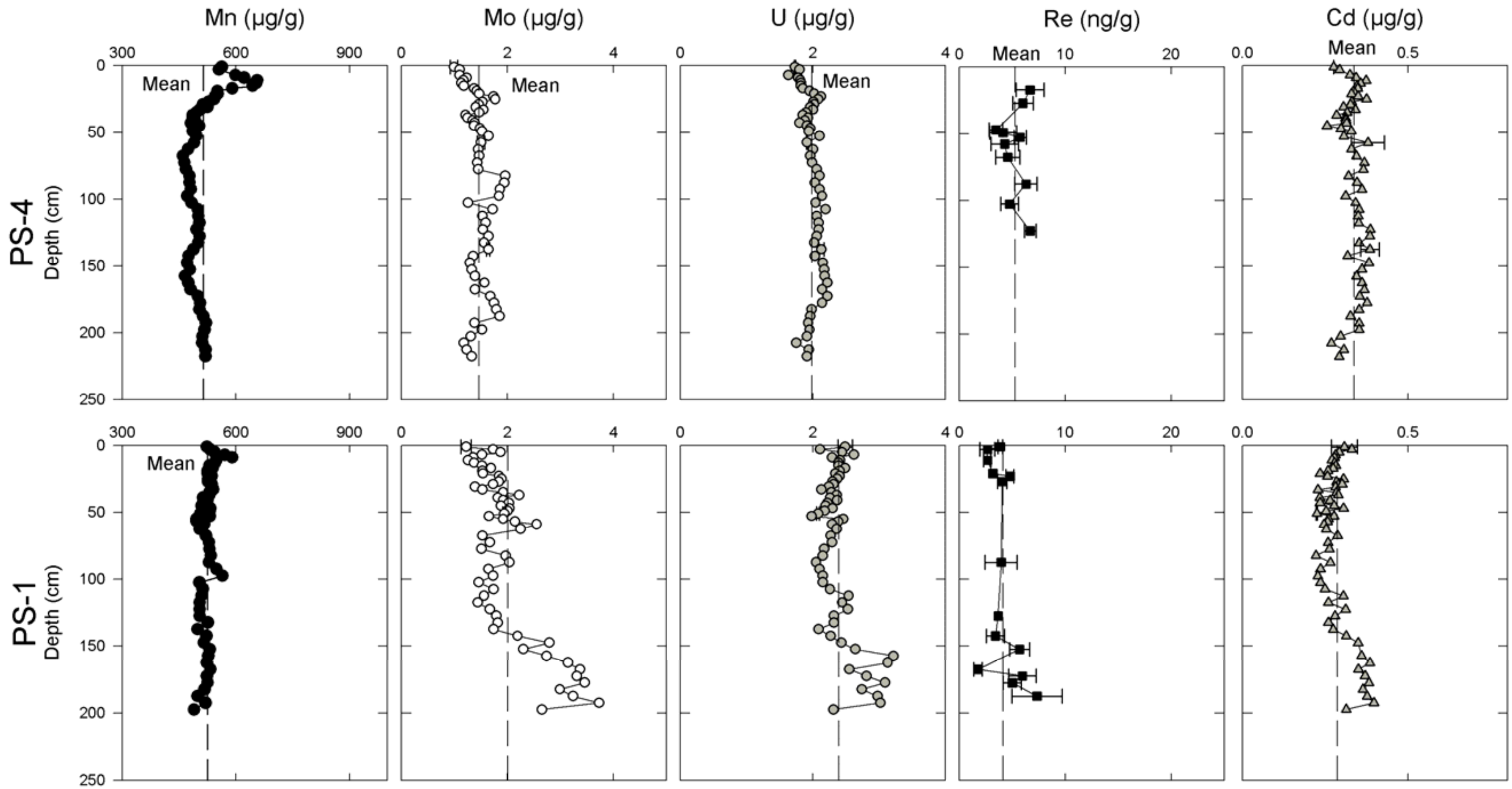


Figure 16. Concentrations for Mn, Mo, U, Cd in µg/g and Re ng/g for Puget Sound cores PS-4 (top panel) and PS-1 (bottom) plotted against core depth (cm). Dashed vertical lines represent the core mean and error bars are at 1σ.

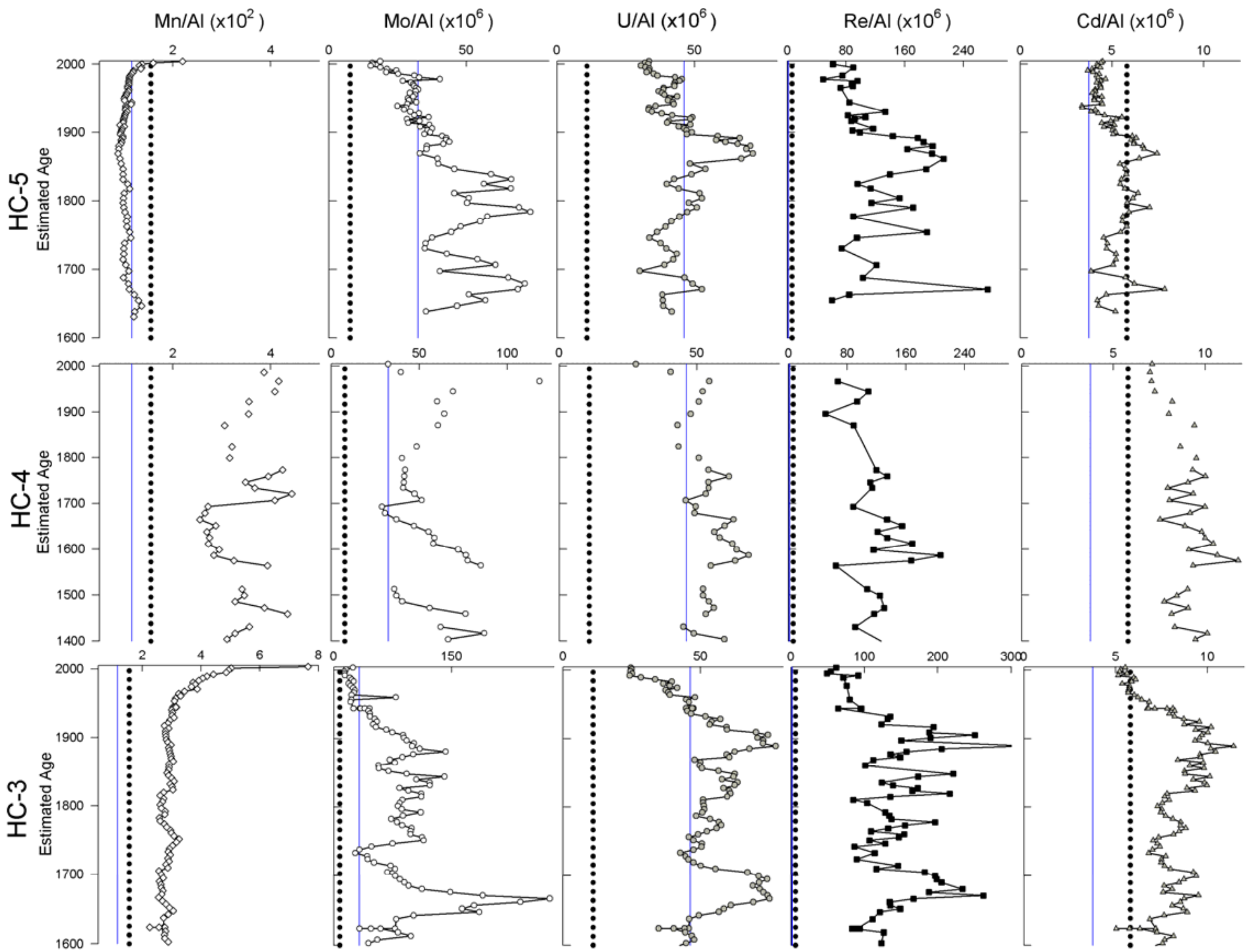


Figure 17. Metal/Al ratios for Mn, Mo, U, Re, and Cd plotted against estimated age for Hood Canal cores HC-5 (top panel), HC-4 (middle), and HC-3 (bottom). Solid blue vertical lines represent global average shale ratios (Turekian and Wedepohl 1961) for all metals except Re reported as crustal (Colodner 1991) and dotted lines represent Cowichan River ratios (Russell and Morford 2001).

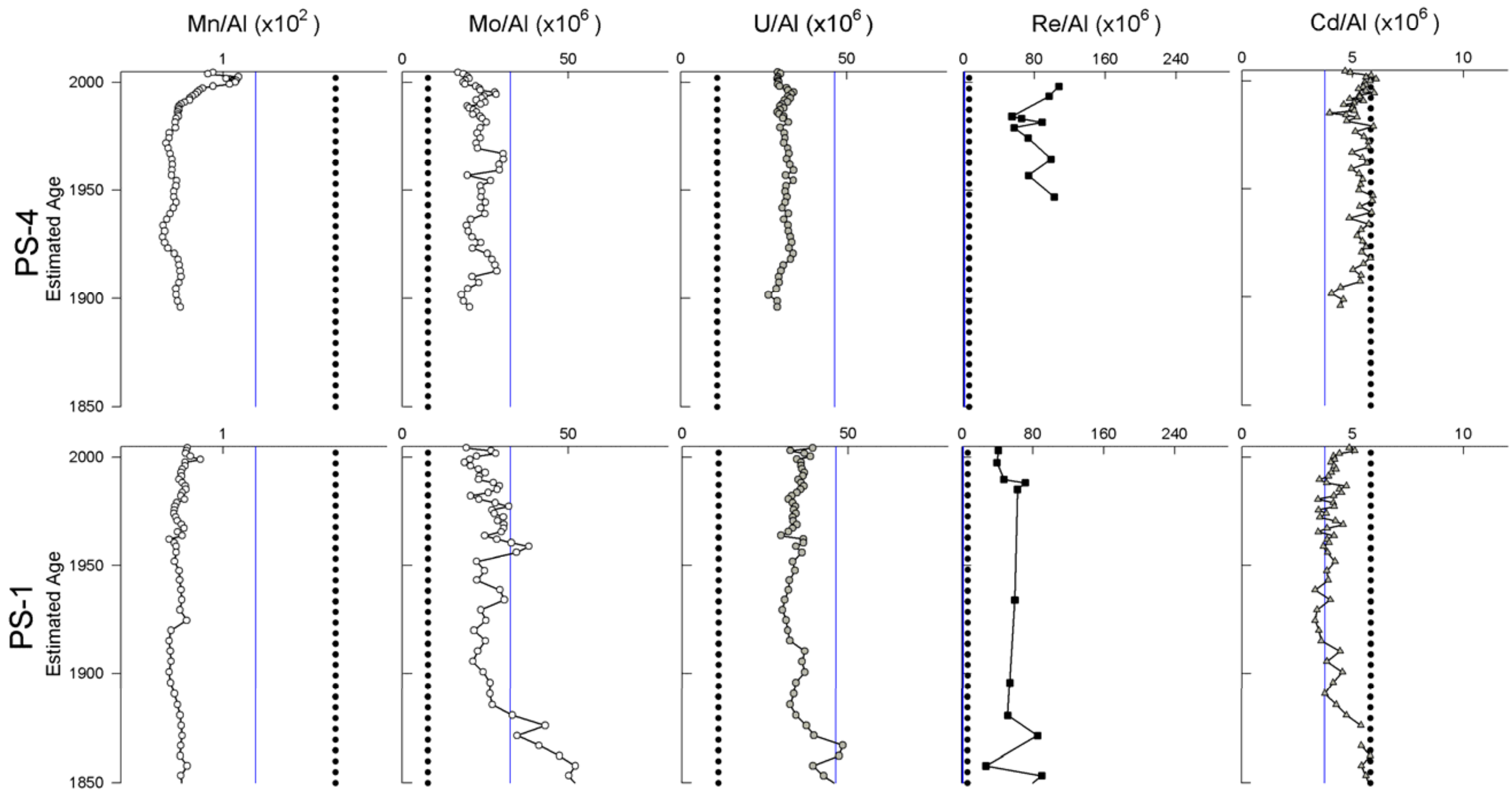


Figure 18. Metal/Al ratios for Mn, Mo, U, Re, and Cd plotted against estimated age for Puget Sound cores PS-4 (top panel) and PS-1 (bottom). Solid blue vertical lines represent global average shale ratios (Turekian and Wedepohl 1961) for all metals except Re reported as crustal (Colodner 1991) and dotted lines represent Cowichan River ratios (Russell and Morford 2001).

3.1.3. Diagenesis and Re-oxidation

The solid-phase reconstructions represent a time-averaged record of diagenetic or re-oxidation changes occurring within the upper few centimeters (i.e. mixed/redox boundary). The behavior of individual RSM is highly variable during diagenesis as their sedimentary accumulations may occur in various phases (e.g. metal sulfides, oxyhydroxides, adsorbed onto organic matter). Several studies have addressed these factors for Re, Mo, and/or U across a gradient of sediment types (Colodner et al. 1992; Yang et al. 1995; Crusius et al. 1996; Morford and Emerson 1999; Morford et al. 2001; Russell and Morford 2001; Crusius and Thomson 2003; McKay et al. 2007). These metals can undergo diagenetic redistribution resulting from changes in bottom water oxygen concentrations and/or organic matter (OM) fluxes [see (Russell and Morford 2001; Crusius and Thomson 2003) and references therein]. Crusius and Thomson (2003) found Re was significantly altered by diagenetic processes in organic poor sediment (< 1% OC) and areas with oxidized sediment in a low-sedimentation environment (<0.005 cm/yr). These factors are not apparent in this study as the OC was > 1% (see section 3.2) and sedimentation rates are much higher (> 0.4 cm/yr, Table 3). The higher sedimentation rates reduce the depth of the redox boundary, which enhance preservation and support the usage of Re, Mo, and U as paleo-tracers (Yang et al. 1995; Crusius and Thomson 2003).

The potential for metals, particularly Mo, to be entrained in Mn/Fe-oxyhydroxide cycles complicates the RSM reconstructions (Morford et al. 2007). Compared to the profiles reported by Sundby et al. (2004) for the Gulf of St. Lawrence, these core profiles show little relationship between Mo and Mn cycling. The subsurface peak in Mo, may indicate association with Mn-oxyhydroxides; however, this peak is also noted in the U and Re profiles. In addition, the core concentrations are well below values reported for Mn-oxyhydroxide pumps (~10,000 μg/g) where a surface oxic layer overlays a reduced sub-surface layer (Calvert and Pedersen 1993). This suggests the enrichment of Mo is not significantly influenced by the oxidation of Mn-oxyhydroxide and is instead primarily resulting from authigenic enrichment.

Although many studies have shown that U can be remobilized during alterations in the sedimentary redox conditions (Rosenthal et al. 1995a; 1995b; Thomson et al. 1998; Mangini et al. 2001), there is evidence of preservation in systems with a greater sediment and OM fluxes (Yang et al. 1995). In post-depositional oxygenation, such as irrigation or migration of the redox boundary, authigenic U enriched under euxinic conditions (sulfate reduction) may be remobilized and lost while Mo and Re are only minimally altered (Morford et al. 2001). On the other hand, U, Cd, and Re may be enriched in core segments without Mo, which indicates a depositional environment without free H_2S (Tribovillard et al. 2006). To better understand the potential redistribution of the RSM profiles, the pattern match between RSM within the same core and features between cores were evaluated. Figure 19 shows the metal/Al profiles for HC-5, HC-3, and PS-1. The PS-4 core is not shown as it has little overall enrichment of RSM through time. The periods of enrichment for each RSM are generally in phase within each core and significant periods of enrichment agree across cores in the same basin. The most notable period of enrichment is observed in the bottom of HC-3, where ratios are significantly elevated above average shale, Cowichan River (Figures 17), and the down-core average (Figure 15).

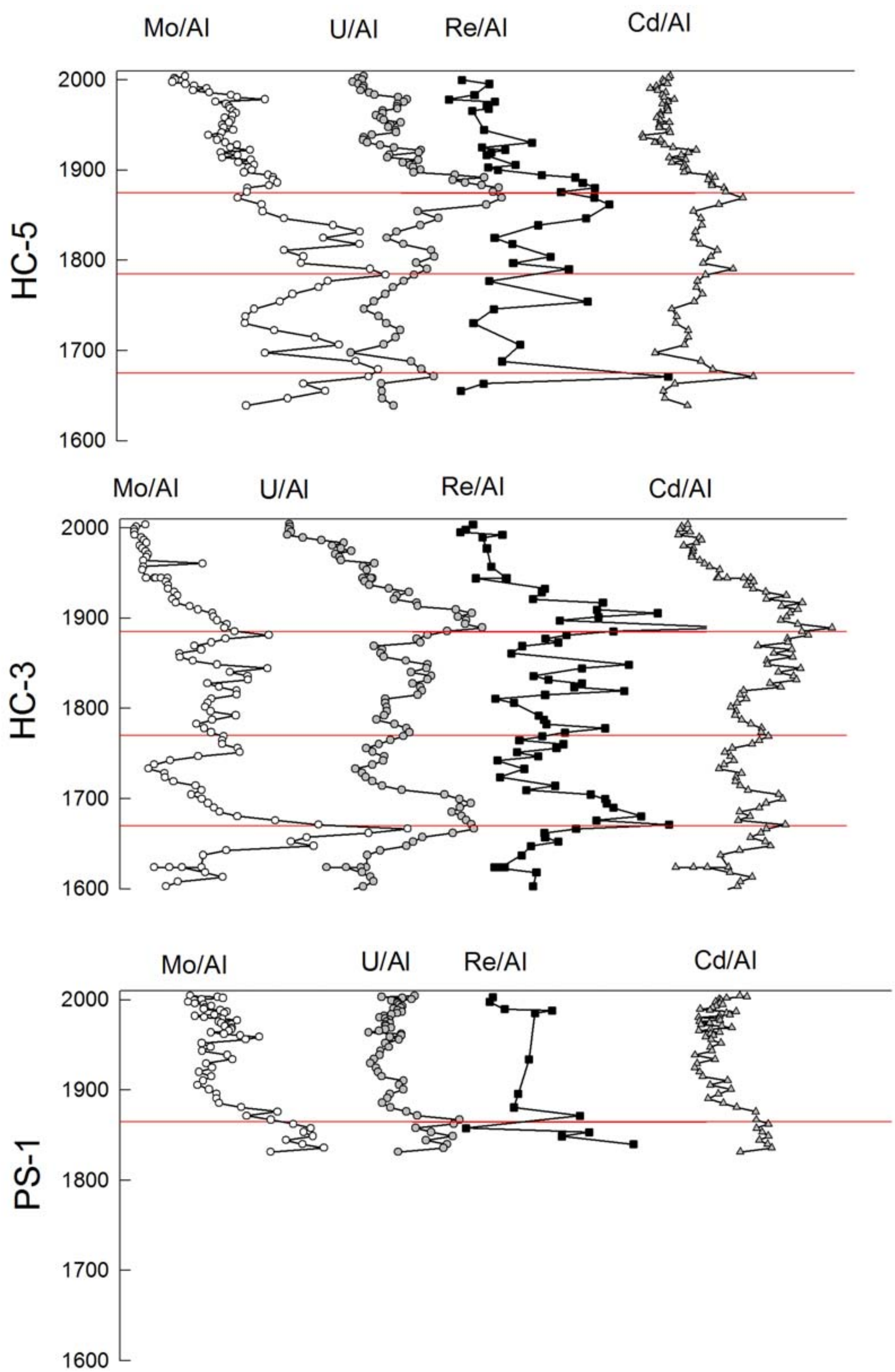


Figure 19. Metal/Al ratios (x10^6) for Hood Canal (HC-5 and HC-3) and central Puget Sound (PS-1) sediment cores plotted against estimated or extrapolated age from ^{210}Pb chronology. Red lines denote periods of overall higher enrichments.

There are three timer periods of interest in Hood Canal cores and only one in Puget Sound due to the higher sedimentation rates and lack of older core segments dating beyond the 1850s. In Figure 19, the red lines mark the general time-frames in each core showing comparatively elevated RSM ratios in the late 1600s, 1700s and 1800s.. Although the ^{210}Pb chronology does not extend beyond ca. 1850, ages were extrapolated for Hood Canal cores based on the premise that the surrounding watersheds were not significantly altered prior to the 1850s. This allows for a reasonable assumption that the sedimentation rates have not been significantly altered during the extrapolated time-period of ca. 1600-1850.

One area of potential re-distribution of RSM was noted in HC-5 as a set of black and rust colored bands from 125-130 cm, which corresponds with ~1830s. The RSM profiles show this period as a peak in Mo, but no corresponding peak in the other RSM. This suggests a period of re-oxidation and remobilization and this peak should be discussed with caution. Other peaks occur in the core segment noted as the pronounced black band in HC-5 (215-230 cm), which extrapolates to ~ late 1600s with enrichment noted for all RSM. An example of potential suboxic enrichment of RSM was noted in HC-5. The late 1800s peak only occurs in the U, Re, and Cd profiles suggesting conditions were not sufficiently reducing to enrich Mo during sedimentary deposition.

In HC-3, there was a burrow noted from 75-80 cm that corresponds to ~1870s. The RSM profiles show some indication of redistributions as the peaks do not match exactly. However, the other cores record elevated ratios during this time-period suggesting this was a period of basin-wide RSM enrichment. The lower portion of HC-3 contained a notable H_2S odor suggesting preservation under more sulfidic conditions. These core segments contain the highest RSM ratios of all cores and occur around the same time-period as the black band in HC-5.

The Pearson correlation coefficients between RSM within a given core were evaluated and summarized in Table 6. In most cases, the individual RSMs were strongly correlated to each other (Pearson correlation coefficient > 0.6). There are a few notable exceptions, particularly for PS-4. The lack of strong correlations may be attributed to little overall enrichment in the core. However, as seen with all the cores, the Cd and U are statistically significantly correlated demonstrating the strong coupling noted by Rosenthal et al. (1995a; 1995b). In addition, Re tends to have a stronger correlation with U than with Mo, which may result from their similar reduction potentials as discussed above. In some cases, statistical correlation may be hindered by diagenesis or post-depositional oxidation in individual core segments. Figure 19 illustrates there was the potential for re-oxidation of selected Hood Canal core segments as a result of burrows (noted in Table 2 as black non-uniform). Collectively, the correlations indicate the RSM were not significantly redistributed outside the individual core segment.

Table 6. Pearson correlation coefficients for the redox-sensitive metals in Puget Sound cores PS-4 and PS-1 and Hood Canal cores HC-5 and HC-3.

	Mo	U	Cd
PS-4 U	0.403		
PS-4 Cd	0.345	0.729	
PS-4 Re	0.424	0.363	0.472
PS-1 U	0.797		
PS-1 Cd	0.885	0.929	
PS-1 Re	0.461	0.652	0.937
HC-5 U	0.333		
HC-5 Cd	0.627	0.815	
HC-5 Re	0.335	0.692	0.840
HC-3 U	0.719		
HC-3 Cd	0.579	0.840	
HC-3 Re	0.448	0.813	0.705

In conclusion, the core profiles indicate some redistribution due to both irrigation and re-oxidation; however, it is difficult to see how these mechanisms could explain the broad, large-scale increase noted in HC-3 as the other Hood Canal core is also enriched during this time-period. In fact, there are notable periods within a given core and, more importantly, between cores from the same basin, where all RSM are simultaneously enriched or depleted. The RSM from both the Hood Canal cores indicate a more oxygenated "stance" during the 1900s compared to prior periods of the late 1800s, ca.1700s, and ca.1600s. The enrichment recorded in Puget Sound core (PS-1) occurs earlier in time (ca. 1860s) relative to that recorded in Hood Canal (ca. 1880s). However, this difference is within the resolution of the cores and may, indeed, represent a period of lower oxygen conditions in both the central Puget Sound and Hood Canal.

3.1.4. RSM Discussion

The enrichment factors (EF_{CR}) for each metal and core segment were calculated relative to Cowichan River (CR) detrital ratios expressed as the metal (Me) to Al ratio (Russell and Morford 2001) as shown in Equation 5.

Equation 5. The equation for the redox-sensitive metal enrichment factors relative to Cowichan River (CR) detrital metal (Me) ratios (Russell and Morford 2001).

$$EF_{CR} = \frac{\frac{Me}{Al}}{CR\left(\frac{Me}{Al}\right)}$$

The EF_{CR} for each core, minus the mixed depth, were divided into those associated with core segments dated as older than 1900s and those from 1900-2005. Table 7 summarizes the average $EF_{CR} \pm 1\sigma$ for the two time periods (pre-1900s and 1900-2005). If the EF_{CR} is greater than 1, then the metal is enriched relative to the Cowichan River detrital values. We hypothesize that the RSM enrichment factors for each core represent a gradient in bottom water ventilation with PS-4

> PS-1 > HC-5 > HC-3 suggesting southern Hood Canal location exhibits the lowest oxygen concentrations in its bottom waters. This hypothesis is supported by the instrumental dissolved oxygen records available for the last ~50 years (see Section 3.7 for further discussion). The comparison of these two timeframes, which represent pre- and post-western settlement, indicates the sediments in Hood Canal and central Puget Sound are not significantly enriched in RSMs as a result of urbanization within their respective watersheds. In fact, the RSM signatures indicate overall higher enrichment prior to significant western settlement in the pre-1900s time period (Figure 20). The dating tools used do not resolve variations in the sedimentation fluxes prior to the mid-1800s; therefore, greater authigenic enrichment in the past may be attributed to changes in OM fluxes or sediment supply, but collectively the data do not suggest this.

Table 7. The average enrichment factors (EF_{CR}) ± 1σ for pre-1900s and 1900-2005 for each core. The EF_{CR} are calculated relative to Cowichan River (CR) detrital values (Russell and Morford 2001). The n represents the number of core segments in the average.

	Ti EF_{CR}	Fe EF_{CR}	Mn EF_{CR}	Mo EF_{CR}	U EF_{CR}	Re EF_{CR}	Cd EF_{CR}
Pre-1900s							
HC-3 (n=70)	1.4 ±0.1	1.3 ±0.03	1.8 ±0.1	12 ±5.8	5.1 ±1.0	24 ±7.7	1.4 ±0.2
HC-5 (n=40)	1.0 ±0.03	0.90 ±0.04	0.67 ±0.07	6.4 ±1.5	4.5 ±1.0	23 ±8.6	0.98 ±0.15
PS-1 (n=15)	0.80 ±0.01	0.73 ±0.01	0.51 ±0.01	5.4 ±1.3	3.7 ±0.51	11 ±4.6	0.83 ±0.26
PS-4	NA	NA	NA	NA	NA	NA	NA
1900-2005							
HC-3 (n=21)	1.4 ±0.01	1.2 ±0.01	2.0 ±0.12	6.3 ±2.8	4.8 ±0.93	22 ±9.4	1.4 ±0.24
HC-5 (n=39)	0.98 ±0.02	0.84 ±0.03	0.70 ±0.07	3.8 ±0.72	3.7 ±0.48	14 ±3.2	0.75 ±0.08
PS-1 (n=38)	0.81 ±0.01	0.74 ±0.01	0.50 ±0.02	3.4 ±0.56	3.1 ±0.19	9.0 ±2.1	0.68 ±0.07
PS-4 (n=52)	0.92 ±0.01	0.77 ±0.01	0.50 ±0.04	3.0 ±0.41	2.9 ±0.15	13 ±3.1	0.90 ±0.08

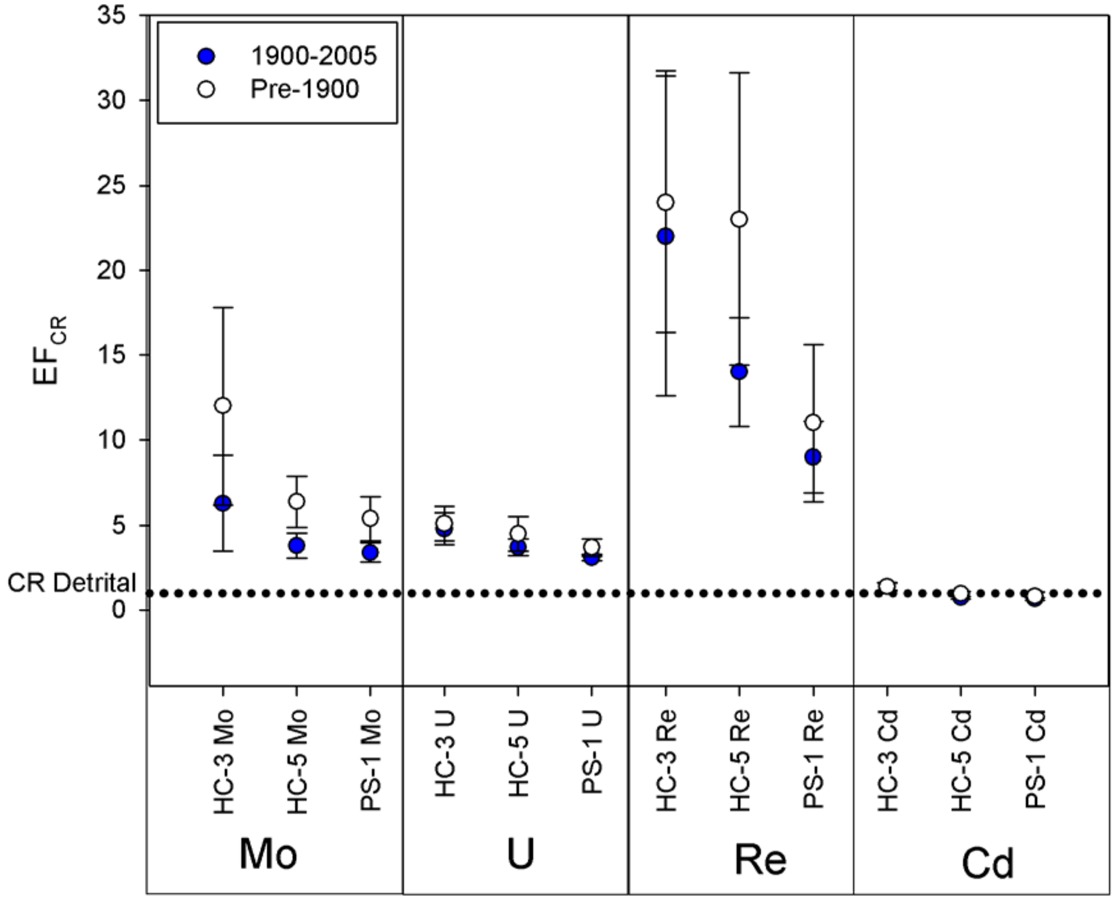


Figure 20. The average enrichment factors (EF_{CR}) ± 1σ for redox-sensitive metals for 1900-2005 and Pre-1900s in two cores from Hood Canal (HC-3 and HC-5) and one core from central Puget Sound (PS-1). The dotted line represents the Cowichan River detrital values (Russell and Morford 2001).

Since U and Re can be authigenically enriched under denitrifying conditions while Cd and Mo require sulfate-reducing conditions, differences in enrichment patterns may indicate the status of the depositional environment. Based on the approach presented by Crusius et al. (1996) the sedimentary Re/Mo ratio indicates that bottom waters were primarily suboxic through time with only the late 1600s representing potentially anoxic bottom water in southern Hood Canal (Re/Mo ratio averages 0.65 for 170-180 cm in HC-3). In fact, the RSM ratios are similar to those found in basins oscillating between oxic and suboxic/anoxic conditions in the water column (Crusius et al. 1996) and not permanently anoxic (Calvert and Pedersen 1993; Russell and Morford 2001). Crusius et al. (1996) found Re enrichment of around 25 ng/g in sediment underlying waters with < 2 µM O_2 (<0.064 mg/L) and < 2 ng/g in waters with > 10 µM O_2 (> 0.32 mg/L). The highest concentrations of Re are recorded in the bottom of HC-3 (20.3 ng/g). The average concentrations of dissolved oxygen (DO) in the long-axis of Hood Canal at > 20 m are ~ 3-7 mg/L with significant seasonal and interannual variability for the years 1952-2006 [see Figure 50 in Section 3.7 (Newton et al. 2007)]. However, DO concentrations in Lynch Cove are generally much lower with values of 0.1-0.3 mg/L at water depths of 15-36 m (Paulson et al. 2006) and long-term monitoring data show bottom water concentrations from similar low values to highs ~ 5-6 mg/L during the 1950s (Newton et al. 2007). This is in contrast to bottom water oxygen concentrations in the main basin of Puget Sound, which are consistently ~5 mg/L; (Collias et al.

1974). The RSM profiles generally follow these patterns of DO concentrations for the two basins except for the most recent decade, which is within mixed depth of the sedimentary record. However, the overall higher EFs prior to significant urbanization in the 1900s suggest there are natural processes associated with the development of hypoxia in Hood Canal.

3.2. Stable Carbon and Nitrogen Isotopes and Biomarkers

Sediments from the Puget Sound/Hood Canal Basins show relatively low OM content with organic carbon (OC) concentrations ranging 1.6-2.4% in Puget Sound cores (PS-1 and PS-4) and 1.9-2.8% in Hood Canal cores (HC-3 and HC-5) [see Appendix C]. Similarly, N content is relatively low in all cores ranging from 0.17-0.26% in Puget Sound (PS-1 and PS-4) and from 0.20-0.29% in Hood Canal (HC-3 and HC-5). These values are consistent with published OM data from Dabob, Bay in Hood Canal and the Straight of Georgia (Hedges et al. 1988b; Macdonald et al. 1991; Walsh et al. 2008). In both basins, a gradual increase in OM concentrations begins around the end of the 19^{th} Century with abrupt increases in the early and/or middle of the 20^{th} Century. Each OC profile was modeled using a first-order G-Model (Berner 1980) to evaluate if OM concentrations respond to steady-state diagenetic processes. The calculations of solid-phase degradation rates in Puget Sound and Hood Canal sediments were thus carried out using Equation 6 (Berner 1980).

Equation 6. Solid-phase degradation rates (Berner 1980).

$$G_z = G_{mo} \times e^{-kt} + G_\infty$$

Where G_z is the total sediment substrate concentration at depth z; G_{mo} is the initial concentration of metabolizable OM at the sediment surface; t is the mean age of the sample horizon, and G_∞ is the asymptotic, or 'refractory', concentration of OM in the lowest part of the core. The slope of the relation between $\ln(G_m/G_{mo})$ and t corresponds to the best estimate of the first-order decay constant (k) for the compound in question. In this calculation G_m is the absolute concentration of metabolizable OM at any time and represents the difference between the measured concentration at depth z and G_∞. The first-order decay constants derived from these four cores ranged from 0.02-0.03 y^{-1}. These values are within the general ranges (0.01-0.03 y^{-1}) reported for OC decomposition in coastal environments over similar decadal time scales (Henrichs 1992; Eadie et al. 1994; Louchouarn et al. 1997b; Zimmerman and Canuel 2000). Yet, they are up to an order of magnitude lower than first-order decay constants reported for sedimentary OC in Saanich Inlet (k = 0.08-0.11 y-1) (Hamilton and Hedges 1988; Cowie and Hedges 1992). The sources of OM to deep waters and sediments of Saanich Inlet are primarily derived from labile autochthonous particle fluxes, which are extensively regenerated both within the water column and in surficial sediments (Hamilton and Hedges 1988; Cowie et al. 1992). In Puget Sound basins, on the other hand, OM inputs are more influenced by watershed sources of terrestrial OM (see discussion below) and may be more similar to the deep channel environments found in the St. Lawrence Estuary where OM sources are a mixture of terrestrial and marine inputs leading to comparable first-order decay constants (0.02-0.03 y^{-1}) (Louchouarn et al. 1997b). Using first-order decay constants of 0.03±0.01 y^{-1} and 0.02±0.01 y^{-1} for PS and HC cores, respectively, demonstrates that with the exception of core HC-5, none of the OM profiles show a behavior consistent with steady-state diagenesis (Figure 21). Rather, and in contrast to environments like the St. Lawrence which show ideal diagenetic behavior (Louchouarn et al. 1997a), the Puget Sound profiles suggest that input processes may have had a strong influence on OM deposition or preservation in the last 100-150 years.

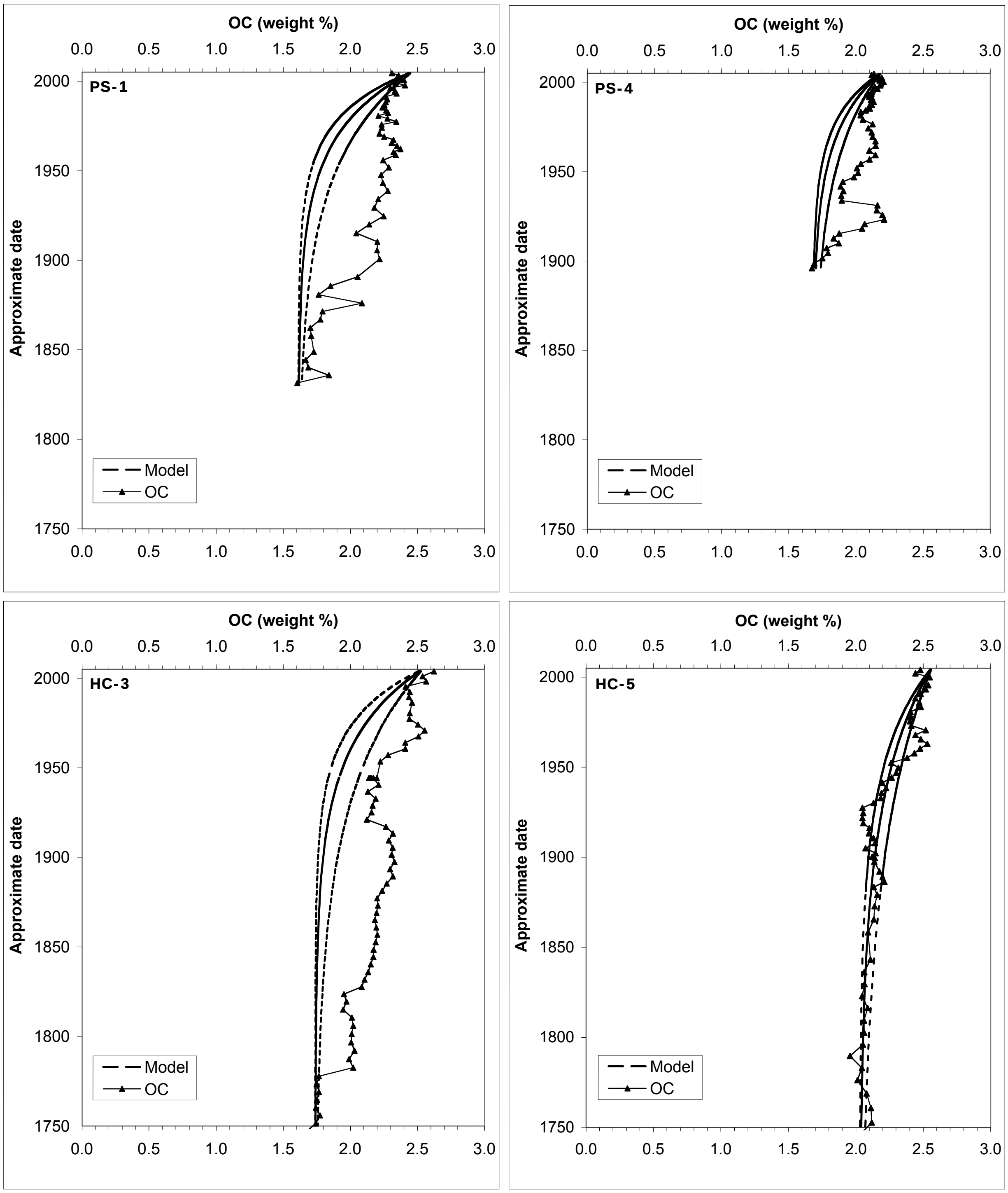


Figure 21. Total organic carbon concentrations (weight %) in sediments of central Puget Sound (top; PS-1 and PS-4) and Hood Canal (bottom; HC-3 and HC-5). The curved lines represent diagenetic profiles modeled using a range of empirically-derived degradation rate constants (PS: 0.03±0.01 y^{-1}; HC: 0.02±0.01 y^{-1}).

Fluctuations in the sources of OM reaching the PS and HC sediments can be inferred initially from the profiles of atomic C to N ratio ((C/N)a; Figure 22). This ratio increases markedly in both basins from average values of 10-11 prior to the late 1800s and mid-1900s in Puget Sound and Hood Canal, respectively, to values of 12-13 in the 1950s in both basins. The (C/N)a ratio then decreases synchronously in both basins back to or close to pre-20th Century values (9-11). The (C/N)a ratio can serve as an integrated indicator of OM inputs from both the landscape and *in-situ* productivity (allochthonous and autochthonous, respectively) with sediment values between 6 and 9 being typical of algal-derived OM and values above 20 more characteristic of terrestrial plant material (Meyers 1994; Meyers 1997; Nuwer and Keil 2005). Although diagenetic processes in aquatic systems and selective sorption in soils can alternatively lead to higher or lower (C/N)a values, respectively, the elemental ratio usually retains reliable qualitative information about source inputs of OM to sediments (Meyers 1994; Meyers 1997; 2006). For example, regional studies in Dabob Bay and Saanich Inlet, have shown that (C/N)a ratios track the seasonal inputs of autochthonous and allochthonous OM throughout the water column and surface sediments (Hedges et al. 1988c; Cowie and Hedges 1992). Similarly, studies in the Straight of Georgia, central Puget Sound, and Vancouver Island (Macdonald et al. 1991; Nuwer and Keil 2005; Walsh et al. 2008) showed that (C/N)a values of surface sediments can also help trace the mixture of OM inputs from water column productivity and watershed plants/soil inputs. In particular, MacDonald et al. (1991) used (C/N)a ratios in combination with stable isotopic carbon signatures ($\delta^{13}C$) to show that anthropogenic inputs of terrigenous OC have increased by 40% in sections of the Straight of Georgia during the 20th Century due to increased influence of pulp and paper mill effluents during the 1950-1970s.

Similar "industrial" inputs of terrigenous OM to fjord-like systems and their resulting impact on (C/N)a ratios have also been recorded on the east coast with values exceeding 20 during periods of large-scale discharges of pulp and paper mill effluents (Pocklington and MacGregor 1973; Louchouarn et al. 1999). The clear historical peak in (C/N)a ratios in cores from both basins similarly suggest a shift towards increased inputs and preservation of terrigenous OM in sediments of Puget Sound during the mid-20th Century consistent with the observations of MacDonald et al. (1991) for the Straight of Georgia. Additional indicators are needed, however, to demonstrate that such changes are mostly due to shifts in source inputs rather than major diagenetic transformation of settling OM.

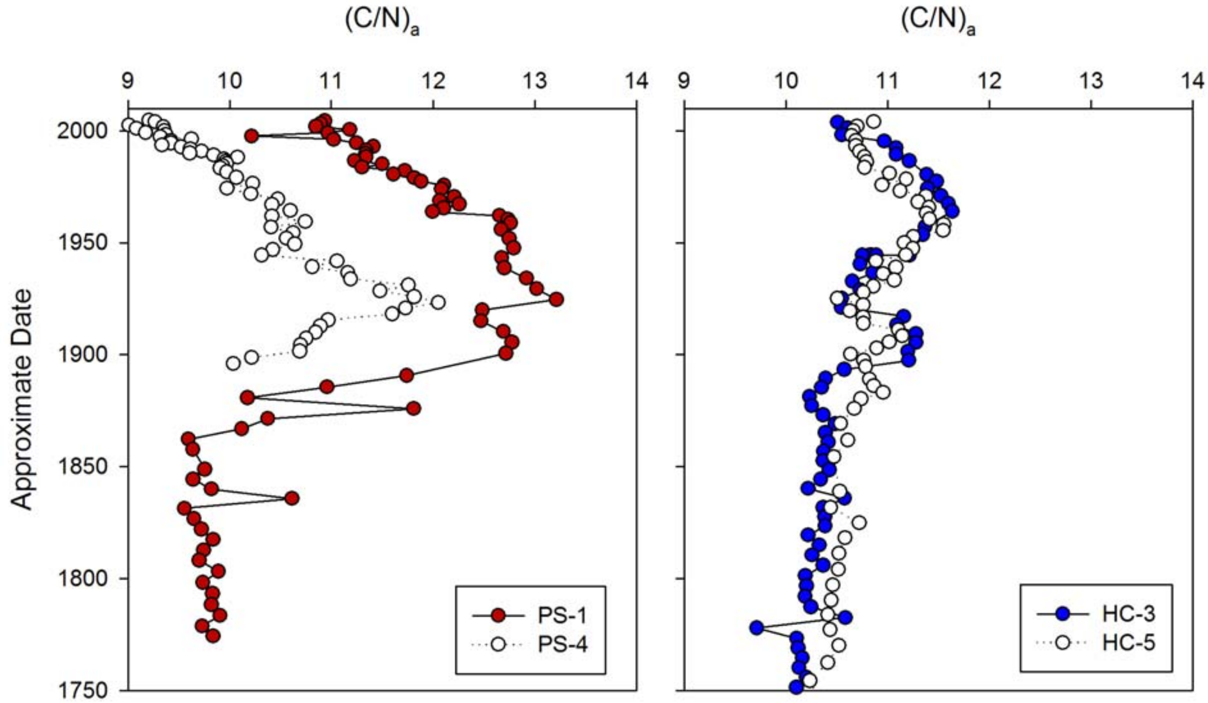


Figure 22. Atomic organic carbon to nitrogen ratios ((C/N)a) in central Puget Sound (PS-1 and PS-4) and Hood Canal (HC-3 and HC-5) sediment cores.

3.2.1. Biomarker Concentrations

In addition to elemental ratios and stable isotopic signatures (see discussion below), a vast series of biomolecules, or biomarkers, can help trace source inputs of OM in aquatic environments. Among these biomarkers, lignin is a complex and important structural component of vascular plants (Sarkanen and Ludwig 1971). Because of its relative recalcitrance, lignin is abundant in soil OM (Kögel-Knabner et al. 1991; Hedges et al. 1997) and in aquatic environments that receive substantial inputs of terrigenous OM (Prahl et al. 1994; Goñi and Montgomery 2000; Houel et al. 2006; Sánchez-García et al. 2008; Walsh et al. 2008). Alkaline CuO oxidation is a technique commonly used to analyze lignin in plant tissues and environmental matrices such as soils, sediments, and dissolved OM (Goñi and Hedges 1992; Opsahl and Benner 1995; Rumpel et al. 2002; Benner et al. 2005; Otto and Simpson 2006; Kuo et al. 2008). Upon oxidation, the lignin macropolymer is hydrolyzed to small structural units belonging to three classes of methoxylated phenols: vanillyl (V), syringyl (S) and cinnamyl (C). Each class of lignin oxidation products (LOPs) is in turn comprised of an acid, an aldehyde and a ketone (for V and S) or only acids (for C). The yields and ratios of these lignin phenols have been extensively used to identify the structure of plant lignin (Hedges and Mann 1979; Goñi and Hedges 1992) and estimate inputs of vascular plant carbon to coastal systems (Hedges et al. 1988a; Hedges et al. 1988c; Prahl et al. 1994; Louchouarn et al. 1999; Goñi et al. 2000; Sánchez-García et al. 2008; Walsh et al. 2008). For example, internal LOP ratios such as syringyl to vanillyl and cinnamyl to vanillyl phenols (S/V and C/V, respectively), have been used for tissue type and taxonomic source reconstructions (i.e. angiosperm *vs*. gymnosperm, soft *vs*. hard tissues, respectively). Acid to aldehyde ratios from vanillyl phenols ([Ad/Al]v) can also provide information on the oxidative alteration of terrigenous OM prior to sediment burial or illustrate the importance of selective dissolution of acidic constituents from plant OM and their sorption onto soil and sediment minerals (Opsahl and Benner 1995; Opsahl and Benner 1998; Rumpel et al. 2002; Hernes and Benner 2003; Houel et al. 2006; Hernes et al. 2007).

Among additional CuO oxidation products, the phenolic compound 3,5-dihydroxybenzoic acid (3,5Bd) is a common product of soil degradation (Christman and Oglesby 1971; Ugolini et al. 1981; Prahl et al. 1994) and regularly found in freshwater and marine sediments (Prahl et al. 1994; Louchouarn et al. 1999; Houel et al. 2006; Dickens et al. 2007; Sánchez-García et al. 2008). It derives mostly from the oxidation of soil OM (Ugolini et al. 1981), except for some marine sediments receiving large inputs from brown macroalgae (Goñi and Hedges 1995). In turn, the ratio of 3,5Bd to total vanillyl phenols (3,5Bd/V) has been shown to be much higher for humic matter than for bulk sediment OM (Sánchez-García 2007), confirming the use of the ratio for determining the degree of oxidation of different soil OM (Otto and Simpson 2005; Otto et al. 2006). Recently, Dickens et al. (2007) and Sánchez-García et al. (2008) further validated the use of this ratio as a robust tracer for soil OM input to aquatic systems, including coastal and shelf environments.

We use all these parameters to evaluate the potential shifts in terrigenous OM inputs to Puget Sound basins over the past few centuries with particular attention to the past 100-150 years following the significant western settlement of the region. The carbon-normalized yields of the eight major lignin-derived phenols ($\lambda 8$) were detected in all sediments analyzed in this study and ranged from 1.2 to ~4.0 mg/100 mg OC (Figure 23). All profiles showed a historical peak in concentrations in the 1940-1960s. The onset of increasing lignin yield started in the late 1800s in the central Puget Sound and early 1900s in Hood Canal. Lignin yields decrease markedly since the late 1960s suggesting a recovery trend towards pre-20th Century values (Brandenberger et al. 2008). The start of increasing lignin yields in all the cores are coincidental with the start of significant logging in Puget Sound lowlands (Kruckeberg 1991) and seem to confirm that the increase in urbanization and land clearing has released greater amounts of terrigenous OM to Puget Sound. These transformations to the drainage basin are further confirmed by the pollen records (see pollen discussion 3.3) which show synchronous shifts in the relative abundance of Alder and conifer stands in the watershed illustrating the increased impact of land clearance starting in the late 19th Century. Although there were logging and lumber mill activities occurring in Hood Canal as early as the late 1800s, they were not sufficient enough to overcome the natural lignin inputs until the mid-1900s when logging technology allowed greater access to the more rugid terrain of Hood Canal compared to the Puget Sound lowland. The delayed onset of increasing lignin inputs is corroborated by the Alder and total conifer pollen records.

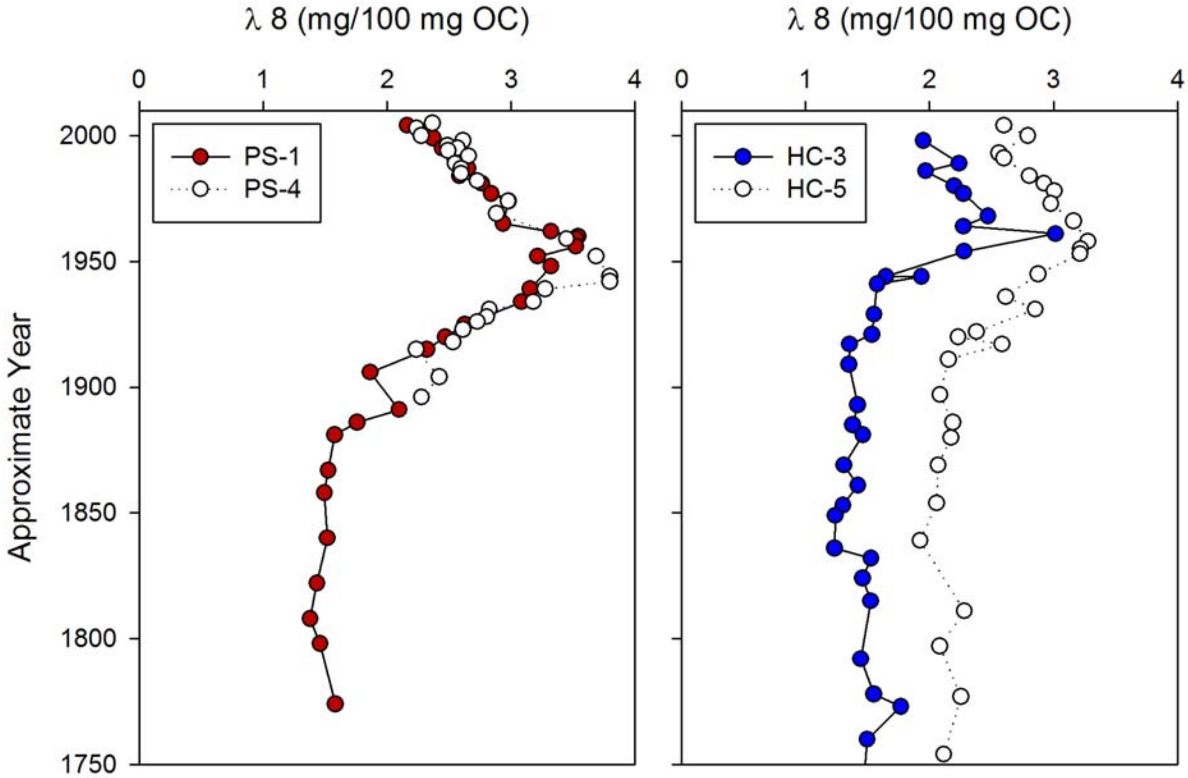


Figure 23. Carbon-normalized lignin yields (λ8, mg/100 mg OC) in central Puget Sound (PS-1 and PS-4) and Hood Canal (HC-3 and HC-5) sediment cores. The increasing lignin yield in all cores occurs during significant logging and urbanization during the 1900s.

Because wood harvesting and transformation by the North American pulp and paper industry is often performed on softwood rather than on hardwood species, industrial inputs of softwood lignin materials have substantially altered sedimentary lignin signatures since the beginning of the 20th Century in coastal systems heavily influenced by forestry (Louchouarn and Lucotte 1998; Louchouarn et al. 1999). For example, in the St. Lawrence Estuary/Saguenay Fjord system substantial inputs from pulp and paper effluents have led to a marked shift in internal lignin signatures (S/V, C/V, and [Ad/Al]v), as well as, in the 3,5Bd/V ratio in sediments (Louchouarn and Lucotte 1998; Louchouarn et al. 1999). Such changes are apparent in Puget Sound with strong shifts in S/V and C/V signatures (Figure 24) pointing to predominant inputs of woody materials from gymnosperms during the peak of lignin inputs (1940-1960s). Parallel to this increase in woody inputs, is a factor of 2-3 decrease in 3,5 Bd/V ratios (0.05-0.06 to 0.02-0.03; Figure 25) during the same time intervals as lignin maxima confirm the predominance of woody material inputs. In contrast, little change is observed in the [Ad/Al]v ratios (range: 0.35±0.02 and 0.39±0.03 for PS and HC cores, respectively; Appendix C) suggesting that the terrigenous OM is relatively unaltered and/or that little of it has undergone selective processes of dissolution and sorption prior to its introduction to the coastal basins.

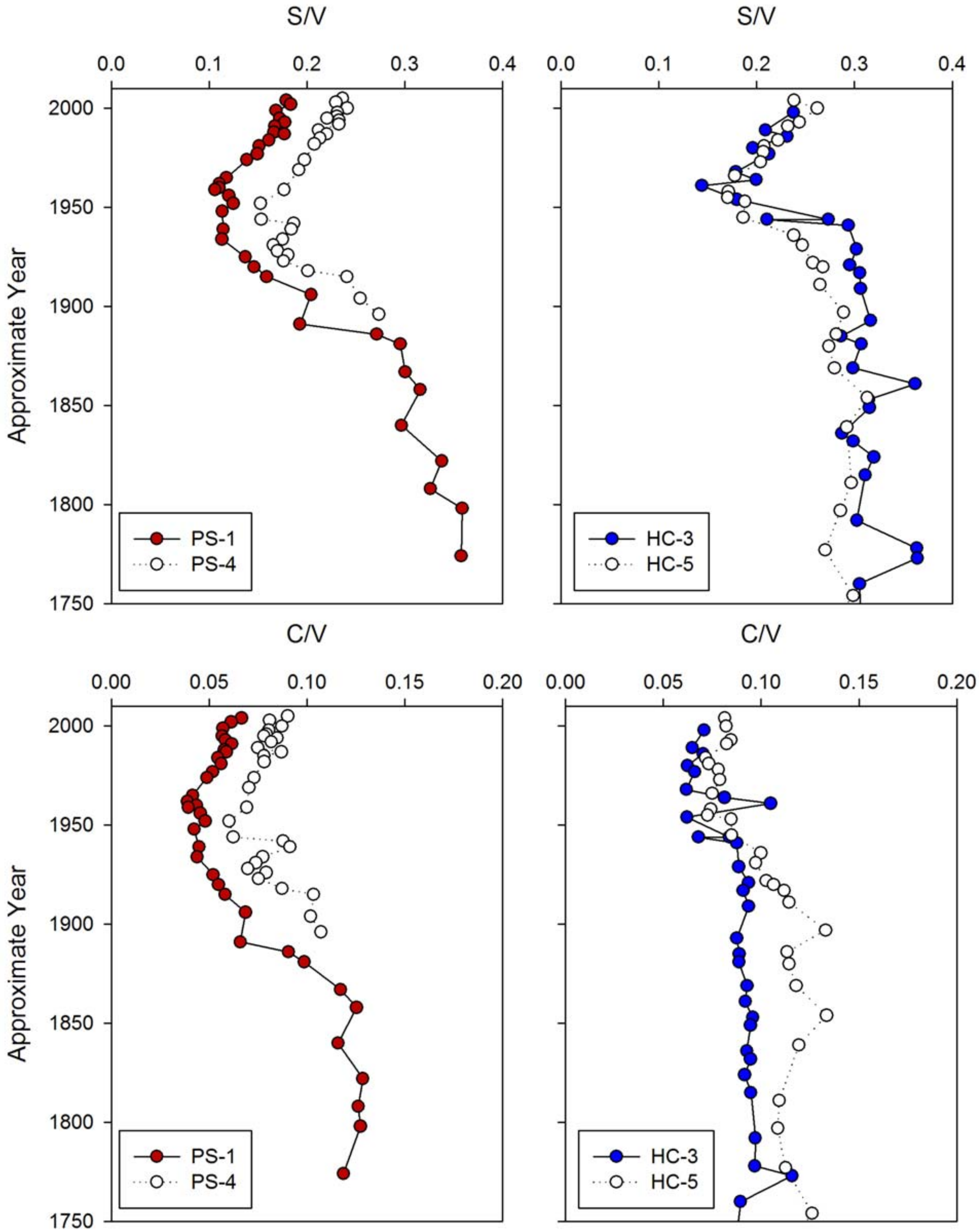


Figure 24. Ratios of syringyl to vanillyl phenols (S/V; top panel) and cinnamyl to vanillyl phenols (C/V; bottom panel) in central Puget Sound (PS-1 and PS-4) and Hood Canal (HC-3 and HC-5) sediment cores.

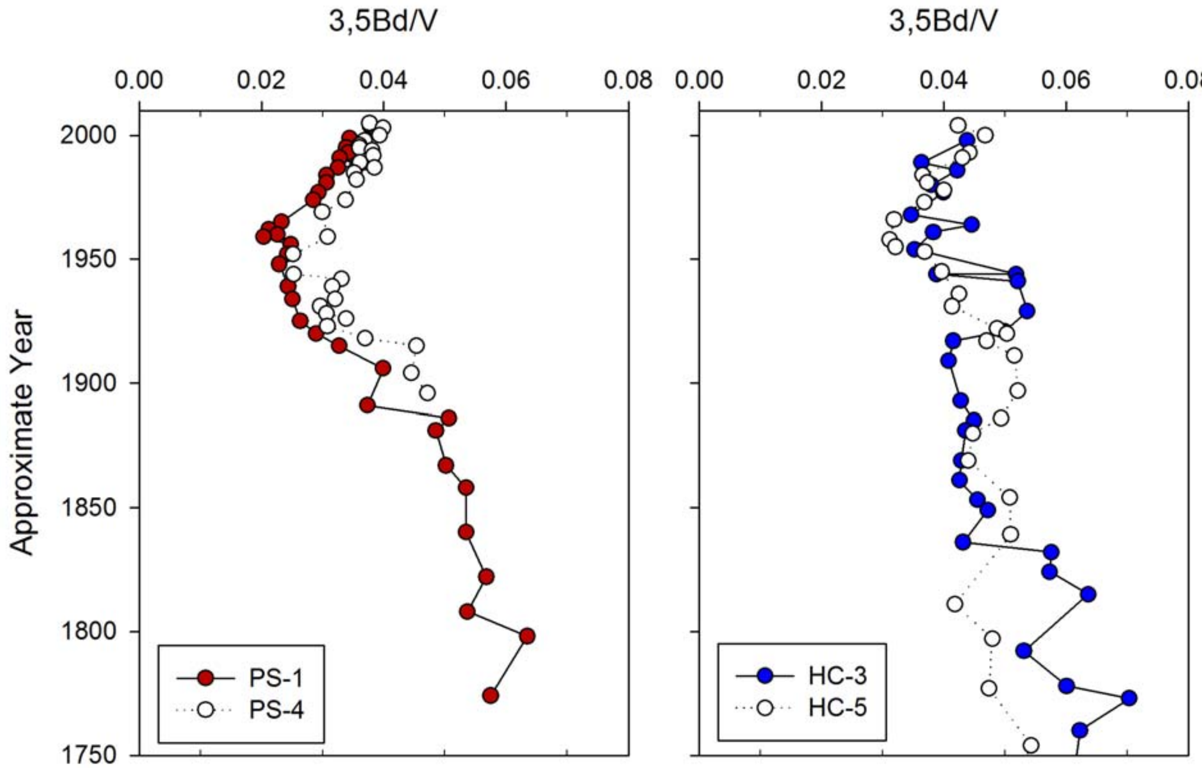


Figure 25. 3,5 dihydroxybenzoic acid to vanillin ratios (3,5 Bd/V) in central Puget Sound (PS-1 and PS-4) and Hood Canal (HC-3 and HC-5) sediment cores.

The lignin phenol vegetation index (LPVI) is an additional index of lignin sources recently developed by Tareq et al. (2004) as a more sensitive indicator of vegetational changes in a drainage basin than the lignin phenol ratios (S/V and C/V). The new index has been applied to lignin source reconstructions efforts in soils (Otto and Simpson 2006) and lake sediments (Tareq et al. 2006). This index was calculated using the binary equation originally presented by Tareq et al. (2004) in Equation 7 where V, S and C are expressed in % of the λ8 value.

Equation 7. The lignin phenol vegetation index (LPVI) (Tareq et al. 2004)

$$LPVI = \left[\frac{S(S+1))}{(V+1)} + 1 \right] \times \left[\frac{C(C+1)}{(V+1)} + 1 \right]$$

To interpret the signature changes of the LPVI in Puget Sound cores (Figure 26), values for relevant regional samples (settling particulate matter, plant tissues, and soils) are summarized in Table 8. Particles settling in the water column of Dabob Bay showed a marked seasonality in LPVI values with an average yearly signature of 9.6 that is driven by the low values and large fluxes characteristic of winter months (7.1-9.4). These values are slightly lower than fresh and degraded conifer needles (Table 8) collected in the region (Hedges and Weliky 1989) and are more typical of a mixture of gymnosperm woody and nonwoody tissues (Tareq et al. 2004). Prior to the 20th Century, the LPVI signatures in Puget Sound and Hood Canal sediments are similar to those found in coniferous soils of the region (Figure 26; Table 8), albeit showing a lower degradation state ([Ad/Al]v <0.40 vs. >0.50 and 3,5Bd/V <0.06 vs. >0.10 for sediments and soils, respectively; Table 8). Starting in the late 1800s in Puget Sound and early 1900s for Hood Canal, the LPVI decreases markedly towards gymnosperm woody signatures reaching a minimum (2-5; Figure 26) during the mid-20th Century's peak in carbon-normalized lignin yields. Such an unambiguous shift towards woody gymnosperm signatures during the 1940-1960s confirms that the increase in urbanization, land clearing, and the regional development of the forest industry have significantly contributed greater amounts of vascular plant OM to Puget Sound during the 20th Century. Nevertheless, the positive influence of environmental regulations on industrial point sources of contaminants and land management in the watershed (Brandenberger et al. 2008) is confirmed by the post-1960s transition towards a recovery in biomarker concentrations and signatures.

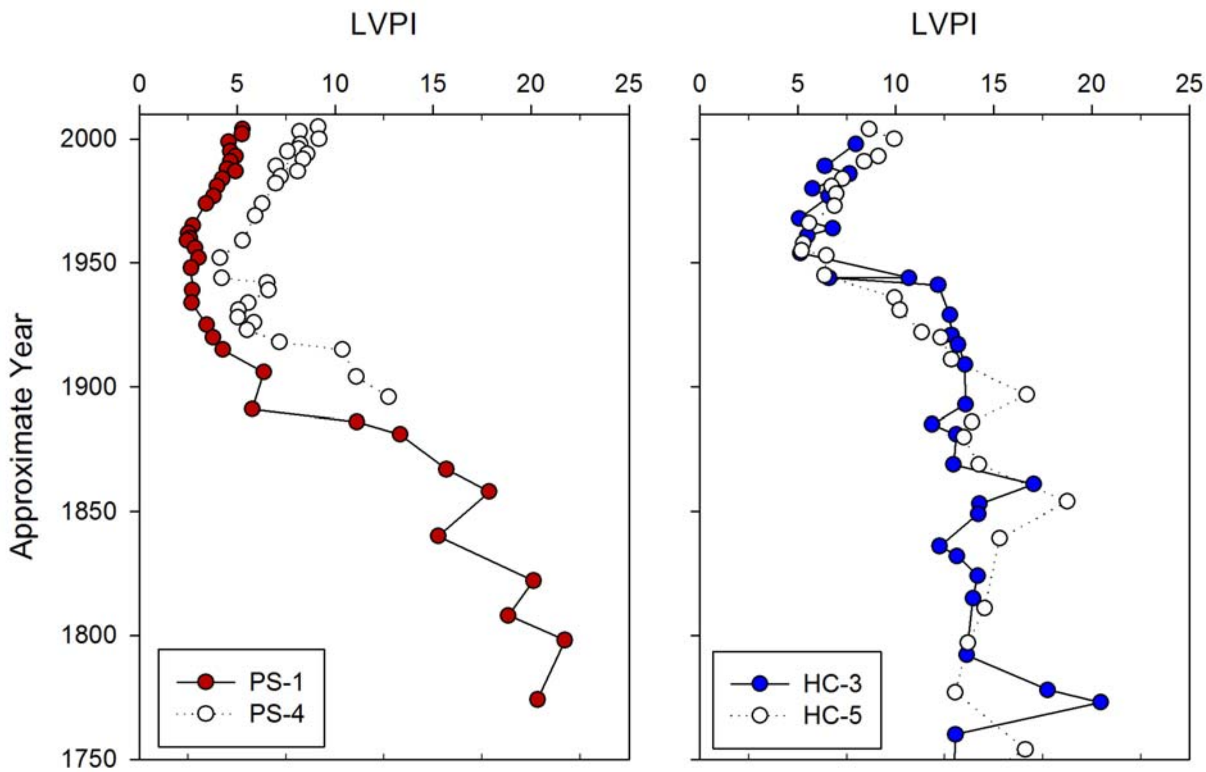


Figure 26. Lignin phenol vegetation index (LPVI) in central Puget Sound (PS-1 and PS-4) and Hood Canal (HC-3 and HC-5) sediment cores.

Table 8. Lignin content and signatures in a series of samples from the Puget Sound region. The lignin phenol vegetation index (LPVI; (Tareq et al. 2004) was calculated using Equation 7.

	$\lambda 8$	S/V	C/V	[Ad/Al]v	LPVI
Sediment Traps (60m)[a]					
12-Jul-81	0.78	0.25	0.07	0.36	8.4
5-Aug-81	0.57	0.22	0.02	0.43	5.3
4-Sep-81	0.48	0.21	0.03	0.41	4.9
30-Sep-81	0.86	0.28	0.07	0.32	9.6
28-Oct-81	1.04	0.29	0.06	0.31	10.7
23-Nov-81	3.27	0.30	0.05	0.33	9.4
31-Dec-81	2.57	0.24	0.05	0.36	7.1
29-Jan-82	2.95	0.26	0.06	0.33	8.2
26-Mar-82	0.50	0.35	0.10	0.35	15.6
13-Apr-82	1.05	0.27	0.11	0.34	12.5
2-May-82	0.85	0.22	0.26	0.35	27.2
28-May-82	0.57	0.21	0.18	0.38	18
24-Jun-82	0.58	0.27	0.21	0.40	26.1
Weighted average annual signature[b]	3.06	0.27	0.07	0.34	9.6
Hemlock[c]					
Green	3.51	0.00	0.47	0.36	16.2
Litter	5.56	0.08	0.30	0.31	11.9
Douglas Fir[c]					
Green	3.82	0.03	0.41	0.38	13.9
Brown	4.05	0.02	0.38	0.27	12.1
Litter	5.99	0.09	0.29	0.28	12
Fir/Hemlock[c]					
Green	3.69	0.02	0.43	0.37	14.6
Litter	5.82	0.09	0.29	0.29	11.8
Soil-Conifers[d]	14.60	0.22	0.18	0.54	16
Soil-Deciduous[d]					
>250 um	3.60	0.72	0.17	0.41	76.4
64-250 um	3.60	0.40	0.08	0.45	18.1
<64 um	3.00	0.30	0.07	0.59	11.1

a. Lignin composition of Dabob Bay sediment trap samples at 60 m depth (Hedges et al. 1988b).
b. Weighted annual average signatures calculated based on average annual flux (mg m^{-2} d^{-1}) provided by Hedges et al. (1988c).
c. Regional plant soft tissues from Hedges and Weliky (1989).
d. Soils from the Columbia River drainage basin (Willamette Valley) (Prahl et al. 1994).

3.2.2. $\delta^{13}C$ Analyses and Sources of OM in Puget Sound Sediments

The stable isotopic and/or molecular approaches have been used by several studies in the Pacific Northwest to evaluate the contribution of terrigenous OM to the sediments of the Washington Margin (Prahl et al. 1994; Keil et al. 1998), inlets of Vancouver Islands (Nuwer and Keil 2005), the Straight of Georgia (Macdonald et al. 1991), and Puget Sound basins including Dabob Bay (Swanson 1980; Hedges et al. 1988c; Walsh et al. 2008). Overall, such reconstructions estimate that surface sedimentary OM is comprised of 33±6% terrigenous sources in the Straight of Georgia (Macdonald et al. 1991), ~20±10% in Puget Sound (Walsh et al. 2008), and up to 65% in Dabob Bay (Hedges et al. 1988c). Few have shown sediment profiles except for MacDonald et al. (1991) who, based on isotopic and elemental signatures, estimated that the proportion of terrigenous OM increased from 28 to 40% in younger sediments. The authors ascribed this change to the extra burden from terrestrial OC inputs released from six pulp and paper mills located around the Straight of Georgia. Estimates of the historical proportion of terrigenous OC in Puget Sound and Hood Canal sediments were made here using a simple mixing model in which the marine end-member was determined empirically and the terrestrial end-member derived from published data of regional riverine (-26.9±1.9‰) and soil (-26.6±0.8‰) samples (Simenstad and Wissmar 1985; Walsh et al. 2008). The light signatures characterizing this latter end-member, suggest an OM source predominantly comprised of plants using a C_3 carbon fixation pathway. Plants that survive solely on C_3 fixation (C_3 plants) thrive in the Pacific Northwest climate (Raven and Edwards 2001). To constrain the isotopic composition of marine-derived OC, we extrapolated the correlation lines between $\delta^{13}C$ and carbon-normalized lignin yields for each core (Figure 27) to a biomarker concentration of zero (Prahl et al. 1994; Louchouarn et al. 1999; Sánchez-García et al. 2008; Walsh et al. 2008). The marine end-members resulting from each of these relationships (r^2 = 0.62-0.81; Figure 28) are strikingly similar (-19.7±0.2‰) and are consistent with $\delta^{13}C$ signatures from phytoplankton collected during spring blooms in Puget Sound (-20.2±0.8‰) and Dabob Bay (-19.7±0.4‰) (Swanson 1980; Hedges et al. 1988c). The OC isotopic signatures from marine plankton collected in the Clayoquot Sound fjord system of Vancouver Island (-17.0±0.2‰) (Nuwer and Keil 2005) were heavier than the average values reported for Puget Sound, but not uncommon since a few plankton tow samples in Puget Sound showed similarly heavy signatures (Swanson 1980). We thus used our empirically determined marine end-member (-19.7‰) and the literature derived terrigenous end-member (-26.8‰) to calculate the proportion of terrestrial and marine OM preserved in the historical sedimentary records from Puget Sound and Hood Canal.

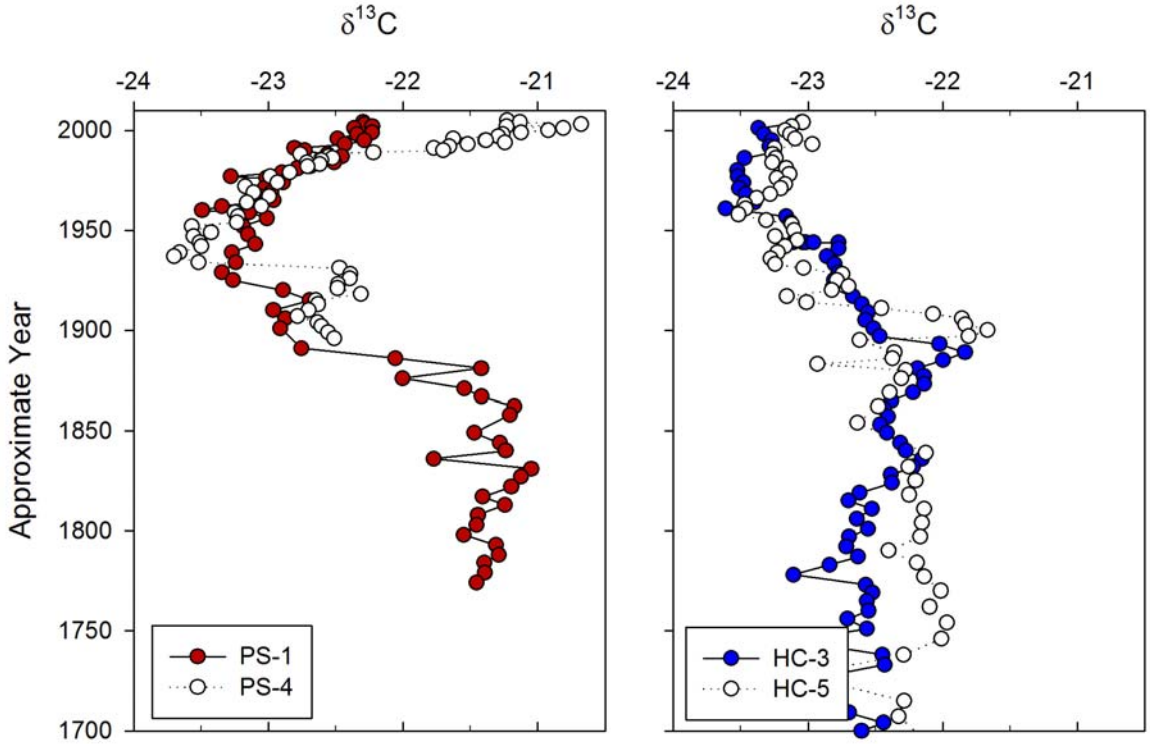


Figure 27. Stable isotopic signatures of carbon ($\delta^{13}C$) in central Puget Sound (PS-1 and PS-4) and Hood Canal (HC-3 and HC-5) sediment cores.

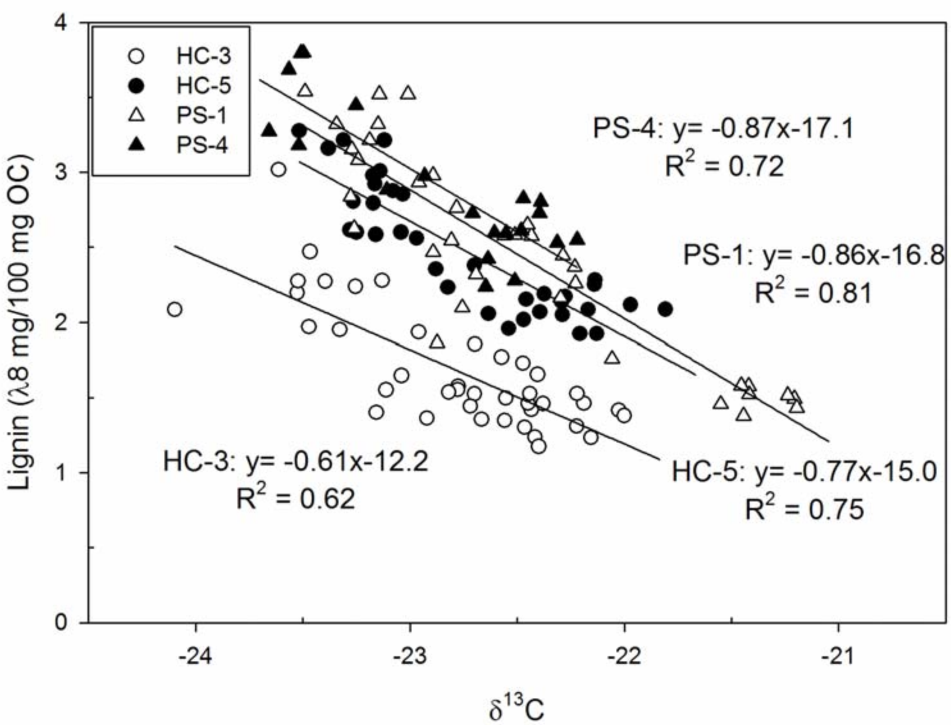


Figure 28. Relationships between carbon-normalized lignin yields (λ8 in mg/100 mg OC) and stable isotopic signatures of carbon ($\delta^{13}C$) in central Puget Sound (PS-1 and PS-4) and Hood Canal (HC-3 and HC-5) sediment cores.

The proportion of OC from marine sources in Puget Sound cores ranged from ~45-80% with higher values (70-80%) in sediments deposited prior to the early 1900s and minima (45-50%) during the mid-20th Century (Figure 29). The historical trend in marine/terrigenous OM proportions is independently verified by both the (C/N)a ratios and lignin yields and demonstrates that major shifts in source inputs, rather than diagenetic transformation, have been the predominant factor influencing the signature of settling OM being preserved in sediments of the entire Puget Sound. Whether the decrease in the proportion of marine OM is entirely the result of a "dilution effect" by added terrigenous inputs (mostly from land clearance and forestry industry) and/or traces a significant change in primary production in the system over the last 100 years is still unclear. However, the covariance between BSi concentrations and $\delta^{13}C$ signatures in cores HC-5 and PS-1 (Figure 30), suggests a relationship between OM source inputs and productivity. In addition, the overall abundance of diatoms, discussed in Section 3.4 decreased during this same time period.

The extrapolation of these correlation lines to a BSi concentration of zero, produces a terrigenous end-member (-25.9±0.6‰) that is quite consistent with the values reported previously, thus confirming the fluctuating mixtures between marine and terrigenous OM inputs to these systems over the past 100-150 years. Since changes in OC concentrations in these two cores vary by only 0.5% (weight per weight) during that period, it is unlikely that the observed drop in BSi content in sediments (13-15 to 10-11 weight %) could be explained by a simple addition of terrigenous OC. Instead, these profiles suggest that there may have been some changes in productivity in the system that either coincided with or were the result of large terrigenous inputs of OM from the watershed and local industries or some unidentified natural process. Alternatively, increased regeneration rates of marine OM and dissolution of BSi could also be invoked to explain the selective preservation of terrigenous OM in the sedimentary record at these sites. High levels of OM regeneration and silica dissolution have indeed been reported to occur in the less ventilated regions of Puget Sound and particularly in the shallow inlet of Lynch Cove, past the Great Bend of Hood Canal (Paulson et al. 1993; Mackas and Harrison 1997). However, an increased rate of OM regeneration should have led to RSM enrichment and OM diagenetic signatures in deep waters that would attest to such a process. Stable isotopic nitrogen signatures and RSM concentrations do not support this alternative explanation for increased BSi dissolution during the mid-20th Century in HC-5 and PS-1 cores (see discussion below). Moreover, the lower but constant BSi concentrations (9.9±0.5 weight %) observed over the last ~200 years in the core closest to Lynch Cove (HC-3) further suggest that local variations in either productivity and silica fluxes to sediments need to be accounted for to explain these profiles. Specific work will thus be required to address the potential changes in past productivity in Puget Sound and Hood Canal and particularly if and why large-scale terrigenous OM inputs may have altered productivity in the system (e.g. increased shading effect, added inputs of toxic metals) or if natural cyclic processes have attributed to this change.

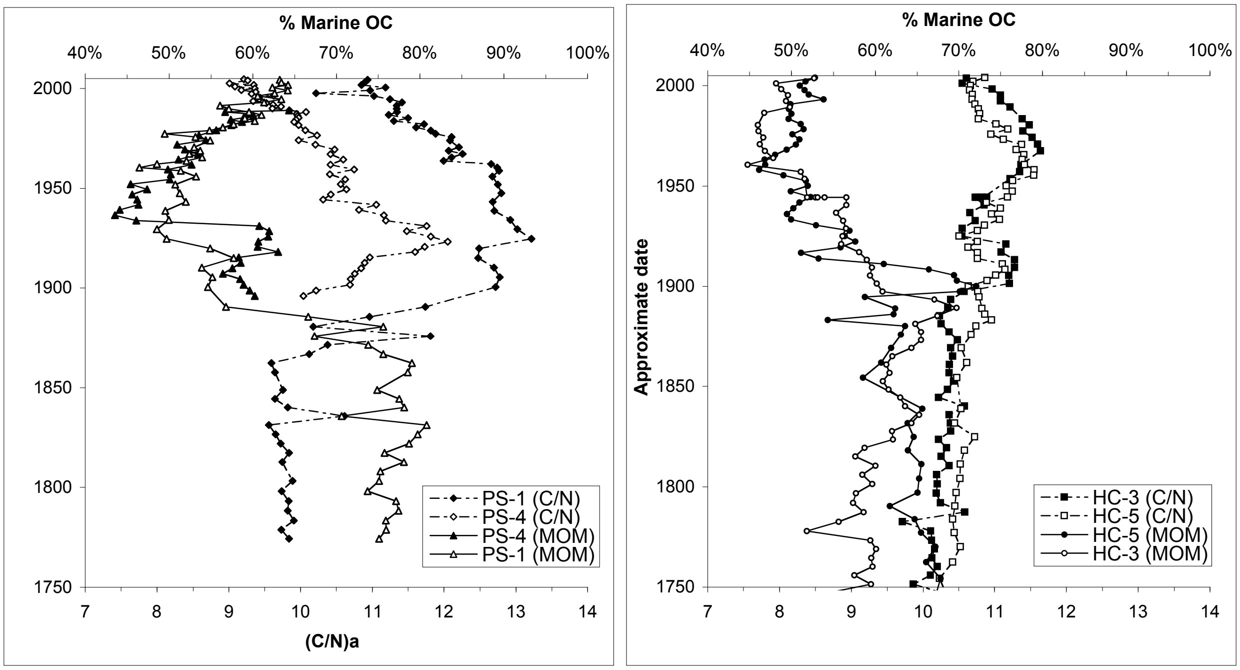


Figure 29. Proportion of marine organic carbon (MOM) calculated using sediment δ^{13}C signatures and the two mixing end-members defined in the text. Profiles of (C/N)a ratios are plotted for comparison.

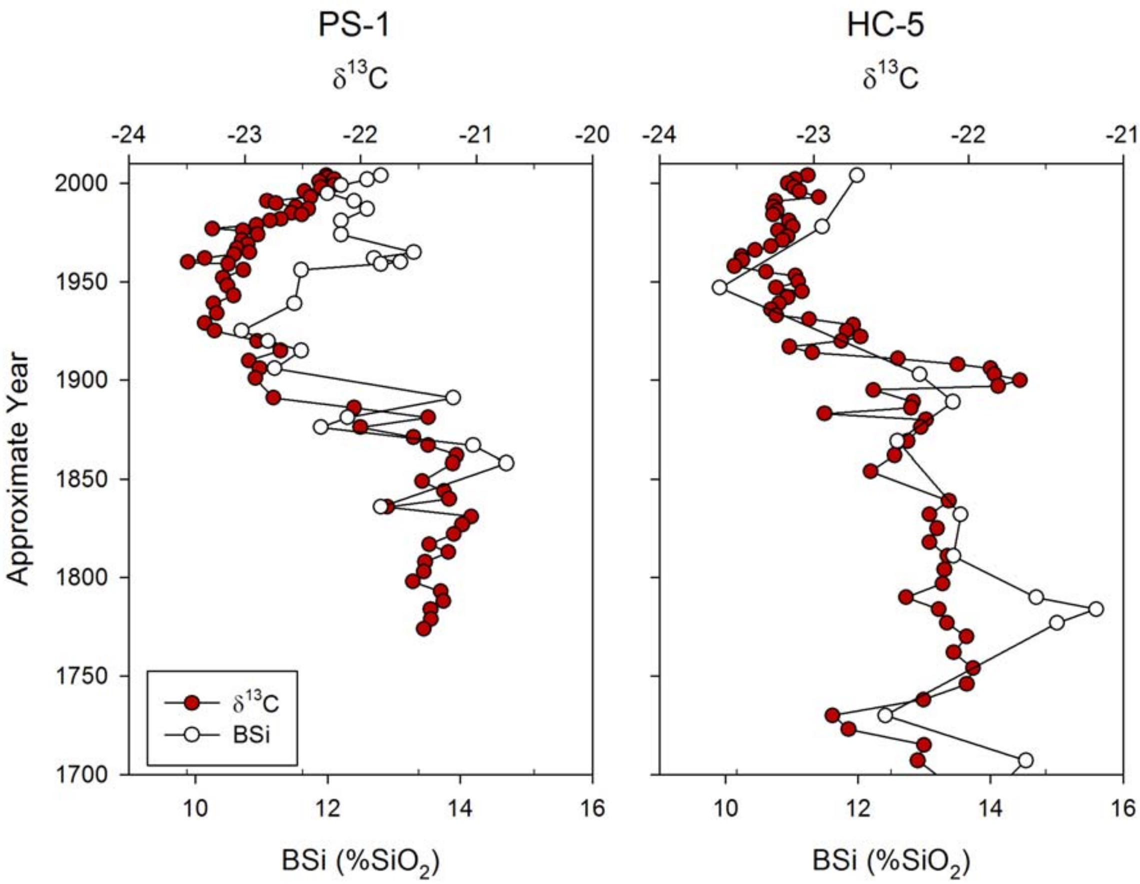


Figure 30. Biogenic silica (BSi) and stable isotopic signatures of carbon (δ^{13}C) in central Puget Sound (PS-1) and Hood Canal (HC-5) sediment cores.

3.2.3. $\delta^{15}N$ Analyses and Shifts in Productivity in Puget Sound

Changes in sedimentary $\delta^{15}N$ signatures are more difficult to interpret than those of $\delta^{13}C$ because they tend to be influenced by a large number of biogeochemical processes including source inputs of dissolved nitrogen, as well as, uptake and regeneration processes in both the water column and in sediments (Fogel and Cifuentes 1993; Macko et al. 1993). In primary producers, $\delta^{15}N$ signatures are generally related to the supply and use of dissolved inorganic nitrogen (DIN) with preferential uptake of lighter isotopes when the DIN pool is relatively large (Mariotti et al. 1984; Meyers 2003). Enriched $\delta^{15}N$ values are thus observed when the DIN pool is depleted and selective discrimination during nutrient uptake diminishes (Mariotti et al. 1984). Other situations resulting in heavier sedimentary $\delta^{15}N$ signatures include external loadings of isotopically enriched N to the bioavailable pool (i.e. farming and sewage waste disposal) or internal recycling processes of nutrients under anaerobic conditions [i.e. denitrification; (Heaton 1986; Macko and Ostrom 1994)]. Strong enrichment of sedimentary $\delta^{15}N$ signatures has thus been used to trace the effect of anthropogenic increases in nutrient loadings to coastal systems and the resulting increased productivity and nutrient regeneration, or cultural eutrophication (Struck et al. 2000; Zimmerman and Canuel 2002; Bratton et al. 2003).

In Puget Sound and Hood Canal cores, a marked enrichment in ^{15}N, suggestive of increased productivity in the basin, does not occur in recent sediment deposits, as was reported for the anthropogenically impacted coastal systems of the Chesapeake Bay, Gulf of Mexico, and Baltic Sea (Eadie et al. 1994; Struck et al. 2000; Zimmerman and Canuel 2002; Bratton et al. 2003). In the last 200 years, and with the exception of core HC-3, the $\delta^{15}N$ record follows that of the $\delta^{13}C$ (Figure 31) with a marked depletion in signatures (from ~+7 to +5-6‰) starting around the end of the 19th Century and reaching a minimum in the middle of the 20th Century. Core HC-3 also shows a decrease during the 20th Century but less intense (from ~+7 to +6) and somewhat delayed towards the late 1970s. A recovery trend is apparent in recent decades in all cores, though signatures still remain depleted with respect to pre-20th Century values. These profiles thus provide little support for increased rates of productivity in the last century fueled by water column nutrient regeneration and/or external inputs from sewage nutrients and agricultural fertilizers. Instead, the $\delta^{15}N$ record suggests, again, a shift in the sources of OM reaching the sediments of Puget Sound.

Recently, Nuwer and Keil (2005) have used nitrogen isotope signatures to calculate the proportion of marine and terrestrial OM inputs to sediments along land-to-sea transects in fjords of Vancouver Island. They have shown that phytoplankton OM is enriched in ^{15}N (8-9‰) consistent with the enriched signatures of nitrates (7-9‰) reported for the coastal systems of the region. The relatively heavy $\delta^{15}N$ signatures observed prior to 1900 (7‰) thus seem consistent with the interpretation that most of the OM preserved during those times is of marine origin (70-80%). During the 20th Century, the dilution of this pool of OM through the addition of lighter soil and vascular plant OM (Nuwer and Keil 2005) may thus help explain the shift toward lighter $\delta^{15}N$ signatures during a time when terrigenous OM inputs were at a maximum.

A reconstruction of marine *vs*. terrigenous OM inputs using the previously discussed isotopic mixing model but using marine and terrigenous $\delta^{15}N$ end-members of 7-9‰ and 1-4‰ (Mariotti et al. 1984; Wada et al. 1987; Cifuentes et al. 1988) produced estimates that correlated with those obtained using $\delta^{13}C$ signatures (r^2 = 0.21-0.77) and which slopes were close to a 1:1 relationship (0.94±0.2). Again, more work would be needed to better constrain terrigenous $\delta^{15}N$ signatures of particulate OM transported into the system, but the estimates used are consistent with suspended particulate matter collected in the Hood Canal basin (Brock 1999) showing higher $\delta^{15}N$ signatures in surface waters of the Hood Canal (7.9±1.4‰) than in the Skokomish River (4.0‰). This simple approach suggests that mixing processes can probably explain a large proportion of the observed shifts in OM signatures observed in Puget Sound sediments over the past 100-200 years. None of these shifts, however, can at the moment support the notion that primary productivity and nutrient regeneration have increased substantially in both basins due to eutrophication.

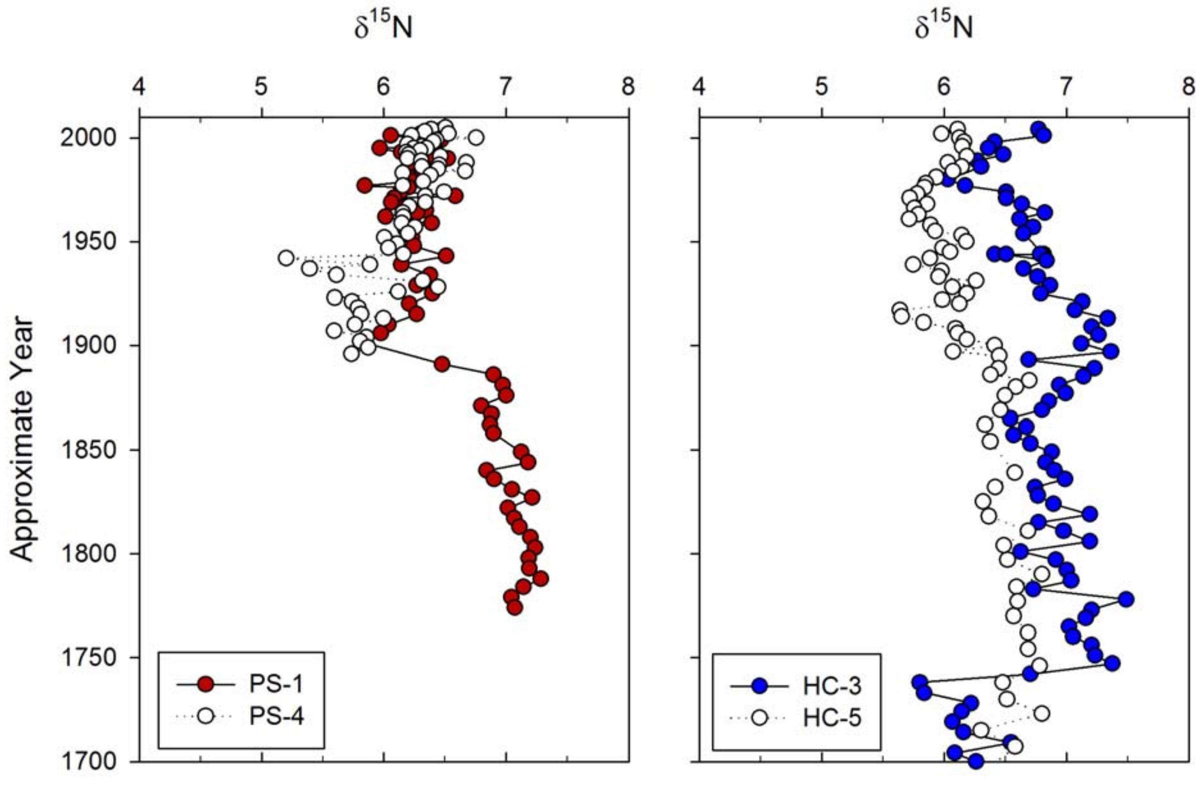


Figure 31. Stable isotopic signatures of nitrogen ($\delta^{15}N$) in central Puget Sound (PS-1 and PS-4) and Hood Canal (HC-3 and HC-5) sediment cores.

3.2.4. Sources of OM and Low Oxygen Levels in Puget Sound

Despite the increased efforts to measure dissolved oxygen in recent decades in Hood Canal, a continuous instrumental record doesn't exist for the past 100-150 years in the water column of the Puget Sound system. This lack of data hampers the understanding of the processes, including the potential impacts from human activities, which have been postulated to drive low oxygen levels in this system. The presence or absence of a suite of RSM indicators in the sedimentary records can help infer such historical changes in oxygen conditions in coastal waters, as discussed above (Crusius et al. 1996; Morford and Emerson 1999; Adelson et al. 2001; Morford et al. 2007). The preservation of RSM enrichment events in sediment cores has indeed been used to determine past changes in oxygen conditions over time, which have been linked to shifts in OM fluxes and biological oxygen demand across the sediment-water interface (Schulte et al. 1999; Adelson et al. 2001; Pailler et al. 2002; Nameroff et al. 2004).

Here, we looked for potential relationships between the reported historical shifts in OM source inputs to Puget Sound sediments and the ratios of RSM, which serve as indicators of redox condition in deep waters of the system (see RSM 3.1.4). In particular, we used the RSM profiles to test our initial hypothesis that early 20th Century changes in land use led to the onset of low oxygen conditions in Puget Sound basins. Of all the RSM discussed in the metals section we selected and used the Cd to Al ratios (Cd/Al) in the present section. Though all RSM ratios show similar behaviors in the four detailed cores, Cd has been shown to act as a nutrient in Hood Canal being removed from surface waters and transferred to deep waters by biological processes (Paulson et al. 1993). Under reducing conditions, substantial sequestration of dissolved Cd into sulphide minerals has also been shown to occur in sediments of a Vancouver Island inlet (Pedersen et al. 1989) and of the Laurentian Trough in the St. Lawrence Estuary (Gobeil et al. 1987) supporting the use of this metal as a tracer for reducing conditions in deep waters or at the sediment-water interface, which result from high productivity and/or low ventilation.

In the present study, the Cd/Al ratio and the marine OM proportion are used as relative “indices” (horizon’s value minus core average), rather than as absolute values. This allows for the visualization of positive and negative excursions of these independent markers with respect to the average core conditions and for a better comparison of anomalies for the two different indices across the four cores. Figure 32 illustrates the changes in these relative indices with positive values for the MOM index illustrating more marine source inputs and positive values in the RSM index indicating more reducing conditions in sediments. With the exception of sediments from the most ventilated core in central Puget Sound (PS-4; see discussion in 3.1.4), all sediment cores show a relatively good relationship between the RSM ratios and the MOM proportions (r^2 = 0.47-0.76). The two cores from Hood Canal and PS-1 all show a strong shift from predominantly marine OM signatures and reducing conditions during the 18th to 19th Centuries to more terrigenous OM signatures and more oxygenated conditions during the 20th Century. A maximum in these latter signatures and conditions seem to have occurred in the middle of the 20th Century. A slight shift towards more marine signatures and relatively reducing conditions during recent decades are apparent in Puget Sound cores, but not clearly so in Hood Canal. The mid-20th Century’s depletion in RSM (more oxygenated conditions) in three of the studied cores is consistent with the instrumental record reporting relatively high oxygen levels in deep waters of Hood Canal during the 1930-50s with respect to today’s depleted conditions (Newton et al. 2007).

Because strongly reducing conditions preserved in the sedimentary records for the 20th Century are not observed, this rejects the initial hypothesis that the expansion of land-use activities would lead to the onset of hypoxic conditions in the system. The synchronous shifts towards more oxygenated conditions in the 20th Century, a time when large inputs of terrigenous OM started to flow into the basins, suggests that natural processes have a strong driving influence on ventilation and oxygen levels in the deep waters of the entire system.

Alternative explanations for the observed shifts in RSM ratios need to be considered. Changes in detrital fluxes (and thus metal fluxes), due to changes in erosional inputs from the basin, could act as alternative process driving such changes over time. However, if shifts in detrital inputs were behind the shifts in metal concentrations, then the Al-normalization (which tends to track aluminosilicate inputs), should yield relatively constant RSM/Al ratios. This is not the case for both RSM concentrations and normalized ratios, as the trends are exactly the same (Figure 32). Alternatively, we could invoke an "aluminum dilution" effect (changes in aluminosilicate inputs over time). If Al dilution were an important factor, then all cores should show the same dilution effect at the same time. That's particularly true since all cores show strong consistencies in the changes in most of the organic and inorganic signatures; for example, the non-redox sensitive metals and lignin yields (Brandenberger et al. 2008). The problem with that alternative is that aluminum concentrations do not change significantly throughout the entire depths of the cores suggesting that substantial changes in Al inputs have not occurred. Secondly, the relationships between Cd/Al vs. %MOM for all four cores illustrate marked differences across cores. In PS-4, the large changes in %MOM were not accompanied by consistent changes in the Cd/Al ratio (and any other RSM/Al ratios) suggesting there is a difference between the sites that cannot be ascribed to a dilution effect (which we would expect to be relatively uniform at least within each basin).

Progressing more ventilated (PS-4) to less ventilated (HC-3) cores sites (Mackas and Harrison 1997), the slope of the relationships between Cd/Al and %MOM increases confirming a relationship between dissolved oxygen concentrations and RSM enrichment. Makas and Harrison (1997) have shown that there is indeed a geographical gradient in dissolved oxygen concentrations in Hood Canal. Hence, the geographical "gradient" in the RSM/Al ratios and the increased magnitude of enrichment in Hood Canal cores *vs*. Puget Sound cores support the redox cycling explanation for the observed trends rather than an influence from an Al dilution effect. The RSM collectively show different levels of enrichment on both geographical and temporal scales (see Section 3.1.4) which support geochemical cycling rather than major changes in detrital inputs as drivers of enrichment in these sediments. The lack of a link between %MOM and Cd/Al at PS-4 also suggests that productivity alone is not the only driving factor for deep water oxygen limitation.

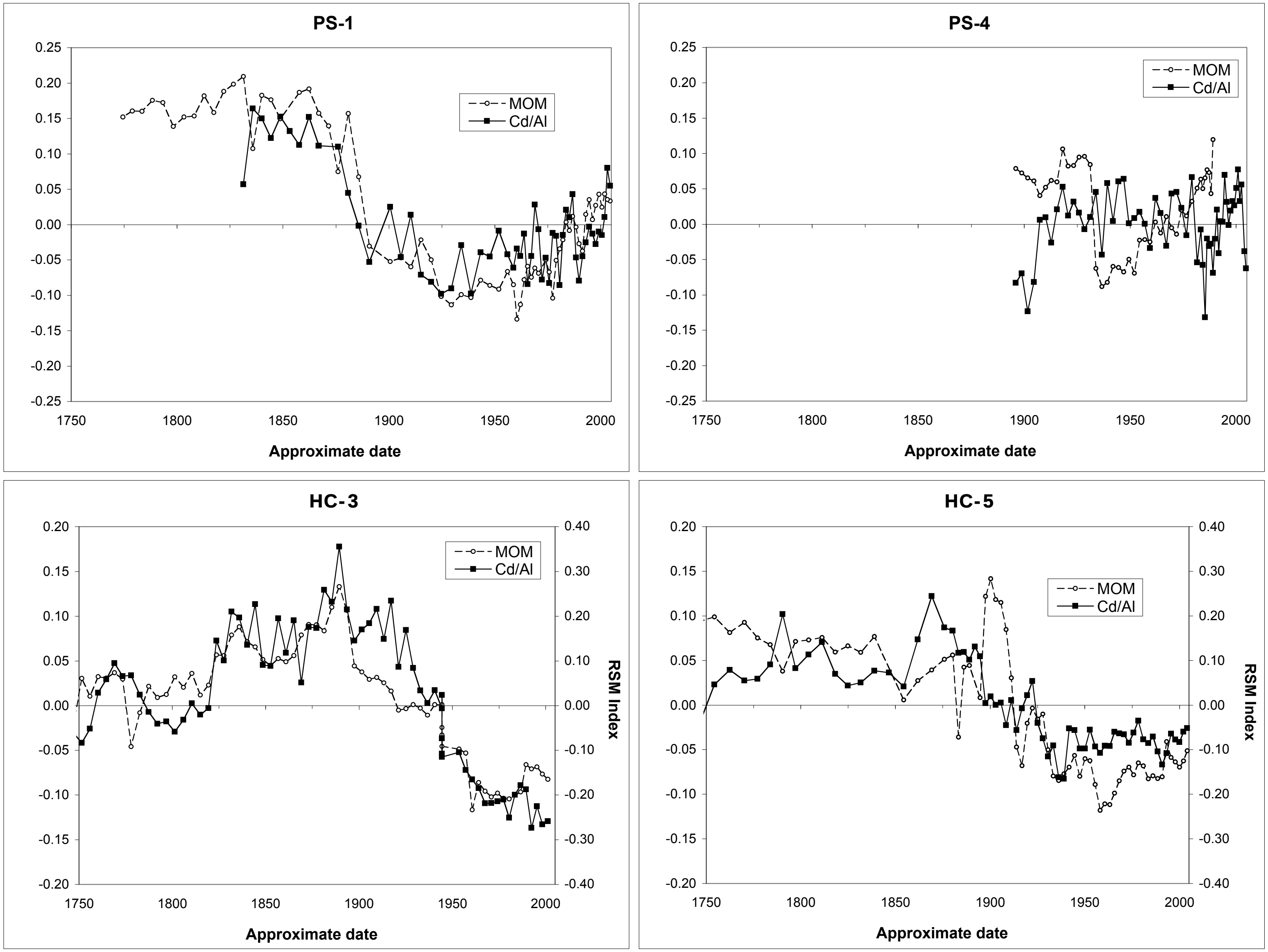


Figure 32. Marine organic matter and redox sensitive metal indices (MOM and Cd/Al, respectively) in central Puget Sound (PS-1 and PS-4) and Hood Canal (HC-3 and HC-5) sediment cores.

3.3. Pollen Horizons

Pollen floras from Puget Sound and Hood Canal cores are relatively simple in composition and dominated by woody, wind-pollinated plants, especially conifers and Alder (*Alnus*). The old growth conifers in this region include the main species as follows: Western Redcedar (*Thuja plicata*), Douglas-Fir (*Pseudotsuga menzesii*), and Grand Fir (*Abies grandis*) with some Pine and Sitka Spruce (*Pinus contorta, Pinus monticola, and Picea sitchensis*). After disturbance and logging, the primary forest secession is red Alder (*Alnus rubra*), weeds, and other shrubs. These are the main arboreal types seen in the pollen diagrams. The results of pollen counts from Puget Sound (Figures 33 through 35; PS-1, PS-2, and PS-3, respectively) and Hood Canal (Figures 36 through 38; HC-3, HC-4, and HC-5, respectively) are plotted as percentages of pollen and spores based on pollen counts for each sediment sample relative to core segment depth (cm). The estimated ages are reported from the ^{210}Pb dating. Pollen percentages are grouped from left to right including conifers, dicot trees, herbs, and ferns. The summation of the pollen types are presented on the right along with miscellaneous items not included in the percentages, such as fungal spores, and algae.

The pollen diagrams show similar composition and changes through time in both Puget Sound and Hood Canal, but at somewhat different initial times. The boundaries between zones occur at different depths depending on the rate of sedimentation in each core, but show similar ages of deposition. These temporal patterns are described by recognizing three primary phases or zones in the pollen profiles consistent between coring locations.

Lower Pollen Zone: This is the earliest phase characterized by a stable pollen rain where total conifer pollens are dominant.

Middle Pollen Zone: This is a transition zone marking a general decrease in the percentage of total conifer pollen and the start of a rise in *Alnus* pollen.

Upper pollen zone: The most recent phase of pollen rain is dominated by *Alnus* and weed pollen and conifer pollen has fallen to about half or less of the original value.

In the Lower Pollen Zone, the prominence of relatively stable conifer pollen values seems to represent the signature of the early old growth forest around Puget Sound. Of the native conifers, the Western Red-cedar produces the most pollen per flower and is expected to be dominant in the count. In the Middle Pollen Zone, the decrease of total conifer pollen is accompanied by the rise of Alder, and suggests a loss of some old growth trees and the appearance of successional “seral” species such as Alder, grasses and weeds, especially of the daisy family. These represent the growing importance of brush and weeds in the disturbed forest. In the Upper Pollen Zone, the low values of conifer pollen and the now dominant weedy species demonstrate the disturbed forest in its most recent phase.

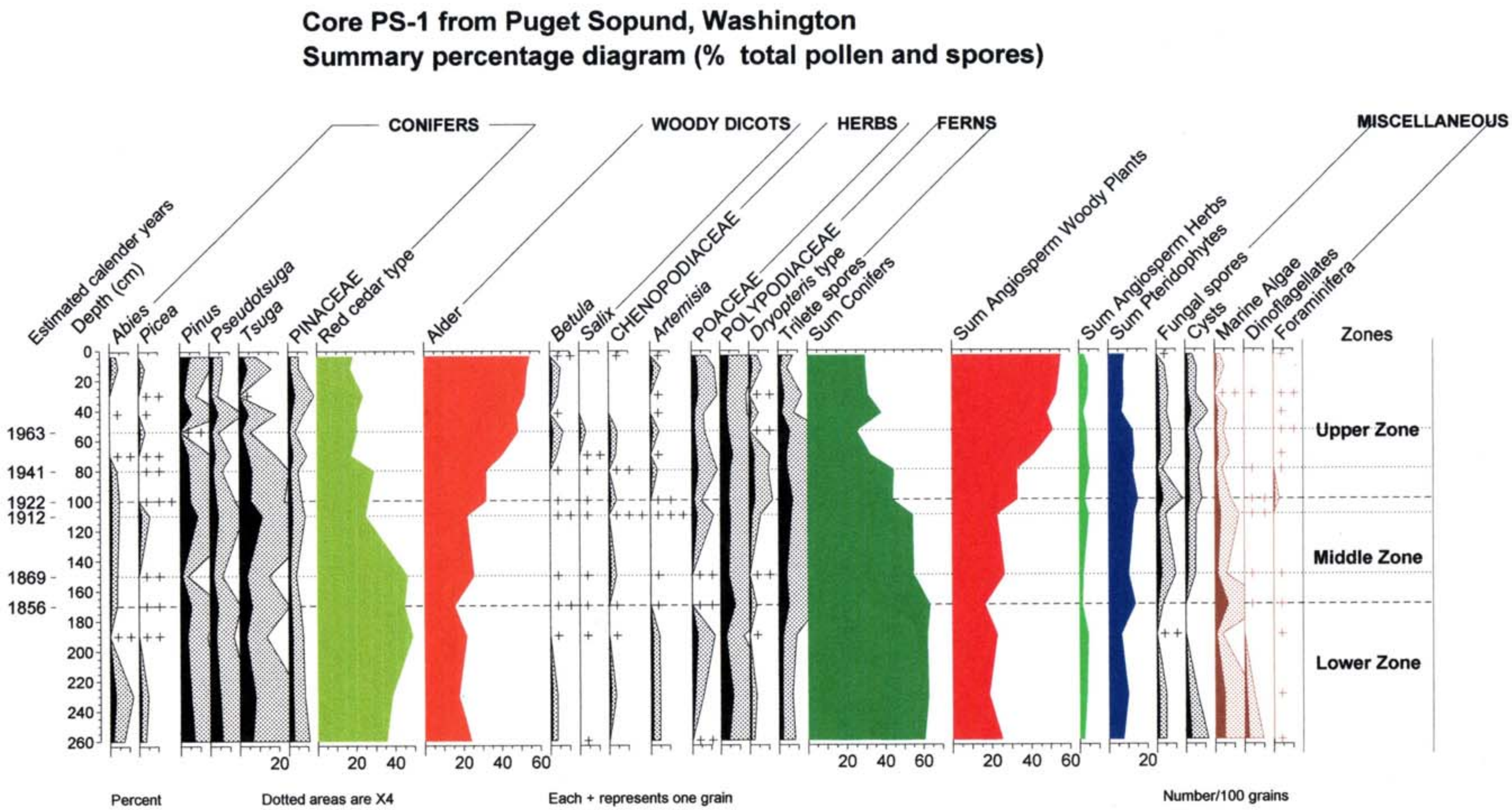


Figure 33. Summary percentage diagram for pollen rain and microfossil reconstructions in Puget Sound core PS-1 plotted as the percent of total pollen and spores relative to down-core depth (cm) and annotated with estimated ages from ^{210}Pb chronology. All three pollen zones are identified on the right.

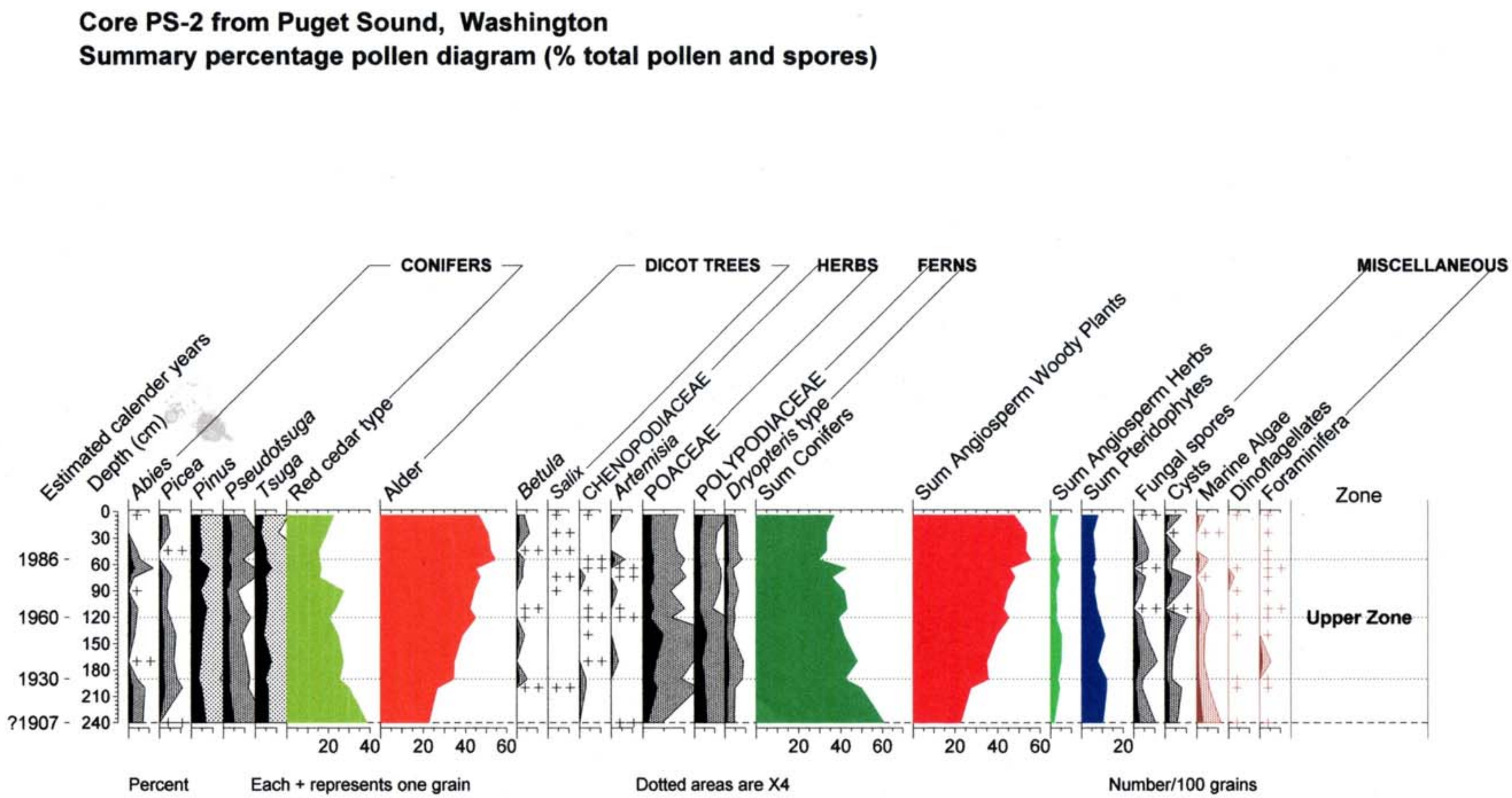


Figure 34. Summary percentage diagram for pollen rain and microfossil reconstructions in Puget Sound core PS-2 plotted as the percent of total pollen and spores relative to down-core depth (cm) and annotated with estimated ages from ^{210}Pb chronology. Only the upper pollen zone is apparent because the core only extends back to the early 1900s.

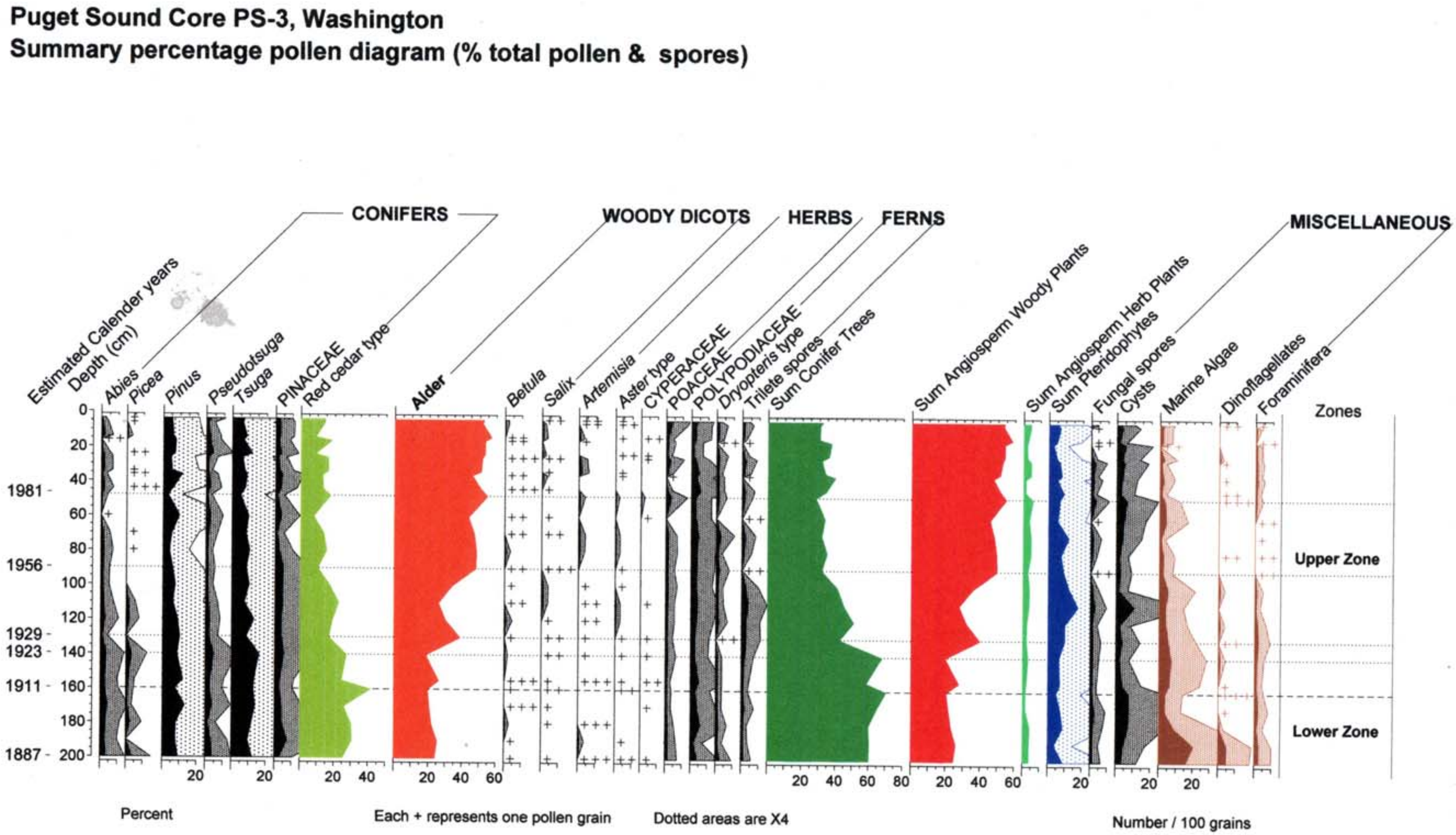


Figure 35. Summary percentage diagram for pollen rain and microfossil reconstructions in Puget Sound core PS-3 plotted as the percent total pollen and spores relative to down-core depth (cm) and annotated with estimated ages from ^{210}Pb chronology.

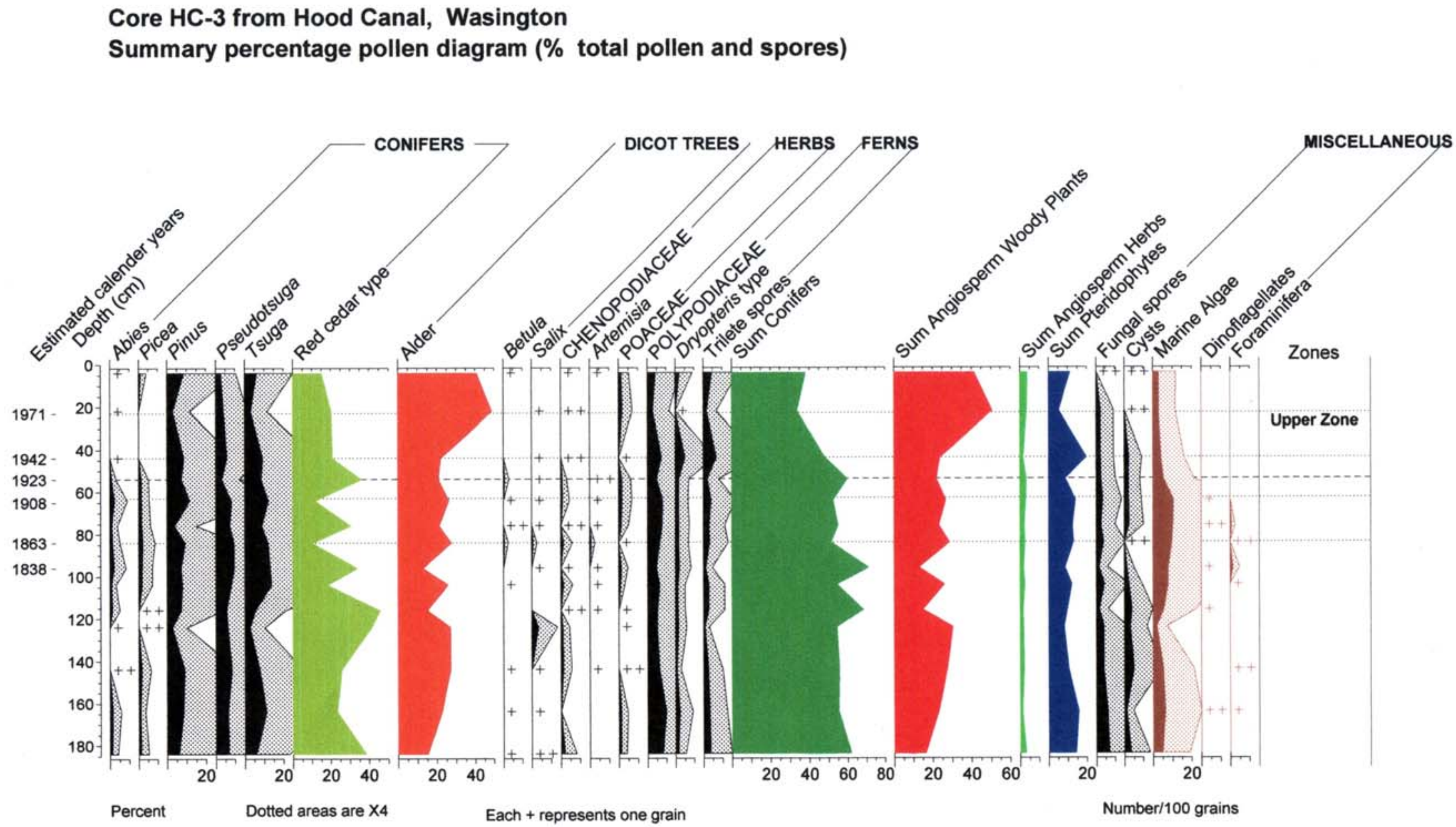


Figure 36. Summary percentage diagram for pollen rain and microfossil reconstructions in Hood Canal core HC-3 plotted as the percent total pollen and spores relative to down-core depth (cm) and annotated with estimated ages from ^{210}Pb chronology. The transitional or Middle Zone is not apparent in the Hood Canal cores. The variability noted pre-1863 maybe due to natural disturbances within the watershed (i.e. fires, floods, etc.).

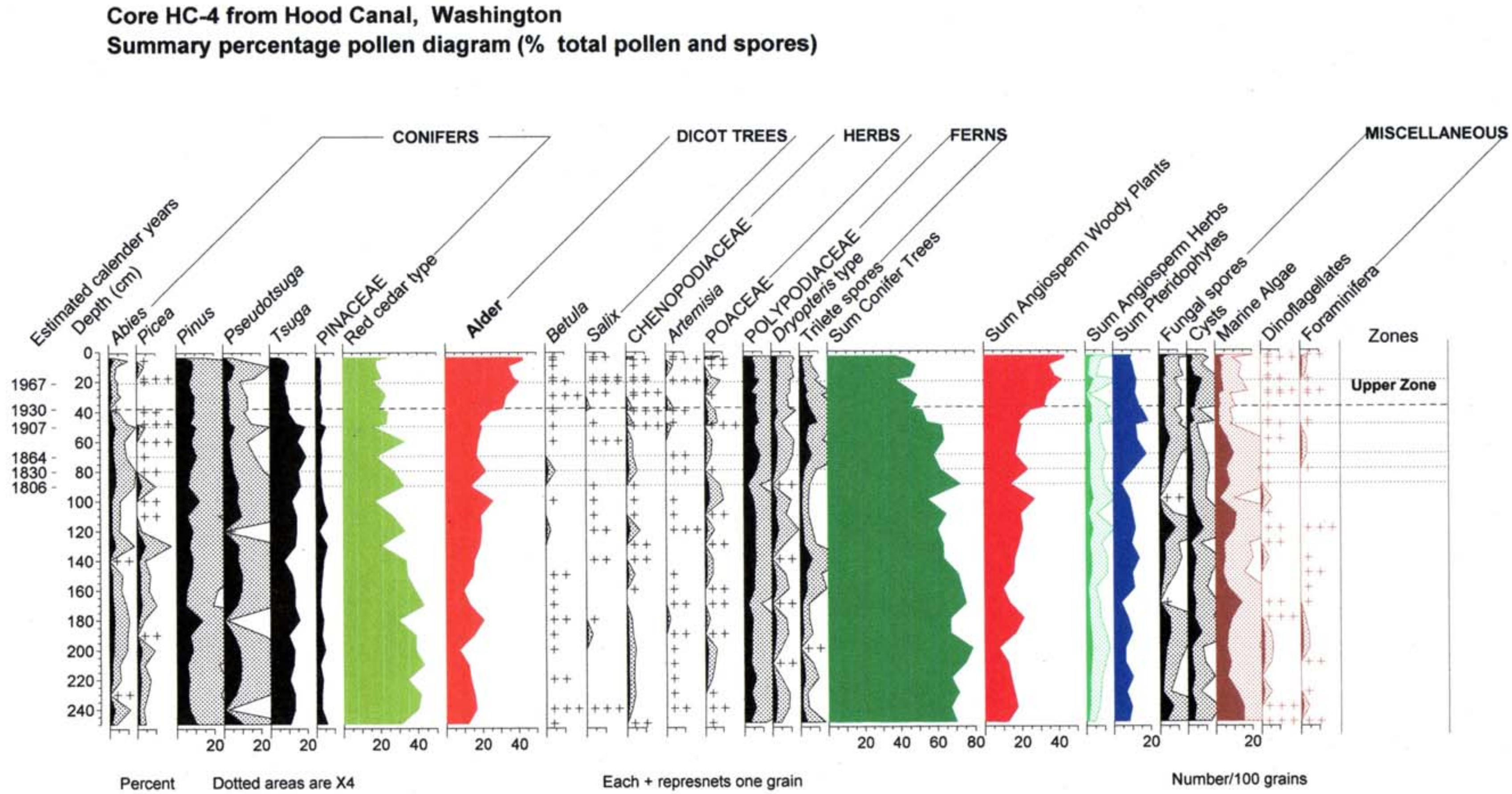


Figure 37. Summary percentage diagram for pollen rain and microfossil reconstructions in Hood Canal core HC-4 plotted as the percent total pollen and spores relative to down-core depth (cm) and annotated with estimated ages from ^{210}Pb chronology. Only the Upper Zone is clearly identified beginning ca. 1930s.

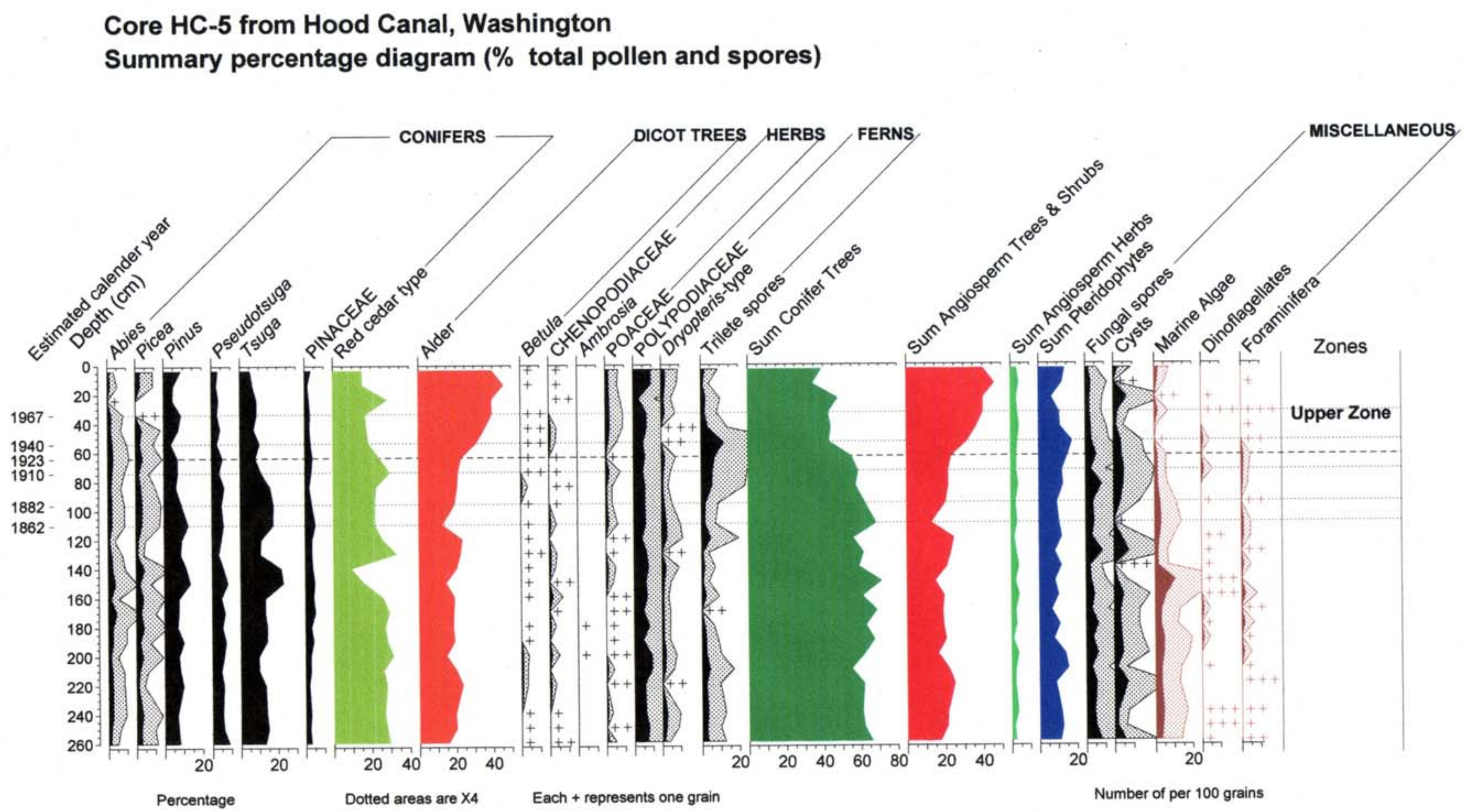


Figure 38. Summary percentage diagram for pollen rain and microfossil reconstructions in Hood Canal core HC-5 plotted as the percent total pollen and spores relative to down-core depth and annotated with estimated ages from ^{210}Pb chronology. The rise in Alder pollen occurs at similar time periods to other cores, but the decline in total percent conifer pollen is much later.

The transition from old growth forest signatures to a more recent disturbed forest marks the time frame of significant forest clearing. Table 9 summarizes the initial dates marking the statistical breaking points in the pollen profiles defined as the conifer decline by 50% or Upper Pollen Zone in the most recent sediment horizons and the point at which Alder pollen counts exceed the natural variability of the forest's historical pollen composition or the Middle Pollen Zone. The natural or background forest signature was calculated as the average and standard deviation of core segments progressing from the oldest or bottom of the core upward. The core segment containing signatures that were outside the mean ± 2σ signature of older segment was defined as the first human induced alteration of the forest composition. The mean and standard deviation of the older segments were considered the natural fluctuation of the Alder pollen for each basin (Table 9). In both basins, this increase in Alder pollen above the natural fluctuations begins around the 1920 or 1930s, with the exception of HC-3. The late increase in Alder may result from an artifact in the core where the core segments from 35-45 cm were considered to be a slump event and multiple core segments were mixed.

The initial ages of significant forest disturbance or the start of the Upper Pollen Zone were determined as the oldest core segment recording total conifer pollen counts that had decreased by ≥ 50% from that of the background or natural forest signature. This point was generally around the 1950s-60s in Puget Sound and 1970s-1990s in Hood Canal, which occurs after 1945 when land clearing practices increased significantly with the mass production of the single-person chainsaw. In Hood Canal, the Alder pollen increases, but does not dominate the composition until around the 1970s, except at HC-5. The late date of the Alder dominance at HC-5 may be due to the distance of this location from a majority of the land-clearing occurring in the Lynch Cove and southern Hood Canal region and also supports the discussion that the sediment supply for HC-5 differs from that of the southern Hood Canal (see Section 3.1.2). A large percentage of the watershed area directly surrounding the HC-5 location is very rugged and not easily accessible to logging activities.

In general, before the 1860s the vegetation shown by the pollen rain in this area remained relatively stable (Lower Pollen Zone), although with some small disturbances probably caused by natural events, which are more prominent in the Hood Canal reconstructions. The pollen reconstructions support the inference that lumbering started at a slow rate between the mid-1800s and early 1900s and then accelerated through the 1900s with technological advances.. Therefore, the profiles conclusively illustrate changes in pollen percentages in the marine sediments related to human influence, e.g., land-use changes of the last 100-150 years. Analogous findings in pollen from European bogs and lakes point to the influence of man on the landscape (Faegri and Iversen 1975). In fact, land vegetation changes in definite trends revealed by the pollen profiles roughly correspond with disturbance horizons recorded in lakes of the central Puget Sound watershed (Davis 1973; Leopold et al. 1982) and undoubtedly reflect human impacts on the forests recorded in the marine sediment cores of Puget Sound basins.

Table 9. A summary of core depths and estimated ages for the earliest disturbance zone for the pollen composition marked as the increase in successional Alder and seral plants above the natural forest signatures and the most recent and highly disturbed forest composition as the old growth total conifer pollen composition falls to less than 50% of the natural forest signatures in both central Puget Sound (PS-1, PS-2, and PS-3) and Hood Canal (HC-3, HC-4, and HC-5) sediment cores.

Puget Sound						
	PS-1		**PS-2**		**PS-3**	
	Core Segment (cm)	Estimated Year ± 1σ	Core Segment (cm)	Estimated Year ± 1σ	Core Segment (cm)	Estimated Year ± 1σ
Conifer decline ≥50%	65-70	1952 ± 5	115-120	1961 ± 3	85-90	1958 ± 3
Alder > 2σ Historical Composition	95-100	1925 ± 7	195-200	1927 ± 5	125-130	1931 ± 4
Hood Canal						
	HC-3		**HC-4**		**HC-5**	
Conifer decline ≥50%	20-22	1974 ± 3	18-20	1971 ± 4	12-14	1991 ± 1
Alder > 2σ Historical Composition	20-22	1974 ± 3	38-40	1927 ± 10	52-54	1939 ± 3

3.4. Diatom Assemblages

3.4.1. Analysis of Diatom Data

Each cubic centimeter of wet sediment analyzed for diatoms from these cores were estimated to contain approximately 89 million to 495 million diatom valves. Appendix E provides a detailed description of the taxa identified and all the diatom data. An interesting result is that diatom abundance may have increased before ca. 1900, but appears to be declining in all but Hood Canal core 1 (HC-1) since ca. 1950 AD (Figure 39). The HC-1 core was not considered an ideal core for historical reconstructions due to a coarser texture, higher porosity, and relatively poor ^{210}Pb profile for the estimated ages. The HC-1 data is included in the following discussion, but trends should be interpreted with caution, as it may not be representative of overall Hood Canal conditions. Ideally, more core segments should be analyzed for a complete history of changes. The largest gaps in the data presented here are between dates of ca. 1800-1865 A.D. and before ca. 1760 A. D. These time periods are probably critical to understanding the history of water quality changes in Puget Sound and Hood Canal related to anthropogenic influences, and comparison with more recent monitoring data. However, some initial information on diatom assemblages is useful for discussing preliminary conclusions and developing future research needs to more clearly define significant changes in the diatom assemblages through time and their implications to historical water quality reconstructions.

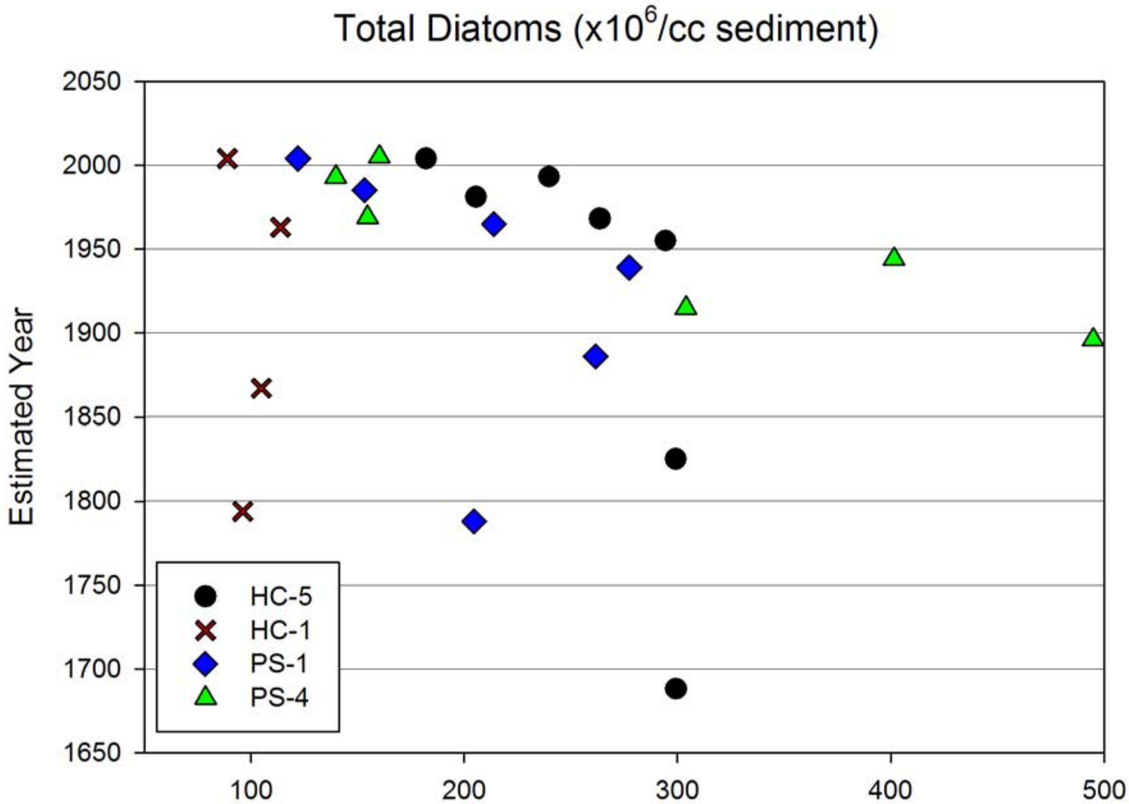


Figure 39. Diatom valve abundance in each cubic centimeter of wet sediment (shown in millions of valves) for Puget Sound (PS-1 and PS-4) and Hood Canal (HC-1 and HC-5) sediment cores. The y-axis indicates estimated year of samples determined by ^{210}Pb chronology.

Over 440 diatom taxa were identified from the 23 core segments analyzed. The diatoms showed mostly good preservation, although there were many fragments. Several taxa in relatively high abundance on the slides were not identified to species, but have been grouped together due to preservation and identification issues. These included *Chaetoceros spp.* (>10% abundance in all samples), *Rhizosolenia spp.* (>5% abundance in 3 samples), *Pseudonitzschia spp.* (>1% abundance in 9 samples), and *Aulacoseira spp.* (>1% in 4 samples). Other taxa have been grouped by genus for data analysis if they were observed to have low abundance and the species in the genus share common ecological requirements. Examples of these include *Gomphonemopsis spp.* and *Fallacia spp.*

The 10 most abundant species identified (followed by their highest percent abundance in any sample) include: *Skeletonema costatum* (Greville) Cleve (25.1%), *Thalassionema nitzschioides* Grunow (10.7%), *Thalassiosira levanderi* Van Goor (6.5%), *Paralia sulcata* (Ehrenberg) Cleve (5.9%), *Thalassiosira decipiens* (Grunow) Jørgensen (5.5%), *Thalassiosira guillardii* Hasle (3.4%), *Achnanthes delicatula* (Kützing) Grunow (3.0%), *Nitzschia frustulum* (Kützing) Grunow in Cleve & Grunow (3.5%), *Thalassiosira oestrupii* (Ostenfeld) Hasle (3.6%) and *Cocconeis* *scutellum* Ehrenberg (2.3%). More detailed descriptions of these taxa were provided in Section 2.5.5.

Diatom slides from HC-5 were counted for every 10 cm depth from the surface to 40 cm (5 slides) dated ca. 1955 to present at five year intervals, and two additional slides; one from 130-135 cm depth (ca. 1825 AD) and one from 220-225 cm depth (ca. 1688 AD). The slides were dominated by small *Chaetoceros*, *Skeletonema* and *Thalassiosira* species. Between 85-102 species were identified for each sample in HC-5.

For the PS-1 core, six samples were counted including the surface sediment sample (dated ca. 2004 AD), 26-28 cm depth (ca. 1985), 50-52 cm depth (ca. 1965), 80-85 cm depth (ca. 1939), 135-140 cm depth (ca. 1886) and 240-245 cm depth (ca. 1788). Especially at the 26-28 cm depth sample (ca. 1985), there was evidence of sedimentation from a freshwater wetland area along with the suite of brackish/marine species. Diatom species representative of epiphytic, epipelic, and epilithic communities present in often low nutrient, wetland, fresh-water (with brackish water affinity) environments, such as *Cymbella microcephala* Grunow in Van Heurck (synonymous with *Encyonopsis microcephala*), *Cymbella sinuata* Gregory (synonymous with *Reimeria sinuata*), *Cymbella minuta* Hilse, *Gomphonema parvulum* Kützing, *Eunotia* species and more freshwater *Achnanthes* species. Between 87-95 species were identified for each sample in PS1.

Six samples were counted for the PS-4 core, but none were dated older than the late 1800s (all between ca. 1896-2005). Between 82-105 species were identified for each sample. The final set of slides counted was from HC-1. Four slides were completed for this core, one from depths/dates within each century (18^{th} – 21^{st} Centuries). Between 98-119 species were identified for each sample. The samples from HC-1 showed the highest diatom diversity compared to the other cores analyzed.

All graphs of diatom data were plotted using a time axis (y-axis) for each of the core segments analyzed determined from the ^{210}Pb radiochronology. The vertical (time) profiles of changes in diatoms can be compared with other indicators of water quality through time. All data are available in Appendix E.

Diatom assemblage diversity as Shannon's H′ does not show clear trends through time in the sediment core samples analyzed (Figure 40). The HC-1 shows the highest overall diatom diversity of the four cores analyzed, and this is evident in the PCA as well. However, the number of genera identified does show an overall decline in more recent samples (Figure 40). Planktonic to benthic diatom ratios between samples show a trend of increasing planktonic forms through time in the southern reaches of the estuaries (see Figure 41; HC-1 and PS-1), but is inconclusive for the HC-5 and PS-4 cores. This increasing trend in the diatom ratio has been used as an indication of eutrophication in other estuaries (Cooper and Brush 1991; Bennion et al. 1996; Cooper et al. 2004; Weckström 2005).

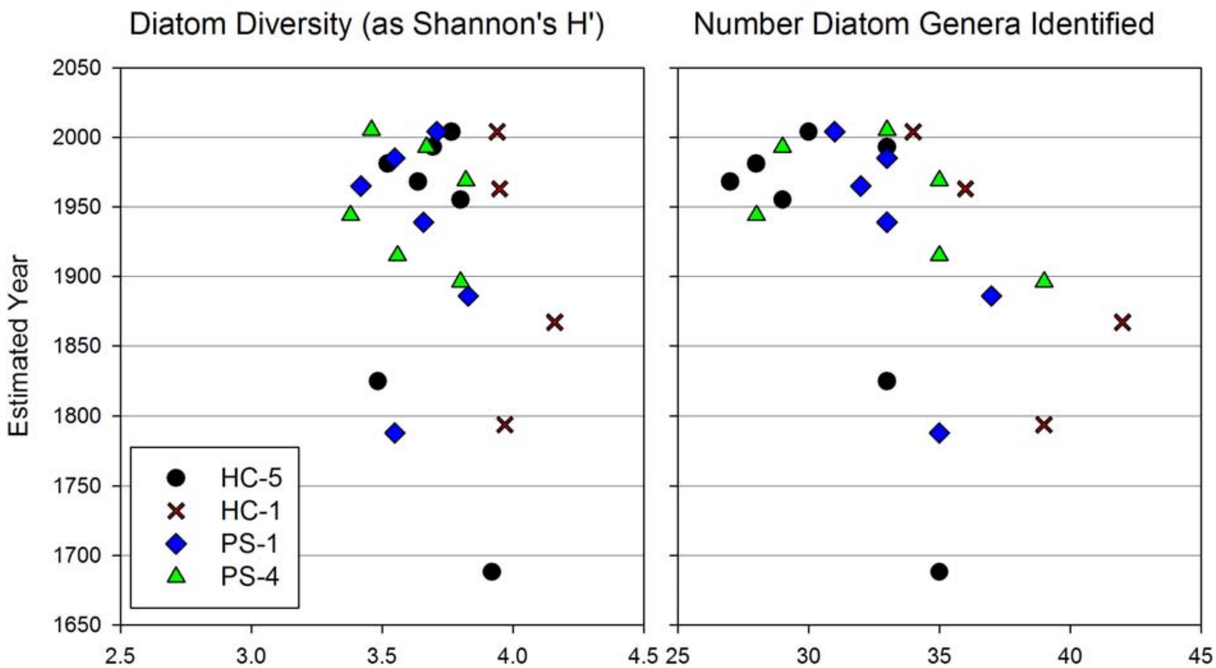


Figure 40. On the left is diatom diversity calculated using Shannon's H' for samples analyzed from central Puget Sound (PS-1 and PS-4) and Hood Canal (HC-1 and HC-5) sediment cores plotted against estimated age. On the right, are the total numbers of genera identified.

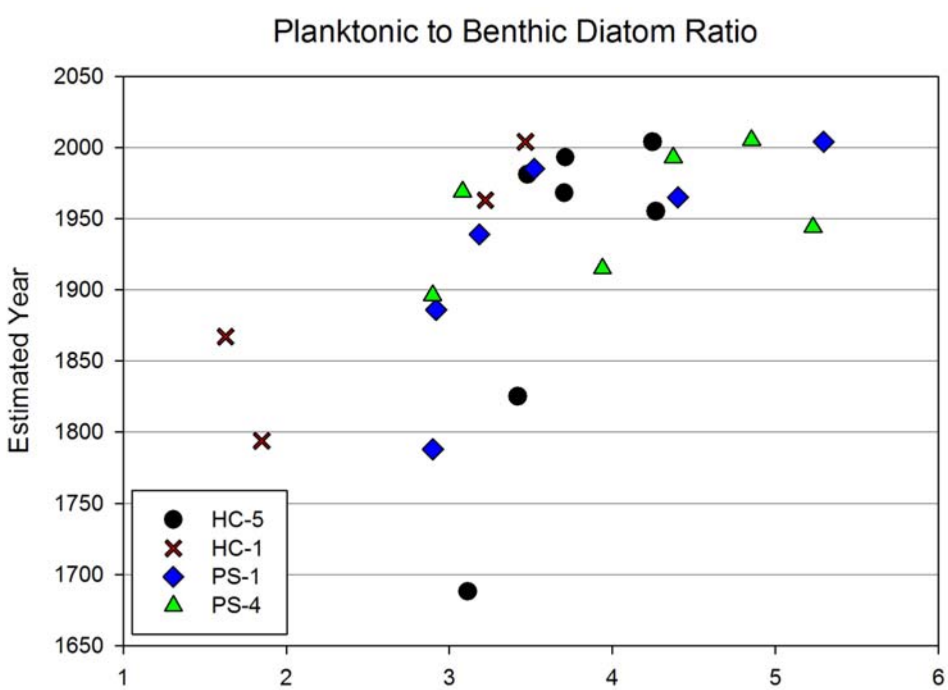


Figure 41. The planktonic to benthic diatom ratio found in samples from central Puget Sound (PS-1 and PS-4) and Hood Canal (HC-1 and HC-5) sediment cores plotted against estimated age.

The DCA indicated that the gradient length of the species data was ≤ 1.14, so PCA was appropriate. Biplots of the samples along the first two PCA axes (using diatom species data) and the supplemental variables are shown in Figures 42 and 43. The first two axes explain 21% and 15%, respectively, of the variance in the species data. The PCA of diatom samples shows that inter-sample differences in diatom assemblages between different coring locations are significant. The HC-1 samples are clustered together, and are most separated from the other core samples along axis 1 (Figure 42). The HC-5 samples are clearly separated from most of the Puget Sound samples along axis 2, but line up with PS-4 along axis 1. In this analysis, HC-1 and PS-1 (oldest samples of PS-1) show differences between samples related to age of sample along the primary axis (older samples being more positive in relation to the scaling of the axis), while HC-5, PS-4 and PS-1 (more recent samples of PS-1) show more differences between samples related to age of sample along the secondary axis (older samples being more negative in regard to the scaling of the axis).

The PCA of diatom samples along with supplemental variables (Figure 43) shows that HC-1 is associated with the highest diversity (H′) of diatom samples, and that the planktonic:benthic ratio (p:b) falls close to the sample date (date) in terms of the first two PCA axes. Date is also similar to total diatom abundance changes (tot dia) along the first axis of the PCA. Total diatom abundance is more closely associated with samples from the two Puget Sound cores analyzed.

Selected diatom taxa are shown in stratigraphic plots by date for all four cores analyzed [Figure 44; created with C2 software (Juggins 2003)]. These plots highlight where data are missing from these cores. Although these plots do not show the species abundance trends between cores that are evident in the PCA (and also when species data is graphed by core rather than grouped together), they do illustrate the overall increase in planktonic taxa and relative decrease in abundance of certain benthic taxa through time in both basins.

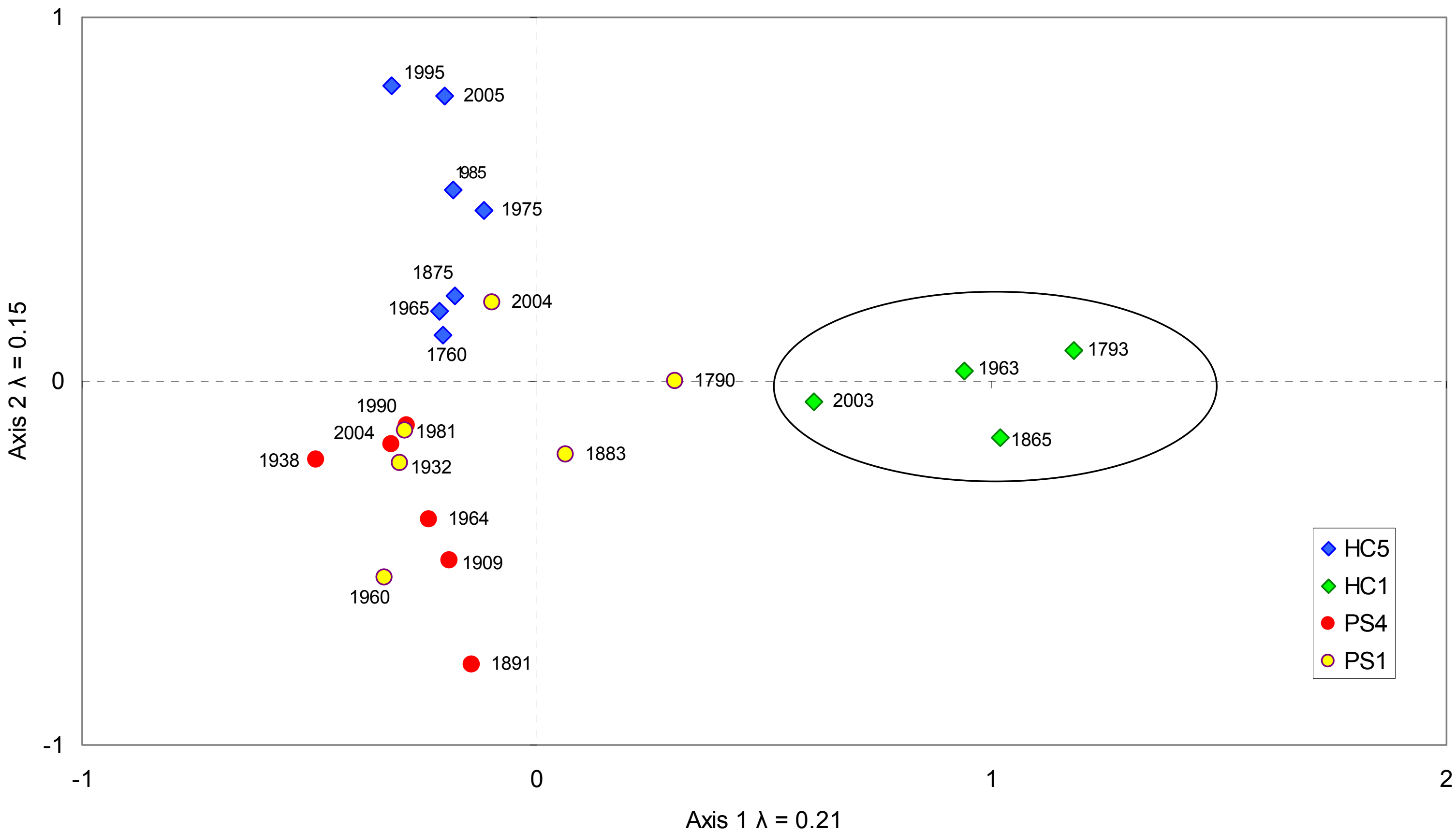


Figure 42. Biplot of principal components analysis (PCA) of diatom species data by sample using the first two axes. The first axis (x-axis) eigenvalue is 0.21 (explains 21% of variance in species data) and the second axis (y-axis) eigenvalue is 0.15 (explains 15% of variance in species data). The surface sediment samples for each core are labeled with the approximate date assigned to that sample, while the legend shows identity of cores by symbol and color. Hood Canal core 1 samples are shown as a cluster on the plot along the first axis.

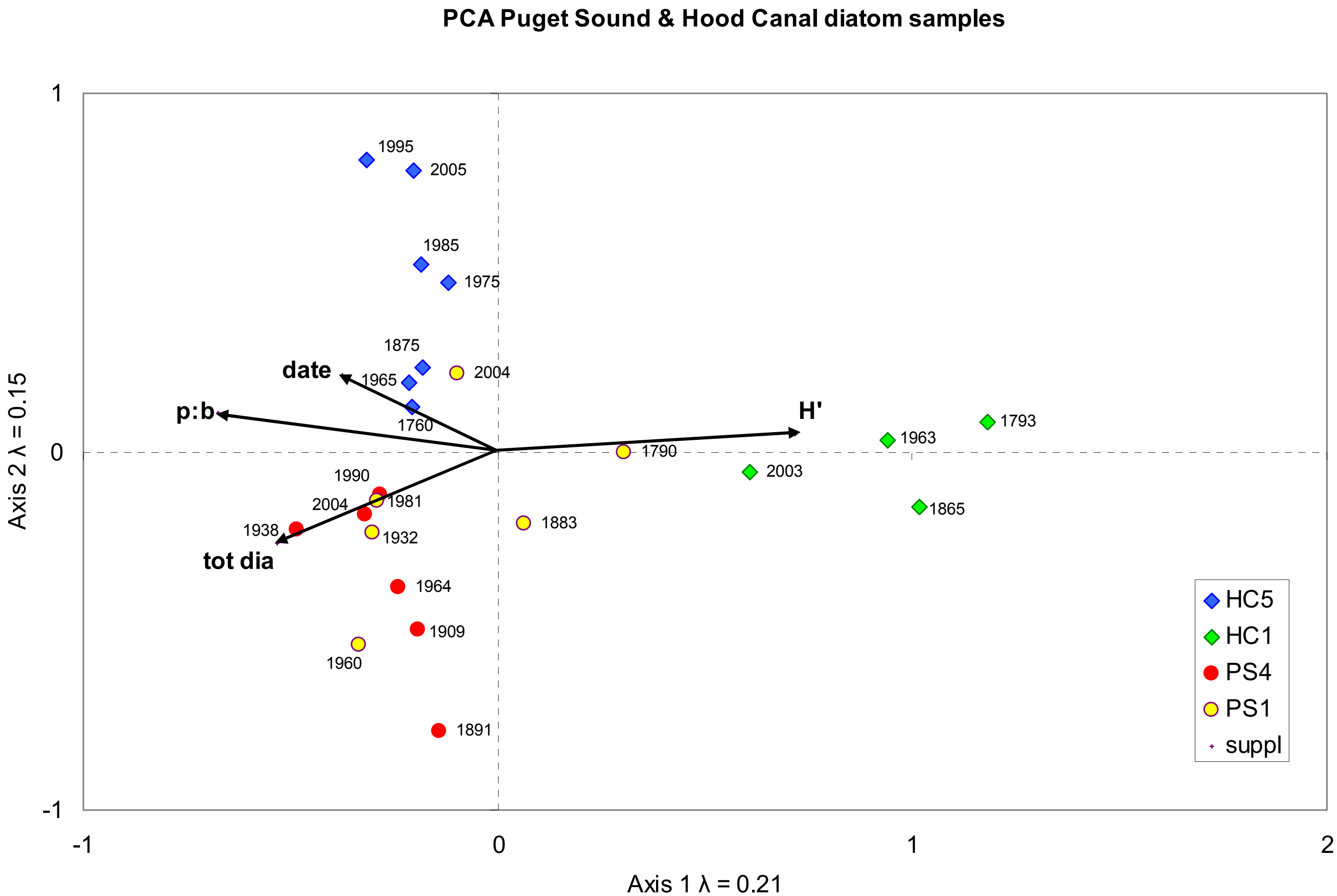


Figure 43. Biplot of principal components analysis (PCA) of diatom species data with supplemental data added, including H' (diatom diversity), date (date assigned to samples), p:b (planktonic:benthic diatom ratio) and tot dia (total diatom abundance in sediments).

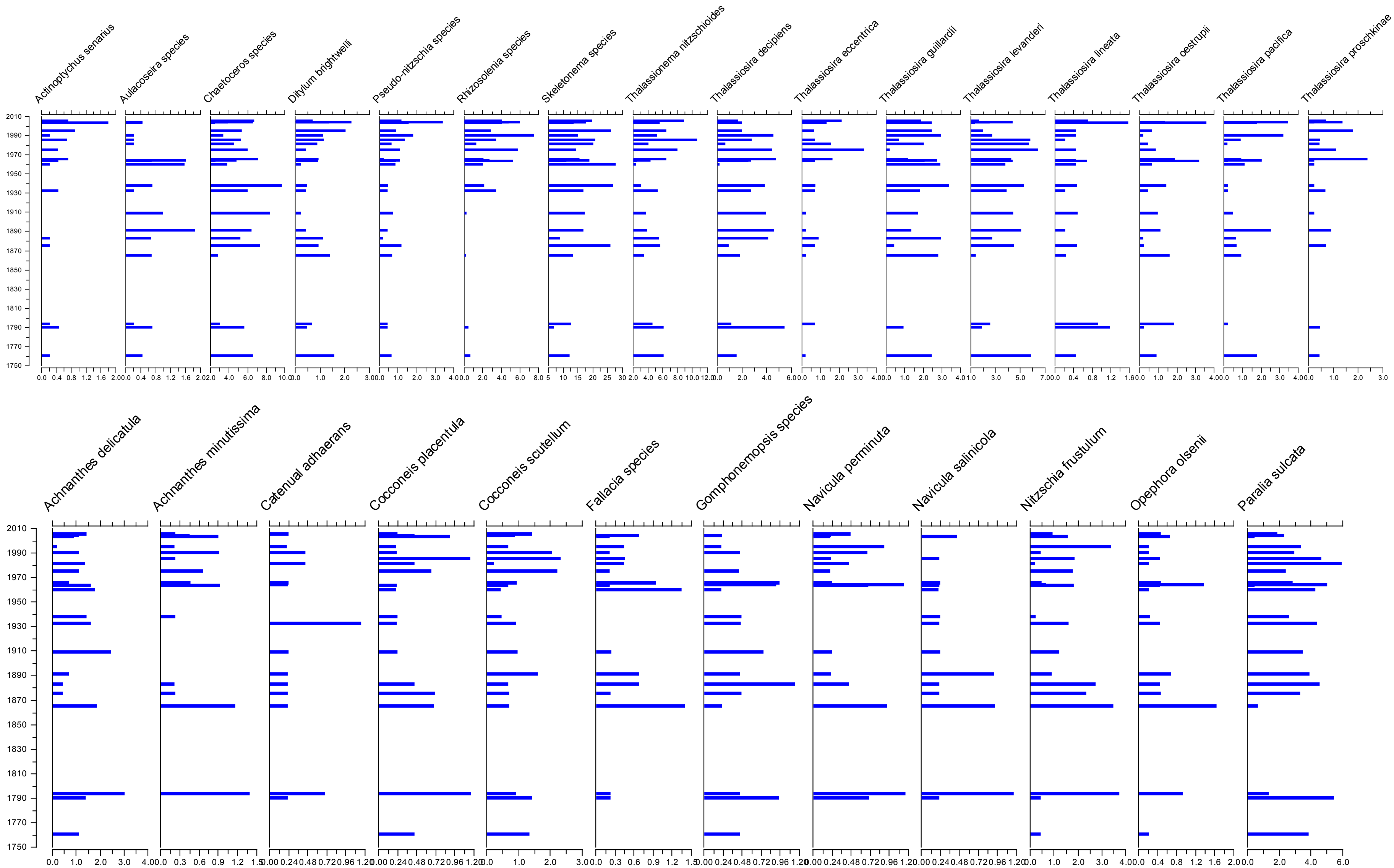


Figure 44. The relative abundance of selected planktonic diatom valves (top) and benthic or epiphytic taxa (bottom) are shown in stratigraphic plots, including all samples analyzed for both basins (HC-1, HC-5, PS-1 and PS-4) using C2 software (Juggins 2003).

3.4.2. Conclusions for Diatoms

The number of diatom samples analyzed from these four sediment cores may not be sufficient for many conclusions about water quality changes in Puget Sound and Hood Canal. The data should be useful in comparison to other fossil and geochemical data from these same cores. The PCA shows that inter-sample distances between cores is greater than sample distances associated with the assigned date of samples (Figure 42). There are diatom species trends through time within individual cores that are not consistent across all cores analyzed. The HC-1 core is especially separated along the main axis for the PCA, which explains 21% of the variability in the species data. The HC-5 core is separated from Puget Sound cores along the second axis, which explains about 15% of the variation in the species data. All cores show separation of samples that roughly follows a timeline along one or both of the first two axes. These PCA results indicate that resident flora and driving factors of diatom abundance may be different between the basins of Hood Canal and central Puget Sound.

The two southern most cores in each basin (HC-1 and PS-1) show a clear trend of increasing planktonic: benthic species ratios through time (lower ratios in older sediments), increasing after 1900 A.D. (Figure 41). A less precise modification of this ratio (c:p ratio) has been used as an indicator of eutrophication in other estuaries (Cooper et al. 2004). Planktonic diatoms are generally centric or relatively long araphid pennate diatoms. The vast majority of the planktonic diatoms encountered in these samples are marine and brackish water species. Raphid pennate diatoms are generally epiphytic, epilithic or epipelic. Some species found in these core samples are marine, but most are brackish water species, or freshwater species with affinity for brackish water. Several relatively abundant species show trends. For example, *Chaetoceros* species are always common, but show an overall decline in more recent sediment that may possibly be related to salinity changes, or preservation issues through time in the sediments. *Naviculales*, *Achnanthes* and *Cocconeis* species also show an overall decline, particularly in HC-1 core. Generally, epiphytic species appear to be on the decline. This may be related to the loss of submerged vegetation, as studies have recorded a significant decline in the area of *Zostera marina* in portions of Hood Canal (particularly the southern region) from 2002-2005 (Gaekle et al. 2007).

In turn, the planktonic genus *Pseudo-nitzschia* shows an apparent increase in abundance in the more recent sediments of three of the four cores (Figure 45). This is of particular interest as this genus is associated with harmful algal blooms and anthropogenic nutrient inputs (Anderson et al. 2002; Parsons et al. 2002) with species capable of producing the toxin domoic acid (Wells et al. 2005). Although additional core segments are required to clearly define increasing trends, the Puget Sound core PS-1 demonstrates a marked increase in relative abundance from around 0.6% to 3.4% in the surface core segment (0-2 cm). This is the highest relative abundance recorded in all the cores and is similar in magnitude to values recorded in the later part of the 20th Century from sediment cores collected in the Gulf of Mexico (Parsons et al. 2002). The Gulf of Mexico sediment core profiles record an increase in the relative abundance of *Pseudo-nitzschia* from < 1% from circa 1900 through 1960 to ~2.5% in the 1990s (Parsons et al. 2002). The authors ascribe this increase to an increasing flux of nitrate from the Mississippi River and silica-limited conditions.

Persistent eutrophication may cause silica depletion of the water column (Conley and Malone 1992; Conley et al. 1993) resulting in increases in weakly silicified diatom species such as *Thalassiosira guillardii* (Figure 45). Although the data are too limited, they appear to show increases in this species in southern basin cores. This would, in turn, indicate water column silica depletion for other species (Weckström 2005).

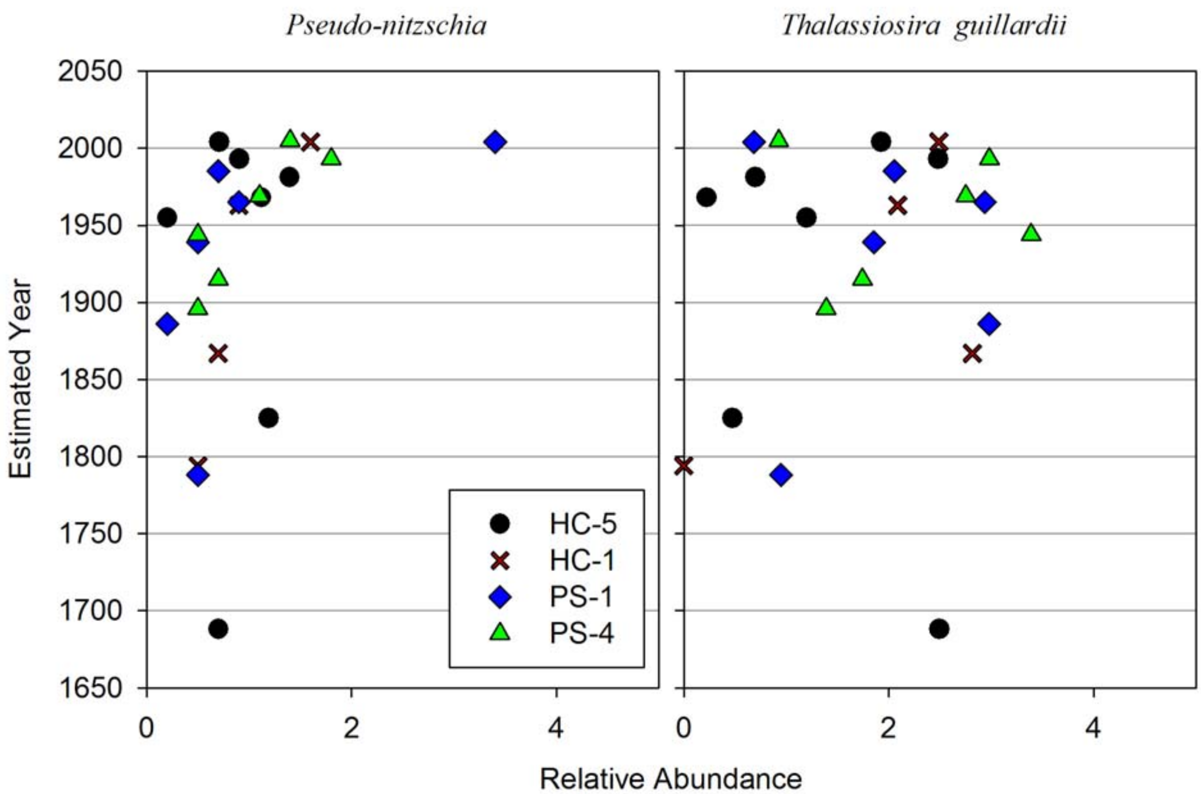


Figure 45. The relative abundance of *Pseudo-nitzschia* and *Thalassiosira guillardii* in sediment cores from central Puget Sound (PS-1 and PS-4) and Hood Canal (HC-5 and HC-1).

The Puget Sound region is generally not considered nutrient/silica limiting and the overall biogenic silica concentrations (7.5-15.6% SiO_2 by weight) are significantly higher than those found in the Gulf of Mexico [highest concentration in recent core segments ~1% BSi; (Rabalais et al. 2007b)] and Chesapeake Bay [recent sediments ~30 mg/g or 6% BSi; (Zimmerman and Canuel 2000)]. The biogenic silica data for the central Puget Sound core PS-1 and the northern Hood Canal core (HC-5) are similar in magnitude and both illustrate a sharp decrease in BSi in the early 1900s (~ 9.9%) with higher concentrations in both more recent sediments (12-13%) and those dated pre-1900s (13-14%; Figure 46). This is in contrast to the southern Hood Canal core (HC-3), which shows an overall lower concentration of BSi (9.4%) with a subtle increase beginning around the mid-1800s before reaching the highest concentration around the 1930s-60s (10.6%), and then decreasing to 9.8 % BSi in the surface sediment. The BSi profiles do not show a decrease in the concentration of BSi in the recent decades potentially due to silica limitations;

however, the lightly silicified diatoms are often associated with poor preservation in sediment and are highly susceptible to dissolution processes near the sediment-water interface (Van Cappellen and Qiu 1997). Other possible factors beside silica-limitations may include nutrient ratio changes, predation pressure, and competition with other algae. It is also possible that periodic cycles in diatom abundance related to climate, currents, and wind are at play.

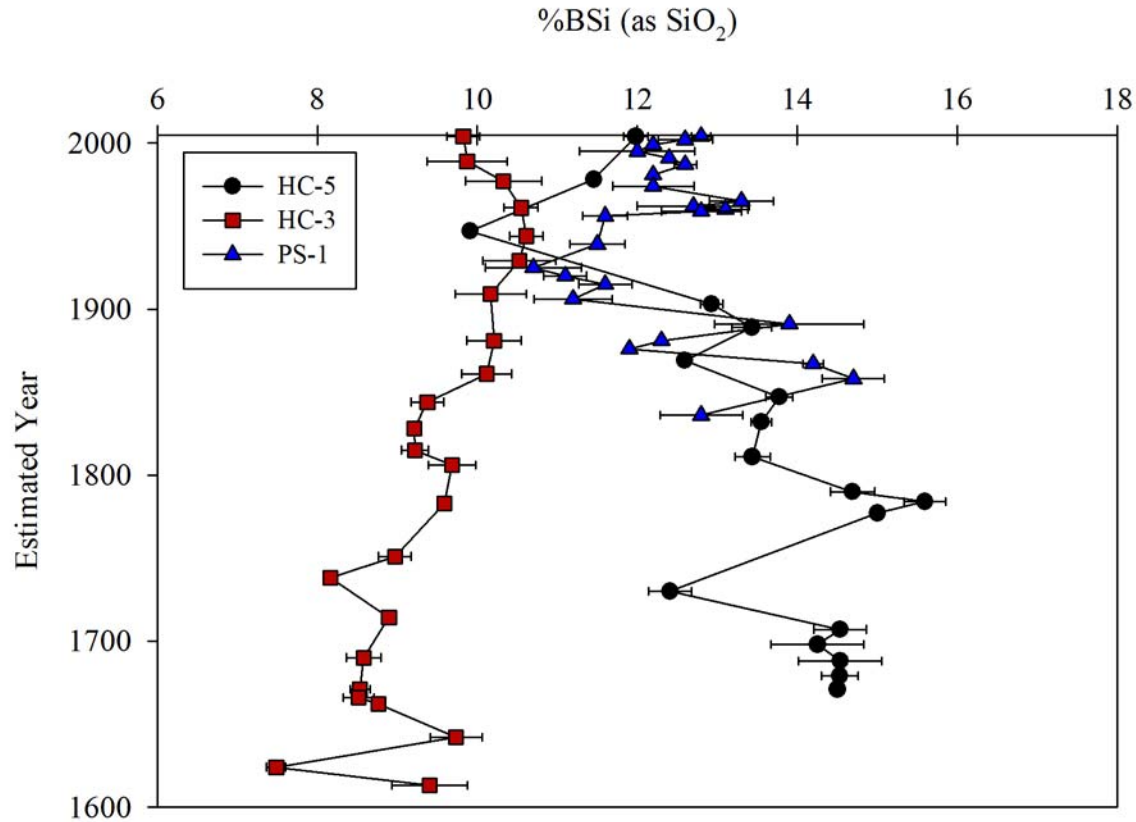


Figure 46. Biogenic silica (BSi) expressed as percent SiO_2 by weight with 1σ error bars for central Puget Sound (PS-1) and Hood Canal (HC-5 and HC-3) sediment cores.

The abundance of preserved diatom valves in the sediments was highest in the two Puget Sound cores analyzed. Overall abundance showed an increase before 1900, then a decline over time since ca. 1900 in the four cores, with the most pronounced decline appearing after ca. 1950 (Figure 39). This trend is opposite to expected results related to eutrophication of the water column. In fact, the decrease in diatom abundance is, again, confirming what the organic markers and BSi are suggesting, namely that productivity went down (or at least that the preservation of all proxies of water column productivity, including the RSM markers, have declined starting in the early 1900s and reaching a minimum in the 1950s. This may be the most significant finding since it is completely counterintuitive and against all our initial hypotheses. One or two long cores at selected sites should be analyzed in more detail for diatom assemblages. In summary, the hypotheses put forth for this diatom research are reiterated and summarized below.

Hypothesis 1 - Increased nutrients (eutrophication) of these estuaries will cause a decline in diversity of diatom species and an increase in centric/pennate diatoms due to a suite of factors including: increased primary production in the upper water column (reducing light availability to benthic pennate species), blooms of less desirable phytoplankton (including small centric diatoms), and competition related to changing nutrient conditions.

There is some evidence from the data that anthropogenic eutrophication, and/or light limitation, or changing nutrient conditions may be factors in the southern Puget Sound and Hood Canal, especially since ca. 1900. The HC-1 core shows the most consistent trends in regards to the expected results of eutrophication and anoxia that have been seen in east coast estuaries, perhaps because this core was collected in shallower brackish water and therefore has the closest environmental characteristics to many east coast estuaries. Although diatom species diversity does not show any trend through time, the number of genera identified in the samples does appear to decline over this time frame (Figure 40). Other diatom data such as the planktonic:benthic diatom ratio and species changes do show trends in the southern cores from Puget Sound and Hood Canal (PS-1 and HC-1,respectively) that may be related to eutrophication or light limitation for benthic production (Figures 41, 45). The centric:pennate ratio is not as useful in these west coast estuarine sediment cores due to the dominance of *Paralia sulcata*, *Thalassionema nitzschioides* and *Pseudonitzschia spp.* that don't fit the general description of planktonic centrics and benthic pennate diatoms. Several planktonic species show overall increased abundance in more recent samples.

Hypothesis 2 - Increased nutrients (eutrophication) will cause an increase in diatom production, evident in total valves counted and biogenic silica (BSi) measurements of sediment samples.

The diatom data collected to date show declines in abundance from the mid to late 20th Century compared to samples dated earlier. This suggests a decline in primary productivity. The inability to draw clear conclusions stems from the lack of detail of the core profiles. Persistent eutrophication may be involved in this trend, causing silica depletion of the water column. Other possible factors may include nutrient ratio issues, predation changes and competition with other algae. It is also possible that periodic cycles in diatom abundance related to climate are at play. One or two long cores at selected sites should be analyzed in more detail for diatom assemblages.

Hypothesis 3 - Increased nutrients (eutrophication) and increased hypoxia/anoxia of bottom waters may contribute to a decline in benthic and epiphytic diatom species due to reduced habitat for these taxa (e.g. less submerged aquatic vegetation, and less light availability to deeper sediments).

There is evidence of a decline in benthic (i.e. Naviculales) and epiphytic species (*Achanthes* and *Cocconeis* in three of four cores) in Puget Sound and Hood Canal over time. These results could support the hypothesis that eutrophication and anoxia may be water quality factors that have changed through time in these systems; however, the other paleo-indicators do not indicate a greater propensity for development of hypoxia/anoxia or eutrophication in the 20th Century. Benthic species are also affected by light availability (phytoplankton blooms and turbidity) and sedimentation processes, which are often linked with eutrophication.

Hypothesis 4 - Increased runoff from the watershed has caused increased stratification of the water column (and eutrophication), resulting in an increase of estuarine and freshwater diatom taxa and a decline in marine and benthic diatoms (due to less light availability to the bottom waters related to increased turbidity and productivity of the overlying fresher water).

The data show evidence of freshwater species in more recent samples (such as discussed for a sample dated ca. 1985 in PS-1). However, most dominant marine and brackish water species do not show consistent declines in the cores over time.

3.5. Foraminifera Assemblages

3.5.1. Analysis of Foraminifera Data

Foraminifer abundance and diversity in all cores were overall very low. Approximately one third of the samples were barren and the remaining samples typically contained less than 50 specimens although some samples contained up to 100 specimens. Diversity is also low; highest diversities occurs in Hood Canal (13 species, HC-4). Abundances and diversities are generally lower in central Puget Sound than in the Hood Canal cores. A description of the taxa identified and the foraminifer data are available in Appendix F.

Four benthic foraminiferal assemblages were observed in the cores: one dominated by arenaceous species and three assemblages dominated by calcareous species. The arenaceous group is composed of about eight species. These small arenaceous foraminifers suggest shallow water depths of less than 50 m, abundant organic matter, and lower oxygen conditions (see Table 10 for reference). This fauna is found throughout Puget Sound and can be thought of as the typical fauna. The three calcareous groups recognized included species with upper depth limits in the inner neritic (0-50 m), middle to outer neritic (50-150 m), shelf/slope break (~150 m), and upper bathyal biofacies (150-500 m). Species in the first calcareous group (group 1; Table 11) have upper depth limits in the inner neritic biofacies, which indicates water depths of less than 50 m, with moderate to high oxygen conditions and cool to cold water. These species are often found at high latitudes or during glacial intervals. The second calcareous group (group 2; Table 12) includes cosmopolitan species with upper depth limits in the outer neritic biofacies (50-150 m). The species in this group are typical of a basin with a shallow sill and a slow or stagnant circulation pattern. Species in this group also suggest low oxygen conditions. The third group (group 3, Table 13) is composed of species with upper depth limits at the shelf/slope break (~150 m) or in the upper bathyal biofacies (150-500 m). The depth distribution of these species is however, more strongly controlled by the water mass than by the depth. Most of the species in this group are associated with the Pacific Intermediate Water mass, which occurs along the East Pacific margin between depths of 150-200 m and about 500 m. The presence of this water mass in Puget Sound either in the main basin or in Hood Canal indicates that sea level was higher or that sill depths were lower. This water mass is formed in the northwestern Pacific Ocean. If the area of formation is warm this water mass has decreased dissolved oxygen values.

These four foraminiferal faunas are recognized in the cores and suggest climatic events (Figure 47). Benthic foraminifers in the Hood Canal cores record events for the past several 100 years whereas faunas from most of the cores from the main basin in Puget Sound record events only from the last 100 years. The benthic foraminiferal faunas are dominated by the arenaceous group and therefore suggest that shallow water depths (< 50 m), high organic matter, and low oxygen conditions prevailed. During the mid-1900's two deviations from this pattern are recognized. Slightly deeper water and low oxygen conditions are suggested by the presence of foraminiferal group 2 in HC-1, HC-3, and PS-4. The data are too limited to assume these represent the same event. A brief interval of cooler, low oxygen marine conditions occurred in PS-4, PS-2, and HC-3 in the early 1900s. These conditions are suggested by the presence of foraminiferal group 1 (cold and shallow) and foraminiferal group 2 (shallow and low oxygen). Common occurrences of group 3 species in the assemblages of the 1800's, generally reflects the warm global conditions of the 1800's and the increased production of Pacific Intermediate Water in the North Pacific. The abundance of calcareous group 1 in both HC-3 and HC-4 correlates with the cold event at +1780. Both of these cores also show an increase in calcareous group 3 at about 1600, which potentially correlates with a global warm event.

Although the benthic foraminiferal assemblages are sparse they can suggest climatic conditions for Puget Sound. Pronounced RSM enrichment periods, which infer hypoxic conditions, occurred in the Hood Canal cores HC-3 and HC-5 circa late 1600s, 1700s, and 1800s. These periods are generally related to warmer climatic cycles, as discussed in more detail in Section 3.8. Warmer climatic cycles in the northeast Pacific create higher sea levels. The Pacific Intermediate water mass, which is created in the northeastern Pacific, has less dissolved oxygen by the time it reaches the northwest Pacific. It may be hypothesized that because of the higher sea levels this water mass and the associated foraminiferal faunas can breach the sills of Puget Sound Basins. Such events are recorded in the cores as an appearance of the deeper low oxygen benthic foraminiferal faunas (foraminiferal group 3) around the 1700s in both HC-3 and HC-5. In addition, this group is not observed in sediment cores throughout the 20th Century concomitant with no RSM enrichment. However, the upper most core segments of HC-4 and HC-5 may record the increases abundance of this foraminiferal group. Additional, analyses of long-cores in other basins of Puget Sound are required to definitively link the shift in foraminiferal assemblages with climatic oscillations in the Pacific Northwest.

Table 10. Arenaceous Foraminiferal Group. Environmental tolerances of benthic foraminiferal species in the Arenaceous Group are given. UDL = upper depth limit of species in marine environment.

Arenaceous Group

SPECIES	ENVIRONMENT	REFERENCES
Ammontium planissimum	UDL = inner neritic biofacies (0- 50 m)	9
Alveolophragmium columbiensis	UDL = inner neritic biofacies (0- 50 m)	9
Eggerella advena	UDL = inner neritic biofacies (0- 50 m); slightly brackish water conditions and dominates the low-diversity assem-blages in areas with sewage discharge along with *Trochammina pacifica*	3, 9, 11
Miliolinella oblonga	UDL = inner neritic biofacies (0- 50 m); slightly brackish water conditions	9
Recurvoides turbinatus		
Reophax scorpius	UDL = inner neritic biofacies (0- 50 m)	9,17
Spiroplectammina biformis	UDL = inner neritic biofacies (0- 50 m)	9
Trochammina charlottensis *Trochammina inflata* *Trochammina kellettae*	UDL = inner neritic biofacies (0- 50 m); slightly brackish water conditions	9
Trochammina pacifica	UDL = inner neritic biofacies (0- 50 m); common in brackish environments	3, 11

References:

3 (Blais-Stevens and Patterson 1998)
9 (Lankford and Phleger 1973)
11 (Murray 1991)
17 (Walton 1955)

Table 11. Foraminiferal Group 1. Environmental tolerances of benthic foraminiferal species in Group 1 are given. UDL = upper depth limit of species in marine environment.

Group 1

SPECIES	ENVIRONMENT	REFERENCES
Buccella frigida	UDL = inner neritic biofacies (0- 50 m) normal, temperate marine conditions	6
Cibicides fletcheri	UDL = inner neritic (0-50 m)	6, 9
Dyocibicides perforatus	UDL = inner neritic (0-50 m)	9, 15
Elphidiella hannai	UDL = inner neritic biofacies (0-50 m)	9
Elphidium clavatum	UDL = inner neritic biofacies (0-50 m); extremely tolerant of dysoxia and even anoxia; it is common in coastal areas subject to pollution	18, 19, 20, 21, 22
Elphidium frigidum	UDL = inner neritic (0-50 m)	6
Elphidium magellanicum	UDL = inner neritic (0-50 m); common to brackish and low salinity conditions	22
Quinqueloculina akneriana	UDL = inner neritic (0-50 m)	6
Rosalina columbiensis	UDL = inner neritic (0-50 m)	5, 7, 9, 15,

References:

6	(Ingle 1980)
7	(Ingle and Keller 1980)
9	(Lankford and Phleger 1973)
15	(Smith 1964)
18	(Feyling-Hanssen et al. 1971)
19	(Olsson 1975)
20	(Alve 1995)
21	(Scott et al. 2001)
22	(Filipsson and Nordberg 2004)

Table 12. Foraminiferal Group 2. Environmental tolerances of benthic foraminiferal species in Group 2 are given. UDL = upper depth limit of species in marine environment.

Group 2

SPECIES	ENVIRONMENT	REFERENCES
Bolivina pacifica	UDL = outer neritic (50-150 m) but rare; shallow oxygen minimum zone; typical dweller of dysoxic conditions	1, 6, 15, 17
Buliminella elegantissima	UDL= inner neritic biofacies (20-50 m)	1, 6, 15, 17
Fursenkoina seminuda	UDL = upper bathyal biofacies (150-500 m)	14, 15, 17
Nonionella basispinata	UDL = outer neritic biofacies (50-150 m)	5, 6, 7
Nonionella stella	UDL= inner neritic biofacies (20-50 m); thrives in most oxygen-depleted sediments	1, 2, 6, 7, 9, 17
Stainforthia feylingi	dysoxic conditions (0.1-0.3 ml/l)	3, 8, 12, 13
Stainforthia fusiformis		

References:

1 (Bandy 1961)
2 (Bernhard et al. 1997)
3 (Blais-Stevens and Patterson 1998)
5 (Douglas and Heitman 1979)
6 (Ingle 1980)
7 (Ingle and Keller 1980)
8 (Knudsen and Seidenkrantz 1994)
9 (Lankford and Phleger 1973)
12 (Patterson et al. 2000)
13 (Patterson and Kumar 2002)
14 (Phleger and Parker 1951)
15 (Smith 1964)
17 (Walton 1955)

Table 13. Foraminiferal Group 3. Environmental tolerances of benthic foraminiferal species in Group 3 are given. UDL = upper depth limit of species in marine environment.

Group 3

SPECIES	ENVIRONMENT	REFERENCES
Epistominella exiqua	UDL = varies, usually shelf/slope edge (~150 m)	6
Globocassidulina globosa	UDL = outer shelf biofacies (50-150 m); warmer AABW, and warmer PDW; decrased oxygen conditions	4,6
Praeglobobulimina affinis	UDL = upper middle bathyal biofacies (500-1500 m); common species in the basin floor assem-blages	4, 6
Trifarina angulosa	UDL = outer neritic biofacies (50 -150 m)	1,4, 6
Uvigerina hispida	UDL = lower middle bathyal biofacies (1500-2000 m); high surface productivity and very little detrital sedimentary input; broad temperature range	4, 6, 7,
Uvigerina peregrina	UDL = upper bathyal biofacies; low oxygen and high organic carbon	6,7,10,16
Uvigerina peregrina dirupta	UDL = upper middle bathyal biofacies (500-1500 m) associated with the cool, high salinity oxygen-poor PIW or Anatarctic Intermediate Water masses	1,6,7

References:

1	(Bandy 1961)
4	(Boersma 1984)
6	(Ingle 1980)
7	(Ingle and Keller 1980)
10	(Miller and Lohmann 1982)
16	(Streeter and Shackleton 1979)

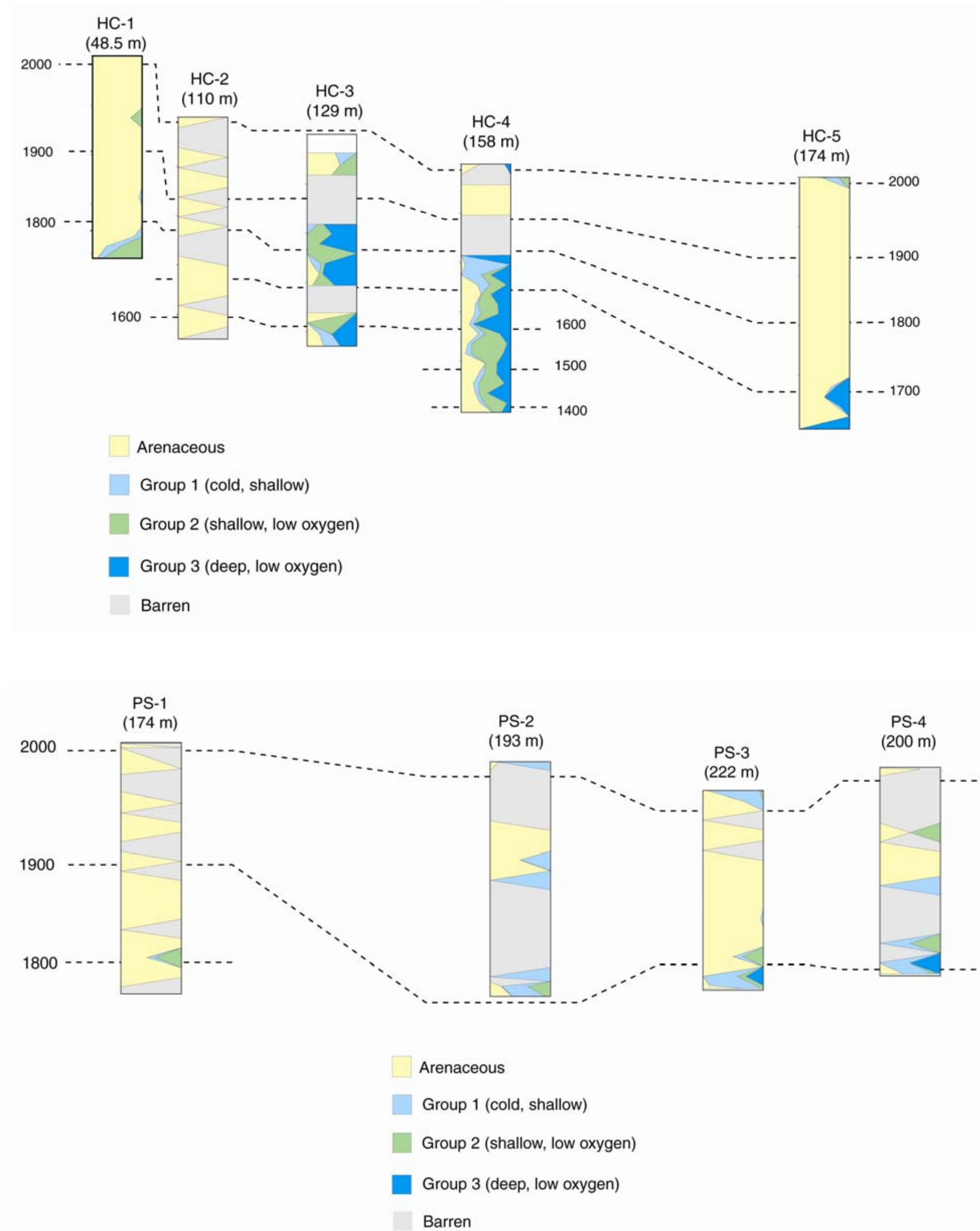


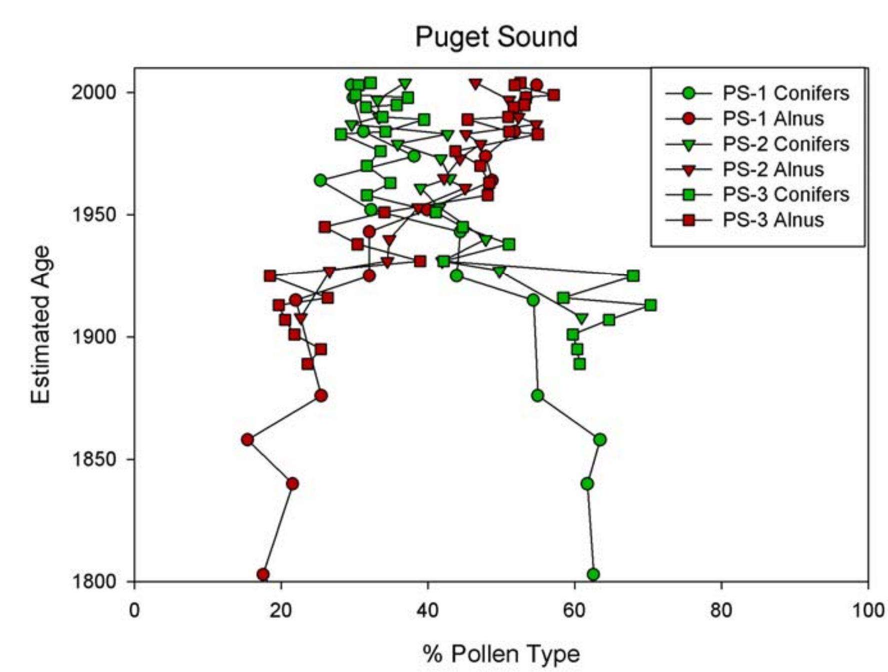
Figure 47. Distribution of foraminiferal groups in the Hood Canal cores (top panel: HC-1 through HC-5) and Puget Sound cores (bottom panel: PS-1 through PS-4). Distribution of groups is given as a percentage of the total benthic foraminiferal fauna. Dashed correlation lines are years based on dates provided by ^{210}Pb dating.

3.6. *Verification of Estimated Ages*

A recent study from our group (Brandenberger et al. 2008) used the same cores presented here to assess increased anthropogenic inputs followed by natural recovery rates of inorganic (Pb, Cu, and As) and organic markers (lignin and soil biomarkers) in the Central Basin of Puget Sound during the 20th Century. This study confirmed that these sedimentary archives provide a historical record of watershed-integrated inputs of metals and organic matter with specific features directly linked to events within the Puget Sound drainage basin. Most importantly, the chronology of the central Puget Sound cores have been confirmed through independent approaches including stable inorganic tracers, radiometric dating, and repeated chronological sampling at the same stations (Brandenberger et al. 2008), producing sediment accumulation rates that were consistent with previously published values for the region (Bates et al. 1984; Carpenter et al. 1985; Bloom and Crecelius 1987; Lefkovitz et al. 1997).

Although, the extensive confirmatory tools were not available for Hood Canal, the pollen reconstructions can serve as an independent marker for the relative ages established using the ^{210}Pb radiochronological methods. The percentage of total conifer and Alder pollen were plotted relative to the age of deposition for the three cores from each basin (Figure 48). In central Puget Sound cores, the initial disturbance from lumbering is marked by an early decline in the overall proportion of total conifer pollen occurring in the late 1800s. The concomitant rise in Alder pollen further supports the decreased conifer stands in the watershed and their replacement by colonizers. This is consistent with the historical record as the first lumber mills in Puget Sound were established in the 1850s (Figure 3). In the 1900s, clear-cut logging began and in 1927 the two person gas chainsaw was mass produced. When the single person chainsaw became widely available in 1945, logging practices changed markedly in the Pacific Northwest. Immediately after this time period, the sedimentary record of Puget Sound shows a marked predominance of Alder pollen, which exceeds that of the total conifers.

In Hood Canal, the disturbance horizons are less distinct until the middle of the 20th Century and illustrate a delay in timing compared to the central Puget Sound where significant LULC changed occurred earlier in the 20th Century. The cutting of old growth forest along Hood Canal was occurring by the 1890's based on the starting dates for the lumber mills in or adjacent to Hood Canal, but the overall pollen composition still falls within the pre-1800s patterns of oscillation. As illustrated in the aerial photograph in Figure 5, significant land clearing on the Kitsap Peninsula occurred prior to 1939. Maxima in the proportion of Alder pollen are recorded later than in Puget Sound (1960-70s *vs*. 1950s, respectively) confirming that this watershed has been less affected by land clearance and only recent expansion in forestry activities and land clearance (e.g. increased sub-urban development in the southern reaches of Hood Canal) have led to major changes in vegetation structure in the system. More importantly, however, although we cannot use these markers to validate the chronologies to a specific date, the parallel shifts in pollen composition in all Hood Canal cores show that these chronologies are all internally consistent.



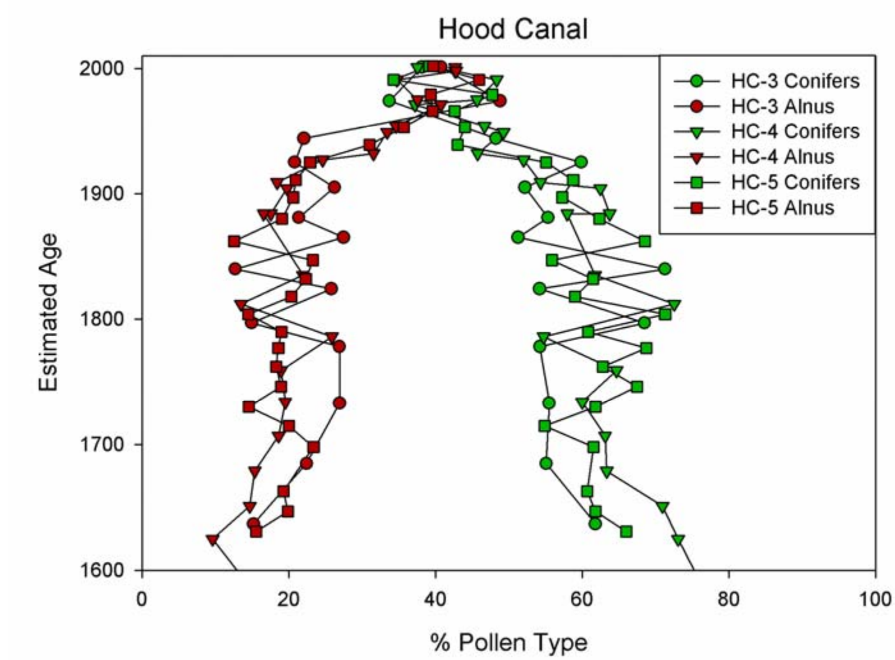


Figure 48. Percent Alder and total conifer pollen in Puget Sound (top) and Hood Canal (bottom) cores plotted relative to age of deposition determined from ^{210}Pb dating.

The stable Pb profile can also be a good independent marker that "anchors" the chronology to an external date. In the central Puget Sound, the history of Pb contamination is linked to large-scale industrial point sources, the evolution of which has been summarized in a recent paper by Brandenberger et al. (2008). The first accumulation of anthropogenic Pb in sediments of the main basin was recorded around 1890 when metal smelting began near Tacoma. The concentrations of anthropogenic Pb continued to increase during the early 1900s and the first peak occurred during World War I (WWI; 1914-1918) when significant industrialization began in central Puget Sound. The Pb concentrations then showed a decrease during the Great Depression (1929) followed by a second increase during WWII (1930s-1945), a peak in the 1960s, and finally significant decreasing trends since the implementation of the first environmental regulations such as the Clean Air and Clean Water Acts. The large-scale Pb inputs in central Puget Sound masked another significant, but more diffuse, source of anthropogenic Pb in these sediments. Indeed, it has been recognized for more than a decade now that the combustion of leaded gasoline has been recognized as a major source of Pb to the environment through atmospheric redistribution and deposition over entire watersheds (Van Metre and Callender 1997; Mielke 1999). The phase-out of leaded gasoline in the late part of the 20th Century (1970-1980) has led to significant improvements in air quality and a reduction in a major source of Pb exposure to humans [see Nriagu (1990) for details on the "rise and fall" of leaded gasoline in the US]. Several studies have shown that sediments from many urban/suburban lakes and reservoirs show prominent peaks in Pb concentrations that are synchronous with the rise and fall of leaded gasoline usage (Van Metre and Callender 1997; Siver and Wozniak 2001; Mahler et al. 2006). In the Strait of Georgia Basin, north of the Puget Sound region, the chronology of Pb recorded in the sediments closely matches the regional history of Pb emissions from gasoline consumption with a notable peak in the mid-1970s (Macdonald et al. 1991). Similarly, the three cores in Hood Canal show synchronous peaks in Pb concentrations right around the early- to mid-1970s (Figure 49). That synchrony confirms, yet again, the comparative nature of the chronology for these environments while the peak in the mid-1970s suggests a potential for the validation of the dating to an external historical event. The north-to-south decrease in concentrations from HC-5 to HC-3 suggests that some point-source inputs may have been introduced into the Hood Canal through its northern sill and that they decreased in importance in sediments closest to the Great Bend and Lynch Cove. This could explain why Pb concentrations increase above background in the early 1900s in the northern portion of the Canal in a way somewhat similar to that observed in the central Puget Sound. In contrast, HC-3 shows a sharp rise in Pb concentration only around the late 1930s-early 1940s, consistent with the increased use of leaded gasoline in the region (Macdonald et al. 1991). The Pb concentrations then decline precipitously in the late 1970s seemingly in response to emission reductions. Further support for the hypothesis that most of the Pb in HC-3 is combustion-derived, comes from the profiles of pyrogenic polycyclic aromatic hydrocarbons (Pyr-PAHs; Figure 49). Although previous publications have reported high concentrations of Pyr-PAHs in the Puget Sound and northern portions of Hood Canal (Bates et al. 1984; Lefkovitz et al. 1997), to our knowledge no PAH data have been published from the southern Hood Canal. The data shown here (Figure 49) suggest some combined regional emissions of combustion-derived organic contaminants and Pb to the airsheds and watersheds of Puget Sound. Spark-ignition motors did not include catalytic converters prior to the phase-out of leaded gasoline and thus released proportionally more incomplete products of combustion (e.g. PAHs) per unit fuel used (National Academy of Sciences 1983). The near perfect match between the Pyr-PAHs and Pb profiles for most of the 20th Century thus implies that a strong relationship exists between these two atmospherically distributed contaminants. Most probably, both were released due to inefficient vehicular combustion until environmental regulations and technological shifts curved such emissions. The resurgence in Pyr-PAH concentrations in recent years is also consistent with prior work in the region and other urban/suburban environments of the country (Van Metre et al. 2000; Lima et al. 2003; 2005; Van Metre and Mahler 2005), which have blamed recent increased in urban sprawl and diesel usage for rising levels of PAHs in modern sediments of urban lakes.

The pollen, Pb, and PAH profiles thus point to both an internal and external consistency in the chronologies of the three Hood Canal cores and provide three independent means of bracketing the estimated ages determined from the radiometric dating, similar to Puget Sound cores.

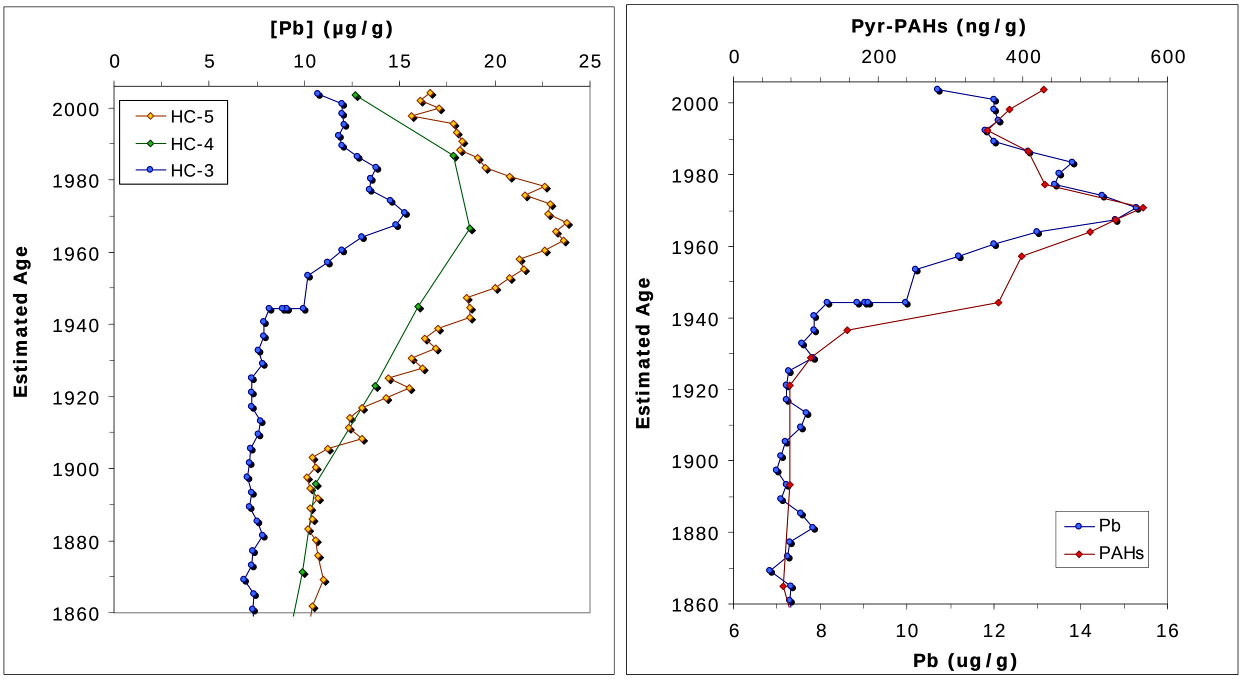


Figure 49. Stable lead (Pb) concentrations in Hood Canal cores (left) and Pb and pyrogenic PAHs (Pyr-PAHs) in HC-3 (right) plotted relative to age of deposition determined from ^{210}Pb radiochronology.

3.7. Overarching Conclusions

Similar studies using a suite of paleoindicators to reconstruct the record of hypoxia in the Chesapeake Bay (Zimmerman and Canuel 2002) and Gulf of Mexico (Rabalais et al. 2007a) concluded that anthropogenic stresses on these systems resulted in the increased occurrence of hypoxia in the 20th Century with more intensive events recorded in recent decades. The paleo-records from both of these systems show a significant shift in the ecological indicators through the period of urbanization and in response to specific anthropogenic activities (e.g. increased nitrate fluxes and land-use/cover alterations). Similar profiles for indicators of urbanization, land-use alterations, and land clearing/deforestation are recorded both in the central Puget Sound and the more rural Hood Canal Basin. However, the sediment cores from both of these basins, collectively differ from the other national hypoxia regions, as the suite of paleo-indicators do not record an increasing propensity to develop hypoxia in the last 100 years concomitant with the significant urbanization in the region. In particular, and in contrast to many other coastal systems impacted by hypoxia, the sedimentary records in Puget Sound do not show unambiguous shifts in nutrient inputs (nitrogen) to the aquatic system. The decoupling between the increase in anthropogenic activities and the low oxygen conditions in the deep waters of the basin is somewhat counterintuitive and opposite to what has been observed in other coastal systems, in which the onset of low oxygen conditions occurs following a rise in land use changes (i.e.

agriculture and deforestation). These observations suggest that Puget Sound is controlled by natural processes of ventilation (physical mixing) that may buffer (or accelerate) changes in oxygen levels in deep waters.

The historical reconstructions of a diverse set of paleoecological indicators preserved in sediment cores from central Puget Sound and Hood Canal provide resource managers with scientific data to support informed decisions regarding hypoxia in Puget Sound by addressing the following questions.

- When did hypoxia begin in Puget Sound and how has the intensity varied over the last several hundred years?
  - Sedimentary reconstructions for redox-sensitive metals (RSM are a proxy for hypoxia) record evidence of sustained hypoxia in Hood Canal around the turn of each century circa 1700s, 1800s, and 1900s with relatively more oxygenated conditions recorded around the middle of each century. For most of the 20th Century, central Puget Sound and Hood Canal have been under a more oxygenated "stance" with respect to prior periods. The early 21st Century is not resolved in the sedimentary record when instrumental records suggest a greater frequency/intensity of hypoxic events. However, the overall reconstructions are in contrast to what was anticipated, as more frequent periods of hypoxia were not recorded in the sedimentary record concomitant with major anthropogenic changes occurring within Puget Sound watersheds during the 20th Century.
- How have the sources of organic matter, nutrients, and pollen changed as a function of increased human population, industrialization, wastewater discharges, and alterations in land-use and land-cover (LULC)?
  - The sedimentary reconstructions confirm that anthropogenic forces throughout the 20th Century have had an unambiguous and substantial impact on the organic matter and nutrient fluxes entering Puget Sound. The paleo-indicators, collectively, record the intense land-clearing, urbanization, and industrialization that occurred beginning in the late 1800s in central Puget Sound and early 1900s in Hood Canal. The evidence of increasing LULC modifications is reflected in the pollen record as increasing abundances of successional species, such as Alder trees, which ultimately over take the signature of the old growth coniferous forest in the 1950s as the dominate pollen in the marine sedimentary record.
  - These land-clearing and other industrial activities are clearly recorded in the inorganic priority pollutants and biomarkers reconstructions, which generally increase in the early 1900s, peak in the 1960s, and begin recovering back towards pre-industrial signatures following the passage of the initial environmental regulatory policies (1970s-1980s). Both the pollen and the biomarker reconstructions are coincidental with the start of significant logging in the respective basins and confirm that the increase in urbanization and land clearing has released greater amounts of terrigenous organic matter to Puget Sound.
  - Collectively, the reconstructions show a strong shift from predominantly marine organic matter and lower oxygen conditions during the 18th to 19th Centuries to more terrigenous organic matter and more oxygenated conditions during the 20th Century.

- How have the assemblages of diatoms in the water column and foraminifera in the sediment changed as the basin was logged and nutrient loading and freshwater inflows increased?
  - The microfossil reconstructions for diatom and foraminifera were too limited to provide statistically valid conclusions. However, overall abundance of diatom assemblages decline over time since ca. 1900 in the four cores, with the most pronounced decline appearing after ca. 1950. This trend is opposite to expected results related to eutrophication of the water column. In fact, the decrease in diatom abundance may confirm what the organic markers and BSi are suggesting, namely that productivity went down or at least that the preservation of all proxies of water column productivity, including the RSM markers, have declined starting in the early 1900s and reached a minimum in the 1950s. This may be the most significant finding since it is completely counterintuitive and against all our initial hypotheses.
  - Trends in the diatom species diversity do not indicate the development of sustained eutrophication; however, the number of genera identified in the samples does decline ca. 1950s along with an overall increase in planktonic species in the most recent sediments. These data may indicate a recent trending toward eutrophic conditions in the last several decades, as there are increasing relative abundances in species generally associated with excess anthropogenic nutrient inputs (i.e. harmful algal species such as *Pseudo-nitzschia* capable of producing the toxin domoic acid).
  - Although the benthic foraminiferal assemblages are sparse, they can suggest a potential link between climatic cycles and RSM. The foraminiferal reconstructions suggest the observed alterations in assemblages may be coupled with large-scale climatic cycles rather than human alterations, similar to the RSM. However, additional data are required to confirm this linkage.

These reconstructions appear to contradict the evidence of increasing fish kills and lower dissolved oxygen concentrations reported recently by water monitoring studies in Hood Canal (Newton et al. 2007). However, the resolution of the sedimentary record in Hood Canal is on the order of 10-20 years due to natural mixing processes, low sedimentation rates, and the thickness of the core segments required for feasibly producing a detailed reconstruction over the entire length of the cores (~300 cm). The increased frequency of hypoxic events associated with fish kills have only been recorded within the last decade (Figure 50) and occur on relatively short time-scales (months), Such intensifications in hypoxia would only appear in the sedimentary record when their magnitude and/or duration are sufficient to overcome the time-integrated sedimentary signature of each core segment. The salinity and nutrient content of the deep Juan de Fuca inflow vary seasonally in phase with outer coast upwelling (Mackas and Harrison 1997). The seasonal intrusion of relatively more oxygenated water is reflected in the fall of each annual monitoring data set. Although the last 10-20 years cannot be resolved as individual years in the RSM profiles, they support the historical water column data for the 1950s when overall higher dissolved oxygen concentrations were measured and RSM show little/no enrichment or evidence of sustained hypoxia in the integrated sedimentary signature.

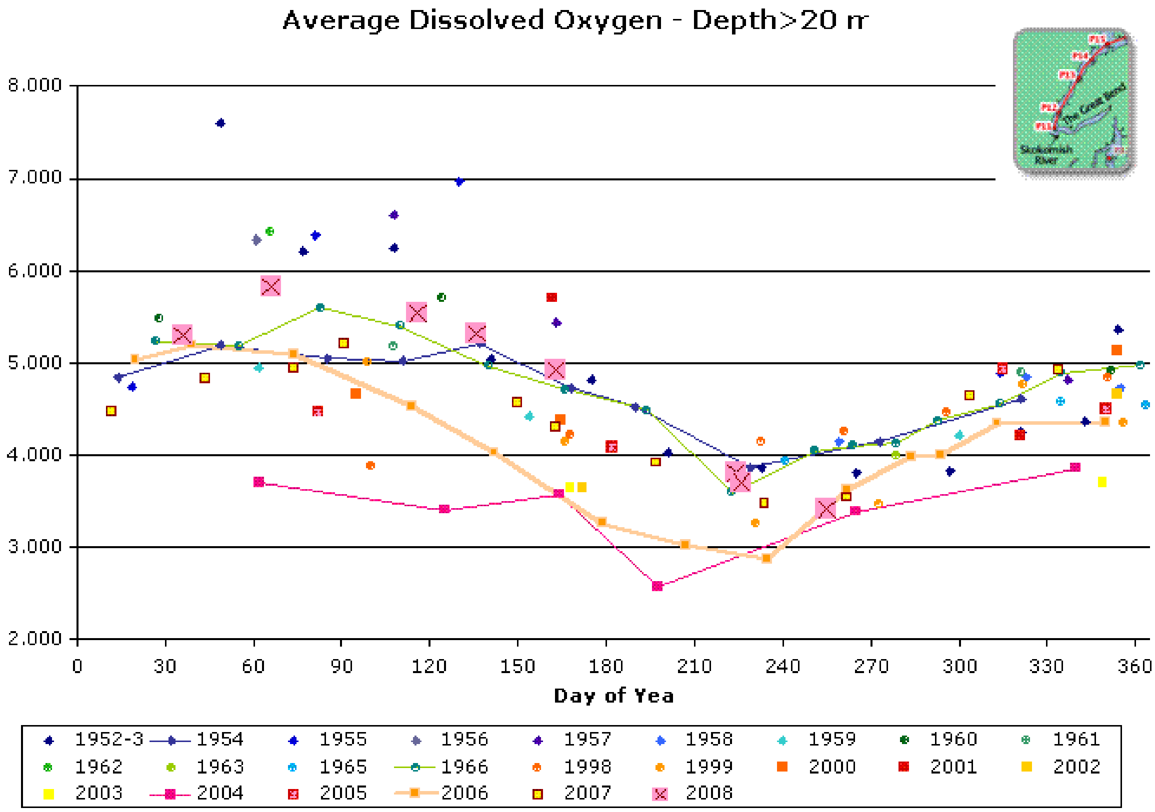


Figure 50. Average dissolved oxygen concentrations (mg/L) measured in central Hood Canal at depth > 20m during 1950s-2008 relative to day of the year. Reprinted with permission from Newton et al. (2007).

The lack of a strong relationship between anthropogenic factors and hypoxia leads to the evaluation of natural processes that would influence the development of abnormally low oxygen conditions in the deep waters of Hood Canal. Although ^{210}Pb chronology only provided dates to around the 1850s in Hood Canal, the long sediment cores provide an opportunity to extrapolate back to 300-400 years B.P. Conducting such an extrapolations required the assumption that the integrated sediment supply has not significantly changed in the earlier time periods. This assumption seems reasonable in Hood Canal, as anthropogenic changes within the watersheds have occurred only within the last 150 years and would be accounted for in the ^{210}Pb data. There exists many potential factors, such as oceanic and atmospheric cycles, that could influence ventilation and/or primary productivity in Hood Canal and many are beyond the scope of this study. However, some initial hypotheses are discussed below.

3.8. Relationship between Hypoxia and Climatic Cycles

Evaluating the linkage between large-scale climatic cycles and the development of hypoxia in Hood Canal requires long time-series records on the order of hundreds of years with similar resolutions as the hypoxia reconstructions (10-20 years). Since there are no instrumental records available for such a long time-series, representative climatic indices and their reconstructions must be identified for Puget Sound. Indices used to express climatic variability in the Pacific Ocean include Pacific Decadal Oscillation (PDO), El Niño/Southern Oscillation (ENSO), and North Pacific Index (NPI). The climatic and societal impacts of the inter-annual anomalies of ENSO are well documented (Glantz 1996); however, ENSO better represents inter-annual variability than decadal. The North Pacific oscillation, which is represented by the PDO index, has been recognized as a decadal-scale indicator of sea surface temperature variability in the North Pacific (Mantua et al. 1997). Each cycle takes 15 to 20 years on average (Mestas-Nuñez and Miller 2006); therefore any correlations with this climate index require a historical record longer than at least five cycles or 100 years to adequately capture the variability in the magnitude of the cycles.

The PDO is linked to shifts in the Aleutian Low pressure cell from west to east (Trenberth and Hurrell 1994). These shifts are subsequently linked to changes in the coastal ocean temperature and stratification, which correspond with oscillations between relatively warm-dry and cool-wet conditions in the Pacific Northwest (Ebbesmeyer et al. 1989; Trenberth and Hurrell 1994; Latif and Barnett 1996). Ebbesmeyer et al. (1989) used the extensive oceanographic data set of the 1950's, a period of cool-wet conditions, to produce the first linkage between climatic regime and the stratification/circulation of Puget Sound. Recently, Moore et al. (2008) used an extension of this data set (1951 to 2002) to demonstrate that sea surface temperature and salinity anomalies in Puget Sound were significantly correlated with winter-time variation of the PDO. Upwelling and downwelling off the Washington Coast are believed to control the salinity of the waters entering from the Straits of Juan de Fuca (Barnes and Collias 1958) and subsequently the circulation in Puget Sound. If fact, Zheng et al. (2000) and Nameroff et al. (2004) found variations in RSMs recorded in sediment cores from the continental margin of the eastern North Pacific. The variations through time were found to be minimally influenced by productivity alterations and more significantly controlled by changes in ventilation.

The instrumental records illustrate two dominant PDO phases, with the cool-wet regime (expressed as a negative PDO index) dominating the Northeastern Pacific from 1947 to 1976 and warm-dry conditions (positive PDO index) from 1976 to 1998 (Smith et al. 2001). However, sea surface temperature records are limited prior to the 1950s in Puget Sound and are too short to adequately describe natural variability at decadal time scales. As a proxy for climatic records, tree rings have been used to reconstruct high-resolution, accurately dated indices of North Pacific climate over longer time periods (D'Arrigo et al. 1999; Cook et al. 2000; Biondi et al. 2001). Biondi et al. (2001) published PDO reconstruction for 1661 to 1981 calculated using a network of tree rings collected from Southern and Baja California. These tree rings suggest the timing, amplitude, and frequency of decadal-scale climate oscillations in the Pacific basin. The PDO is closely matched by the dominant mode of tree-ring variability, which provides a preliminary view of multi-annual climate fluctuations spanning the past four centuries (Biondi et al. 2001). The reconstructed PDO index features a prominent bidecadal oscillation, whose amplitude weakened in the late 1700s to mid-1800s.

Most time series patterns can be described in terms of two basic classes of components: trend and seasonality. The former represents a general systematic linear or (most often) nonlinear component that changes over time and does not repeat within the time range captured. The latter may have a formally similar nature; however, it repeats itself in systematic intervals over time (cyclic). The first step to comparing sediment core reconstructions with tree ring data is to standardize and smooth the data to represent similar resolutions. Since the resolution of the sediment core reconstructions are on the order of 10-20 years, the annual tree ring data must be smoothed to a similar resolution. Smoothing always involves some form of local averaging of data such that the nonsystematic components of individual observations cancel each other out. The most common technique is moving average smoothing which replaces each element of the series by either the simple or weighted average of n surrounding elements, where n is the width of the smoothing "window" [see (Box and Jenkins 1976; Velleman and Hoaglin 1981)]. A smoothing window of 20-year moving median was used to smooth the PDO data.

The best paleo-indicator of hypoxia from the core reconstructions was the RSMs. Since multiple RSMs were generally correlated to each other, a single metal ratio (Mo/Al) could be used for comparative analyses. In addition, Figure 19 indicates that both Hood Canal sediment cores analyzed in detail (HC-3 and HC-5) showed generally similar timings for more hypoxic conditions around the late 1600s, 1700s, and 1800s. Therefore, only the Mo/Al data from the southern Hood Canal core (HC-3) were used for comparisons with PDO. The Mo/Al data were transformed into relative indices by standardizing each core segment relative to the core average, as discussed in Section 3.2.4 for Cd/Al. This allows a visual interpretation of core segments that are either positive (enriched in Mo and indicated more hypoxic conditions) or negative (no enrichment of Mo indicates more oxygenated conditions) relative to the overall core average. Figure 51 shows the relationship between smoothed PDO and the standardize Mo/Al ratio for HC-3. Although no definitive correlations can be drawn, there is a pattern of positive PDO and more hypoxic conditions in Hood Canal dating back to the 1700s based on tree ring dating. And both the PDO index and the RSM reconstructions are supported by the instrumental record confirming the 1950s were relatively cool-wet conditions with more oxygenated conditions in the water column of Hood Canal.

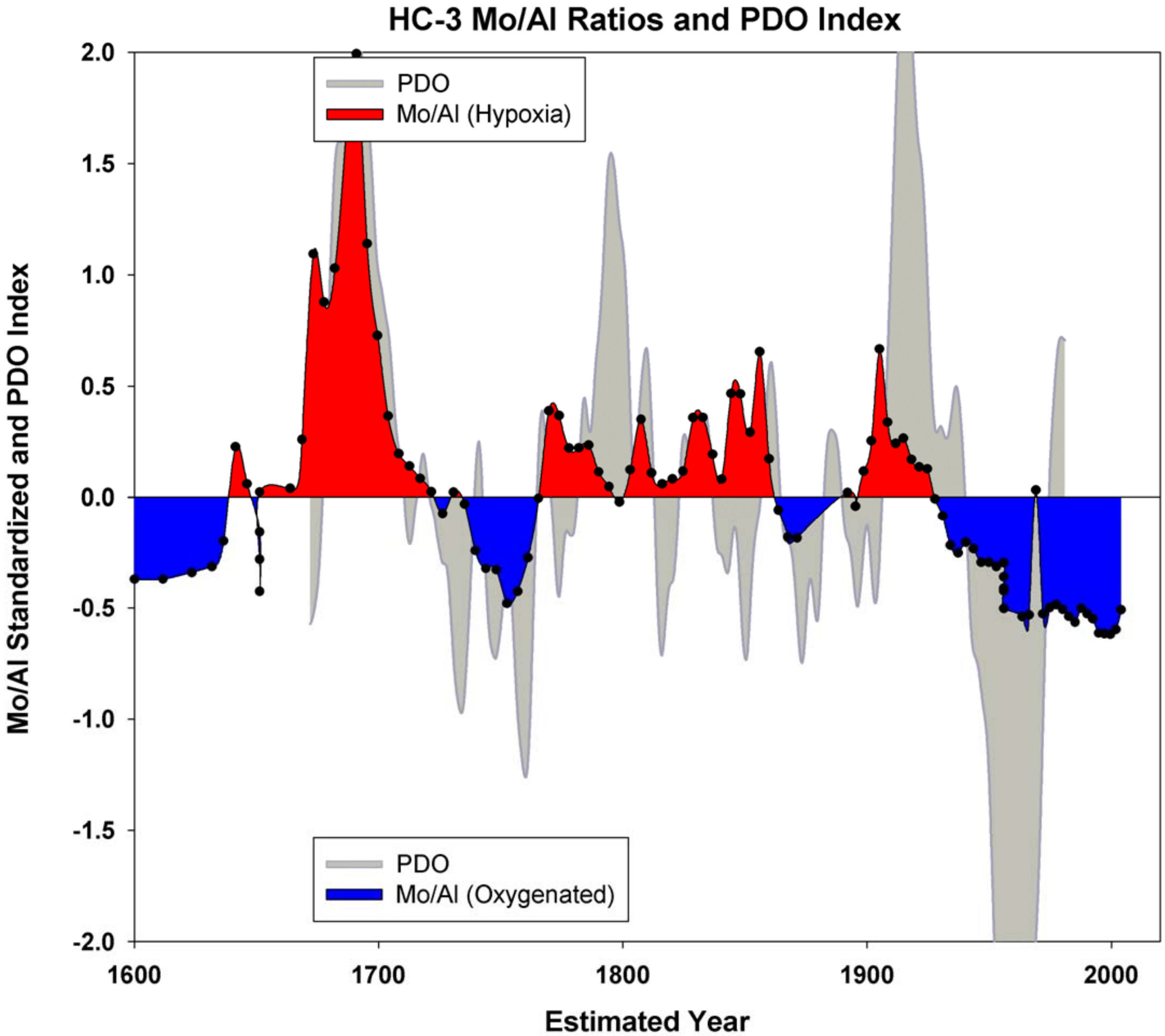


Figure 51. The Pacific Decadal Oscillation (PDO) Index reconstructed from tree rings (Biondi et al. 2001) plotted with standardized Mo/Al ratios for HC-3. Positive indicated Mo enrichment or hypoxia and negative indicates relative depletion of Mo from the core average or more oxygenated signatures.

The reconstruction of RSMs suggest that climate oscillations, and in particular the PDO, may influence the ventilation of deep water in Puget Sound and particularly their least mixed regions at the southern end of each basin. The RSMs reconstructions do not support the conclusions a trend of increasing hypoxia in the 20th Century, as hypothesized. However, the reconstructions do not resolve the last decade, at a minimum, when the greatest frequency and intensity of hypoxia was measured. Coupling the historical record and the current water column monitoring data might support the hypothesis that if anthropogenic impacts (e.g. septic tank inputs of nutrients, increased organic matter flux from soil erosion and waste effluents) are added in phase with natural conditions that prevent deep water ventilation and support surface water primary productivity, an increasing trend in frequency and severity of hypoxia might occur in basins with long residence times (e.g. less mixed). In fact, the paleo-indicators confirm that anthropogenic forces have had an unambiguous and substantial impact on the organic matter and nutrient fluxes to Puget Sound during the 20th Century. The lack of a concomitant rise in indicators of eutrophication and hypoxia may suggest that the development of hypoxia depends on how "in phase" anthropogenic influences are with respect to natural processes. Although, the process(es) supporting such a link is(are) not don't fully understand.

3.9. Research Obstacles or Limitations

Overall this research program encountered few problems that significantly altered the original approach to addressing the hypotheses for each paleo-indicator and although problems were encountered none were considered to negatively impact the overall program. There were two areas where the achieved results somewhat limited the scientist's ability to definitively address the proposed hypotheses. The first was the unexpected dense, diverse, and in some cases fragmented microfossils of the diatoms. The counting and identification of diatom microfossils took more time than expected, as the species encountered differ somewhat from those encountered in east coast estuaries, and a number of taxa were not found at all as whole valves (only broken pieces). There were between 89- 495 million diatom valves per cubic centimeter of sediment. As a result, the sampling density was limited. Due to the potential trends noted in the existing diatom data, more core segments should be analyzed for a complete history of changes to allow more definitive conclusions. The largest gaps in the data presented here are between dates of ca. 1800-1865 A.D. and before ca. 1760 A. D. These time periods are probably critical to understanding the historical cycles in water quality due to natural processes and then couple the cycles with time-period of known anthropogenic alterations.

The second issue encountered was the overall low foraminifer abundance and diversity in all cores. Approximately one third of the samples were barren and the remaining samples typically contained less than 50 specimens. The reduced sample size resulted in a lack of statistically significant number of foraminifers to be counted. More data are needed to understand the role of the sills in the restriction of the water masses and faunas. Although the benthic foraminiferal assemblages are sparse they can suggest climatic conditions for Puget Sound.

3.10. Additional Work

Hood Canal and the southern basin of Puget Sound have had documented problems of seasonal hypoxia for at least 50 years; however, only in the last few years have hypoxic events caused unprecedented fish closures and fish kills with associated severe environmental and economic impacts. The current research documented the existence of natural cycles that influence the development of hypoxia in Hood Canal; however, the mechanisms linking climatic variation with the development of hypoxic events and the potential impact of coupling anthropogenic forces with such climatic-driven periods are not yet well understood. Until these processes are better understood, an appropriate and effective management strategy to mitigate impacts cannot be developed or implemented.

Initial results from this study suggest that deeper regions of Hood Canal show an excellent record of oscillations in oxidation-reduction (redox) sensitive metals, carbon and nitrogen isotopes, biomarkers, and pollen from periods of pre-Euroamerican settlement to the present. The core profiles suggest that the intensity of hypoxic conditions in the bottom waters of Hood Canal increases southward, consistent with historical oxygen and dissolved phosphate data for Lynch Cove. The areas of the Great Bend into Lynch Cove generally record the lowest dissolved oxygen concentrations in the water column and the most anoxic sediments. Collecting additional sediment cores in Lynch Cove would provide a secondary set of reconstruction from an area that has shallower water depths, contains watersheds with the highest percentage of land disturbances (see Figure 4), and the highest population density in the Hood Canal system. These reconstructions would couple with the existing data to provide the best record of the relationship between anthropogenic activities and trends in hypoxia within Hood Canal. The additional cores in Lynch Cove would provide a means to corroborate existing Hood Canal core data and further evaluate links between climatic cycles and hypoxia in Hood Canal. As the sedimentation rate for the central Puget Sound cores were 2-4 times that of Hood Canal, the sediment record only extended back to the 1850s in the core near Tacoma. This core shows some indication of lower oxygen conditions prior to 1900s, but to better understand the preservation of such climatic events in the main basin of Puget Sound additional, longer sediment cores or cores collected from representative basins with lower sedimentation rates are needed. Analysis of sediment cores from the southern basin of Puget Sound, which is recognized for being less ventilated than the central basin and has had documented hypoxic events, should provide a confirmation that low oxygen conditions are strongly influenced by circulation patterns in these semi-enclosed basins.

In addition, high-resolution analyses of marine biomarkers in all these basins are necessary to address the paradoxical indications that primary production may have declined during the mid-20th Century when land use, and terrigenous organic matter inputs, peaked. It is a common assumption that with high transfer fluxes of terrigenous organic matter (particularly from soils), entrained nutrients stimulate at least some increase in water column productivity. The apparent inverse relationship between indicators of marine and terrigenous organic matter in both Hood Canal and central Puget Sound suggests instead that marine productivity may have decreased during the period of highest land use impact. This, in turn, may have prevented deep-water oxygen limitation. To understand if there is an inverse and functional link between land use and marine productivity, more cores need to be studied at a higher resolution during the 20th Century and particularly in basins with lower ventilations (Lynch Cove and South Puget Sound).

Overall diatom abundance showed an increase before 1900, then a decline over time since ca. 1900, with the most pronounced decline appearing after ca. 1950 (see Figure 39). This trend is opposite to expected results related to eutrophication of the water column. In fact, the decrease in diatom abundance is, again, confirming what the organic markers and BSi are suggesting, namely that productivity went down (or at least that the preservation of all proxies of water column productivity, including the RSM markers, have declined starting in the early 1900s and reaching a minimum in the 1950s. This may be the most significant finding since it is completely counterintuitive and against all our initial hypotheses. One or two long cores at selected sites should be analyzed in more detail for diatom assemblages.

These tools will allow a predictive capability for given current conditions and potential natural or anthropogenic scenarios, including management alternatives, such as land use management, nutrient removal, and river flow control. This information will be used to better determine what combination of factors is triggering increased eutrophication in Hood Canal waters.

4.0 Applications - Outputs and Management Outcomes

Puget Sound is a major estuary with documented hypoxia in select sub-basins, which has resulted in both significant ecological and economic damage. Coastal resource managers realized the need to understand the ecological conditions surround the increased frequency of hypoxia and resulting fish kills in Hood Canal in order to better guide the coastal management policies. As a result, environmental programs began with collective objectives of providing resource managers with current ecological conditions within the Hood Canal to provide information so informed decisions can be made to reduce the hypoxia. This study supports the development of future coastal resource decisions by resolving the Puget Sound's chemical and biological signatures for pre- and post-urbanization in basins with differing natural and anthropogenic stresses. Understanding the importance of both stresses within sub-basins of Puget Sound will allow future management applications to optimize required actions to more effectively address hypoxia in a more economically feasible manner.

4.1. Outputs

4.1.1. New Fundamental Knowledge

Coastal eutrophication is often linked to increasing anthropogenic nutrient loadings. While this cause-effect relationship has been established using a suite of paleo-indicators preserved in sediment cores from the Chesapeake Bay and the Gulf of Mexico, the Pacific Northwest also receives nutrient-rich waters from coastal upwelling. The suite of paleo-indicators recorded in central Puget Sound and Hood Canal sediment cores reconstruct a clear anthropogenic impact during the last 100 years of significant western settlement as a result of urbanization, industrialization, land-use alterations, and land clearing/deforestation. However, the sediment cores from both of these basins, collectively differ from the other national hypoxia regions, as the suite of paleo-indicators do not record an increasing propensity to develop hypoxia in the last 100 years concomitant with the significant urbanization in the region. In fact, the records indicate the existence of hypoxic periods prior to western settlement. Therefore, this study provides a new fundamental knowledge of the need to evaluate the status of an ecosystem with respect to hypoxia not only on a time-scale of decades, but also on a time-scale of hundreds of years. In addition, coupling the paleo-indicators provides a set of "tools" in the form of biomarkers or chemical measurements that indicate not only the status of hypoxia on time-scales of pre- and post- coastal urbanization, but also the effectiveness of coastal management strategies (i.e. success of land management practices on the transport of organic matter to the receiving estuary, Section 3.2.4). Collectively, these reconstructions provide a measure of the natural cyclicity within an estuary and the response of the paleo-indicators to documented anthropogenic impacts. The agencies that manage Puget Sound will be able to make informed decisions regarding potential management alternatives based on anthropogenic and natural forcing scenarios.

4.1.2. Scientific Publications

A distribution list for the final report includes interested local private organizations (*e.g.* Seattle Aquarium), tribal organizations, state/local governments, and federal agencies within the Puget Sound region. In addition to the dissemination of the report to public, several peer reviewed publications will be or have been submitted. The first manuscript partially funded by this program was not directly related to the historical reconstructions for paleoecological conditions. However, the manuscript was accepted as a feature article summarizing the historical trends of Pb, Cu, As, and organic matter biomarkers in Puget Sound's main basin through the 20th Century and the status of natural and enhanced recovery anticipated for the 21st Century. This publication was the first of 3-4 manuscripts planned and established the geochronology and dating approach used for this program. A complete list of submitted or manuscripts in progress are listed below.

1. Brandenberger J.M., E.A. Crecelius, and P. Louchouarn. (2008). Historical Inputs and Natural Recovery Rates for Heavy Metals and Organic Biomarkers in Puget Sound during the 20th Century". *Environ. Sci. Tech* 42: 6786-6790.
2. Brandenberger, J.M., P. Louchouarn, and E.A. Crecelius. (2008 - In Preparation). Historical reconstruction of redox sensitive metals in two basins of Puget Sound: Evaluating Natural and Post Urbanization Signatures of Hypoxia. Submitting to *Geochimica et Cosmochimica Acta* in Fall 2008.
3. Louchouarn, P., J. M. Brandenberger, and E.A. Crecelius. (2008 - In Preparation). Historical reconstruction of organic matter inputs to two basins of Puget Sound: Biogeochemical and physical constraints on hypoxia conditions. Submitting to *Geochimica et Cosmochimica Acta* in Fall 2008.
4. Liu, G.W. and E. B. Leopold. (2009 – In Preparation). Pollen Rain in the past 200 years in Puget Sound, Washington. Submitting to *Northwest Science* in early 2009.
5. A synthesis paper of the suite of paleo-indicators will be prepared and submitted to a coastal management journal that is to be identified at a later date.

4.1.3. New or Advanced Tools (e.g. biomarkers)

The approach of using a set of paleo-indicators permitted a validation of historical biomarkers and isotopic signature changes in the sediments of the region. The match between pollen and terrestrial biomarkers, in particular, demonstrated that each basin has undergone substantial changes to their vegetation cover from land use activities in the past century. The parallel shifts in these paleo-indicators also illustrated the intensity of land-use alterations within the watersheds, as seen in the highly urbanized watersheds of central Puget Sound *vs.* the more rural Hood Canal, and also the recent progress in environmental quality with signatures returning toward pre-industrial conditions. However, the decoupling between land use activities and major shifts in oxygen conditions in deep waters of the basins suggest that physical, rather than biogeochemical conditions have the most important impact on hypoxia in these basins.

4.1.4. Presentations

The findings from this study were presented at several local and regional scientific conferences and meetings, as well as, international scientific conferences. In addition, a brief discussion of the results was presented in a public workshop on Hood Canal and directly to Congressman Norm Dick, U.S. Representative for Washington's 6th District which includes counties surrounding Hood Canal and the western-side of the central Puget Sound. The following is a list of presentations at scientific conferences, public/professional meetings, educational outreach presentations, and coastal resource manager presentations.

Scientific Conferences:

1. Louchouarn, P., L-J. Kuo, F. Marcantonio, J. Brandenberger, and E. Crecelius. (2008). Using sediment cores to reconstruct historical inputs of BC and other combustion-derived contaminants to airsheds/watersheds: potentials and limitations. AGU Fall Meeting, Dec. 15-19, 2008.
2. Brandenberger, J.M., E.A. Crecelius, P. Louchouarn, S. Cooper, E. Leopold, and K. McDougall. 2008. "Natural Fluctuations in Coastal Hypoxia: Relationships between Large-Scale Climate Drivers and Deep Water Oxygen Levels Recorded in Sediment Core from Puget Sound, WA". Presented at 2008 American Society of Limnology and Oceanography (ASLO) - Ocean Sciences Meeting, Orlando, FL March 2-7, 2008.
3. Cooper S., J.M. Brandenberger, E.A. Crecelius, P. Louchouarn, E.B. Leopold, and K. McDougall. 2007. "Reconstructing Trends in Hypoxia Using Multiple Paleoecological Indicators Recorded in Sediment Cores from Puget Sound, WA." Presented at 2008 ASLO Ocean Sciences Meeting, Orlando, FL March 2-7, 2008.
4. Louchouarn P., J.M. Brandenberger, and E.A. Crecelius. 2006. "Historical Reconstruction of Reduced Oxygen Levels in Deep Waters of Puget Sound: Biogeochemical and Physical Constraints on Hypoxia Conditions." Presented at ASLO 2007 Aquatic Sciences Meeting, Santa Fe, NM, February 4-9, 2007.
5. Cooper S, J.M. Brandenberger, E.A. Crecelius, and P. Louchouarn. 2007. "Puget Sound and Hood Canal: Past 300 Years." Presented at Estuarine Research Federation, Providence, RI, 4-8 November.
6. Brandenberger J.M. and E.A. Crecelius. 2006. "Historical Record of Trace Metals in Sediment and Natural Recovery in the Main Basin of Puget Sound." Presented at 2007 Georgia Basin Puget Sound Research Conference, Vancouver, BC, Canada, March 26-29, 2007.
7. Crecelius E.A., J.M. Brandenberger, P. Louchouarn, S. Cooper, K. McDougall, and E. Leopold. 2006. "Historical Trends of Hypoxia in Hood Canal." Presented at Georgia Basin and Puget Sound Research Conference, Vancouver, BC, Canada, March 26-29, 2007.
8. Brandenberger J.M., and E.A. Crecelius. 2006. "Historical Record of Trace Metals in Sediment and Natural Recovery in the Main Basin of Puget Sound." Presented at Toxics in Puget Sound, Seattle, WA.

Public/Professional Meetings:

1. A brief synopsis of this research was presented at the Hood Canal Science Summit sponsored by U. S. Congressional Representative Norm Dicks on 30 June, 2008 in Bremerton, WA. The presentation summarized the last three years of progress in research surrounding the low oxygen events in Hood Canal.
2. The team has participated in the Hood Canal Dissolved Oxygen Program (HCDOP) meetings and discussions which incorporate state agencies, cities, counties, special interest groups, and local stakeholders. Eric Crecelius presented, "Historical Trends in Hypoxia in Hood Canal" at the quarterly meeting on October 24, 2006.
3. In November 2007, Estella Leopold presented, "Vegetation history of Puget Sound area, WA" at an invited talk to the Washington Department of Ecology in Bellevue, WA.
4. In January 2008, Estella Leopold presented, "History of the Puget Sound Region" at an invited talk with the Jefferson Land Trust in Port Townsend, WA.
5. Gengwu Liu and Estella Leopold presented, "Pollen Rain in the past 200 years in Puget Sound" at the regional meeting of the Geological Society of America at Bellingham, WA, on May 4, 2007.

Educational Outreach:

The results and implications of this research were incorporated into several student and educational outreach presentations. The following is a list of specific educational outreach initiatives performed during the course of the study.

1. Dr. Patrick Louchouarn is a Co-Principal Investigator and professor at Texas A&M University in Galveston, TX. He incorporated the information on historical trends into seminar presentations titled, "Historical reconstruction of reduced O_2 levels in deep waters of Puget Sound: Biogeochemical and physical constraints on hypoxia conditions" given as an invited seminar speaker at Texas A&M University in Galveston, TX on February 2008 and Texas A&M University's Dept. of Oceanography in College Station, TX in March 2008.
2. Dr. Louchouarn also included part of the information derived from this study in a web-based course, entitled "Environmental Economics in Oceanography" to be used as a main course for the graduate program in Marine Resources Management (M.Sc.) at Texas A&M University-Galveston.
3. Ms. Jill Brandenberger is a Co-Principal Investigator, senior research scientist at the Pacific Northwest National Laboratory's Marine Science Laboratory, and adjunct professor at Western Washington University. She incorporated the new understanding of Puget's Sound natural versus anthropogenically altered signatures into her class on Practical Perspectives on Learning Water Quality and seminar classes on regional environmental issues.
4. Dr. Sherri Cooper is a Co-Principal Investigator and professor at Bryn Athyn College near Philadelphia, PA. Dr. Cooper presented a seminar at Bryn Athyn College on November 29, 2007 titled, "Puget Sound and Hood Canal: Past 400 Years" with information from this research. The talk covered topics related to the history of hypoxia and anoxia of Puget Sound and Hood Canal, and anthropogenic influences on water quality. The seminar was attended by faculty, students and visitors.

Coastal Managers:
The results from this program were presented at an invited meeting with Congressman Norm Dicks in his office at Tacoma, WA on July 18, 2008. The briefing lasted 45 minutes and included discussions on implications of the research findings and directions for future research. In addition, presentations are planned for the Washington Department of Ecology in January or February 2009 and potentially with the Puget Sound Partnership. This information is critical, as targeted decisions regarding nutrient inputs to Hood Canal are currently in progress.

4.1.5. Public Outreach Activities/Products

The findings from this study have been presented in several other media types, including the Washington Public Affairs television station, radio, and newspaper articles. The following is a list of web-sites where these communication products are available.

1. Interview with William J. Cannon of TVW Olympia, WA Public Affairs Programming in September 2006. The segment aired in March 2007 for several months on the public affairs network and was available to state government officials. In addition, the segment is available to teachers and students along with supplementary materials. Mr. Cannon had the following comment to Principal Investigator Eric Crecelius, "Scientists who provide a window into their tax-supported research perform a valuable public service, and you and Jill Brandenberger did an especially good job at explaining your project."
2. Interview with KUOW radio an affiliate of National Public Radio (NPR) operated by University of Washington which aired the story on April 25, 2007 and a sound clip is available at http://www.kuow.org/defaultProgram.asp?ID=12668.
3. Interview and story titled, "Hood Canal Secrets Revealed" printed by the Kitsap Sun newspaper on April 25, 2007, http://www.kitsapsun.com/bsun/local/article/0,2403,BSUN_19088_5503118,00.html
4. KONP radio announcement on April 25th, 2007 at 8:45am entitled, "Sequim scientists say Hood Canal has natural cycles of oxygen levels" http://www.konp.com/local/2781
5. The Columbian printed a story on April 25, 2007, "Study suggests natural high-low oxygen cycle in Hood Canal", http://www.columbian.com/news/state/APStories/AP04252007news131610.cfm
6. KOMO Television aired a segment on April 25, 2007 entitled, "Study suggests natural oxygen cycle in Hood Canal" http://www.komotv.com/news/7184136.html
7. KGW Television aired a segment on April 25, 2007 entitled, "Study suggests natural high-low oxygen cycle in Hood Canal", http://www.kgw.com/sharedcontent/APStories/stories/D8ONL7MG0.html
8. The Olympian printed the story on April 25, 2007, http://www.theolympian.com/130/story/89024.html

4.2. Outcomes for Management Application/Adoption

Environmental policy-making is rarely determined exclusively on the basis of scientific advice (important considerations are provided from stakeholders, communities, the political context, the expectations of various sectors, and the nature and structure of institutions), for scientific information to be effective in influencing environmental policy it needs first and foremost to be credible, legitimate, and relevant to the needs of policy and decision makers (Rabalais et al. 2002b). This project is poised to provide the initial scientific information at a level and credibility required by coastal managers of the region to address mounting pressure to develop strategies to mitigate increasing oxygen limitations in basins of Puget Sound. The research answered critical questions as to the historical evolution of hypoxic conditions in the region and, most importantly, verified that anthropogenic nutrient loading may not be solely responsible for increased eutrophication in this coastal system. The lessons learned in dealing with coastal hypoxia/anoxia in the northern Gulf of Mexico (2002a; Rabalais et al. 2002b) are no where near to be applicable in systems like Puget Sound where the science of the issue is yet in its discovering stages. The historical reconstruction of productivity and oxygen levels in the basins of study are critical particularly as they can be tied to the present efforts of understanding physical constraints on stratification and water column ventilation.

For any management strategy to be truly effective in such complex natural systems, there needs to be a clear dialogue between all involved parties, which include public managers, policy makers, expert groups and public stakeholders (Rabalais et al. 2002a; McDaniels and Gregory 2004). The results from this study have been presents to public, coastal manager, and scientific audiences in an information transfer process similar to the "Packet Model" and "Diffusion Model" described by Rabalais et al. (2002b). These two models describe the initial stages of an interactive relationship between scientists and managers/decision makers that provides the baseline understanding of scientific processes in the context of managerial needs. However, to be truly useful, this approach will need to be open to public information and outreach in what is called the "Triangulation Model" (Rabalais et al. 2002b). The principal investigators will continue to present the findings from this study to the Washington State's sponsored Puget Sound Partnership.

4.2.1. New Fundamental or Applied Knowledge

This project provided relevant scientific information at a level and credibility required by coastal managers of the region to address mounting pressure to develop strategies to mitigate increasing oxygen limitations in basins of Puget Sound. Through a multi-disciplinary approach, this projects answered critical questions as to the historical evolution of hypoxic conditions in the region of study and verified if nutrient loading has been responsible during the past decades for increased eutrophication in this coastal system. Most importantly, the knowledge learned in dealing with coastal hypoxia/anoxia in the northern Gulf of Mexico and the Chesapeake Bay (Rabalais et al. 2002a; 2002b; Kemp et al. 2005) does not appear to be directly applicable to coastal systems Puget Sound where physical circulation, rather than nutrient inputs and land use, seems to be the major factor driving low oxygen content in deep waters. The historical reconstruction of productivity and oxygen levels in the basins of study are particularly critical as they can be tied to the present efforts of understanding physical constraints on stratification and water column ventilation.

The measurement of redox-sensitive metals (RSMs) in sediment profiles as tracers of deep water oxygen limitations allowed our group to reconstruct historical hypoxic conditions in several basins of Puget Sound and show that: a) oxygen limitation has occurred substantially and over extended periods of time in the past in the Hood Canal/Puget Sound System, and b) for most of the 20th Century, the majority of the Puget Sound system (including Hood Canal) has been under a more oxygenated "stance" with respect to prior periods. Finally, and in contrast to what was anticipated, the major land use changes in the Puget Sound's drainage basin over the late 19th to mid 20th Century were not coincidental with low oxygen conditions in deep waters of the basins (including Hood Canal). On the contrary, low oxygen conditions prevailed in the system throughout most of the 19th Century prior to major land use changes and population growth occurred in the drainage basin. The decoupling between the increase in land use and the low oxygen conditions in the deep waters of the basin is somewhat counterintuitive and opposite to what has been observed in other coastal systems, in which the onset of low oxygen conditions came as a result of a rise in land use (i.e. agriculture and deforestation). These observations suggest that Puget Sound is controlled by natural processes of ventilation (physical mixing) that may buffer (or accelerate) changes in oxygen levels in deep waters.

4.2.2. Public Outreach Products

This work has been presented at several National/International conferences and showed that a nutrient-centric view of hypoxia in Puget Sound is probably less applicable than for agriculturally dominated shallow and semi-enclosed estuaries. In the deep and relatively narrow inlets of Puget Sound, more complex drivers (including physical mixing, mixed sources of OM inputs, benthic to water column processes, and hydrological events) are all playing a part with proportions that differ depending on the specific site. In particular, some of these drivers seem to be dominated by circulation (and climate?) patterns.

4.3. Societal Outcomes from Management Actions

The benefits of this study are based on both its scientific merit and the potential information transfer to coastal managers and policy makers. Increasingly, solutions to environmental issues and the development of environmentally sustainable ways of meeting society's needs and wants necessitates greater understanding of very complex ecological systems and cycles, often over long time frames (Lubchenco 1998). Today's complex environmental issues thus require research to be more integrative across scales of time and space; and be more open to exploring the social dimensions of the issues. However, complexity and long time frames do not fit comfortably with many human, societal, economic, and governance constructs with the result that appropriate policy responses to scientific information are often delayed or too slow. Although environmental policy-making is rarely determined exclusively on the basis of scientific advice (important considerations also emphasize information and values coming from stakeholders and communities, the political context, the expectations of various sectors, and the nature and structure of institutions), for scientific information to be effective in influencing environmental policy it needs first and foremost to be credible, legitimate, and relevant to the needs of policy and decision makers.

4.3.1. Improved water quality

A recently published study from our group (Brandenberger et al., 2008) assessed the historical impact of increased point source inputs of inorganic (Pb, Cu, and As) and organic (lignin and soil biomarkers) constituents to central Puget Sound during the 20th Century. This study confirmed that the sedimentary archives used provide a historical record of watershed-integrated metal and organic biomarker inputs with specific features directly linked to events within Puget Sound drainage basin. It also calculated the natural rates of recovery towards pre-industrial conditions in recent decades due to the enactment of environmental regulations like the Clean Air and Clean Water Acts. This work thus showed, in a quantitative way, the positive influence of such regulations and demonstrated that additional regulations are needed on non-point source inputs to further improve the gains obtained in the early decades of point-source abatement. Recent work by the PIs and a graduate student (Li-Jung Kuo, Texas A&M University) further developed this approach by studying the distribution of molecular markers of combustion (pyrogenic PAHs, black carbon, anhydrosugars).

The science around understanding the modern causes of hypoxia in peripheral inlets of Puget Sound is yet in its discovering stages and little of it seems to have been translated into environmental regulation and improvement. Our work suggests that physical processes of ventilation/stratification are main drivers of low oxygen conditions in the system. Hence, a nutrient-centric view of the solution (e.g. nutrient abatement) would most probably be incomplete to manage low oxygen conditions in such basins.

5.0 Evaluation

This multi-institution research group consisting of scientists from the Pacific Northwest National Marine Sciences Laboratory operated by Battelle, Texas A&M University, Bryn Athyn College, University of Washington, and the U.S. Geological Survey (USGS) reconstructed the history of hypoxia in two basins of Puget Sound, WA. This group, led by researchers from Battelle, used a suite of environmental indicators in sediment cores to evaluate if periods of hypoxia existed prior to significant anthropogenic changes in these basins through the 20th Century. The major findings from this research suggest that: 1) oxygen limitations occurred substantially and over extended periods prior to significant anthropogenic influences in Hood Canal, 2) during the 20th Century the central Puget Sound and Hood Canal were under a more oxygenated "stance" with respect to prior periods and climatic-cycles may significantly influence the development of hypoxia in Hood Canal, 3) major changes in land use beginning around the end of the 19th Century have had a substantial impact on the sources of organic matter being transferred to Puget Sound, and 4) the most recent sediments in the southern portions of both of these basins (HC-1 in Hood Canal and PS-1 in Puget Sound) could suggest the initial stages of eutrophication. The cost effective approach of applying a large suite of paleoecological tracers to a single coring study provided a wealth of information for coastal managers, ranging from the effectiveness of past environmental management policies to the natural cycles in organic matter, nutrients, and hypoxia that must be considered along with anthropogenic impacts. Therefore, the overall objectives of the project were met and the project was deemed a success.

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Appendix A: Data and Calculations for Estimated Ages in the 2005 Sediment Cores

^{210}Pb Data

Core ID	Core Interval (cm)	Mid-Depth (cm)	Mid-Depth Total Dry Accumulation (g/cm^2)	Activity ^{210}Pb (dpm/g)	± Error	Supported ^{210}Pb Activity ± 1σ (dpm/g)	$^{210}Pb_{xs}$ Activity (dpm/g)	ln $^{210}Pb_{xs}$ (dpm/g)	Comments
PS-1	0-2	1	0.350	6.67	0.11	0.825 ± 0.332	--	--	Mixing
PS-1	0-2	1	0.350	6.05	0.091	0.825 ± 0.332	--	--	RPD = 10%
PS-1	8-10	9	3.27	6.24	0.094	0.825 ± 0.332	--	--	Mixing
PS-1	18-20	19	7.60	5.38	0.10	0.825 ± 0.332	--	--	Mixing
PS-1	26-28	27	11.0	5.18	0.11	0.825 ± 0.332	4.35	1.47	
PS-1	32-34	33	13.6	4.98	0.087	0.825 ± 0.332	4.16	1.43	
PS-1	38-40	39	16.3	3.82	0.11	0.825 ± 0.332	3.00	1.10	
PS-1	44-46	45	19.1	3.92	0.11	0.825 ± 0.332	3.10	1.13	
PS-1	50-52	51	22.0	3.63	0.10	0.825 ± 0.332	2.80	1.03	
PS-1	56-58	57	24.8	3.39	0.12	0.825 ± 0.332	2.57	0.943	
PS-1	60-65	62.5	27.3	2.60	0.11	0.825 ± 0.332	1.78	0.576	
PS-1	70-75	72.5	31.9	2.23	0.13	0.825 ± 0.332	1.40	0.338	
PS-1	80-85	82.5	36.9	2.01	0.12	0.825 ± 0.332	1.18	0.170	
PS-1	90-95	92.5	42.0	1.59	0.13	0.825 ± 0.332	0.762	-0.272	
PS-1	100-105	102.5	47.3	1.42	0.13	0.825 ± 0.332	0.599	-0.510	
PS-1	115-120	117.5	55.3	1.10	0.18	0.825 ± 0.332	--	--	Supported
PS-1	135-140	137.5	66.4	0.637	0.20	0.825 ± 0.332	--	--	Supported
PS-1	150-155	152.5	74.3	0.743	0.19	0.825 ± 0.332	--	--	Supported
Check Standard				6.19	0.086	--	--	--	PR = 92%

Slope = -0.056
Correlation Factor = 0.981
Average Sediment Accumulation Rate ± 1 σ ($g/cm^2/yr$) = 0.556 ± 0.052
Lower 95% Confidence Limit = 0.504
Upper 95% Confidence Limit = 0.607
Sedimentation Rate (cm/yr) = 1.2 ± 0.1

Core ID	Core Interval (cm)	Mid-Depth (cm)	Mid-Depth Total Dry Accumulation (g/cm^2)	Activity ^{210}Pb (dpm/g)	± Error	Supported ^{210}Pb Activity ± 1σ (dpm/g)	$^{210}Pb_{xs}$ Activity (dpm/g)	ln $^{210}Pb_{xs}$ (dpm/g)	Comments
PS-2	6-8	7	2.46	9.97	0.093	0.965 ± 0.497	--	--	Mixed
PS-2	6-8	7	2.46	9.16	0.10	0.965 ± 0.497	--	--	RPD = 8%
PS-2	16-18	17	6.32	8.84	0.12	0.965 ± 0.497	7.87	2.06	
PS-2	34-36	35	13.5	7.54	0.11	0.965 ± 0.497	6.57	1.88	
PS-2	48-50	49	18.9	7.13	0.11	0.965 ± 0.497	6.17	1.82	
PS-2	62-64	63	25.0	6.38	0.12	0.965 ± 0.497	5.41	1.69	
PS-2	76-78	77	31.2	4.95	0.11	0.965 ± 0.497	3.98	1.38	
PS-2	90-95	92.5	38.2	4.37	0.13	0.965 ± 0.497	3.41	1.23	
PS-2	115-120	117.5	49.7	3.56	0.14	0.965 ± 0.497	2.60	0.960	
PS-2	140-145	142.5	61.5	2.74	0.14	0.965 ± 0.497	1.77	0.570	

(Supported determined as average supported from other PS cores)

Slope = -0.027
Correlation Factor = 0.990
Average Sediment Accumulation Rate ± 1 σ ($g/cm^2/yr$) = 1.14 ± 0.065
Lower 95% Confidence Limit = 1.09
Upper 95% Confidence Limit = 1.19
Sedimentation Rate (cm/yr) = 2.6 ± 0.2

Appendix A: Data and Calculations for Estimated Ages in the 2005 Sediment Cores

Core ID	Core Interval (cm)	Mid-Depth (cm)	Mid-Depth Total Dry Accumulation (g/cm^2)	Activity ^{210}Pb (dpm/g)	± Error	Supported ^{210}Pb Activity ± 1σ (dpm/g)	$^{210}Pb_{xs}$ Activity (dpm/g)	ln $^{210}Pb_{xs}$ (dpm/g)	Comments
PS-3	0-2	1	0.310	7.33	0.10	0.747 ± 0.267	--	--	Mixed
PS-3	0-2	1	0.310	7.11	0.084	0.747 ± 0.267	--	--	RPD = 3%
PS-3	6-8	7	2.51	7.46	0.093	0.747 ± 0.267	6.72	1.91	
PS-3	18-20	19	7.78	6.45	0.11	0.747 ± 0.267	5.70	1.74	
PS-3	28-30	29	12.3	5.02	0.10	0.747 ± 0.267	4.28	1.45	
PS-3	38-40	39	16.9	5.00	0.11	0.747 ± 0.267	4.25	1.45	
PS-3	55-60	57.5	26.8	3.77	0.11	0.747 ± 0.267	3.02	1.10	
PS-3	85-90	87.5	43.4	2.37	0.13	0.747 ± 0.267	1.62	0.480	
PS-3	105-110	107.5	55.0	0.899	0.19	0.747 ± 0.267	--	--	Supported
PS-3	140-145	142.5	76.0	0.594	0.19	0.747 ± 0.267	--	--	Supported
Check Standard				6.09	0.11	--	--	--	PR = 92%

Slope = -0.034
Correlation Factor = 0.987
Average Sediment Accumulation Rate ± 1 σ (g/cm^2/yr) = 0.914 ± 0.042
Lower 95% Confidence Limit = 0.872
Upper 95% Confidence Limit = 0.956
Sedimentation Rate (cm/yr) = 1.8 ± 0.1

Core ID	Core Interval (cm)	Mid-Depth (cm)	Mid-Depth Total Dry Accumulation (g/cm^2)	Activity ^{210}Pb (dpm/g)	± Error	Supported ^{210}Pb Activity ± 1σ (dpm/g)	$^{210}Pb_{xs}$ Activity (dpm/g)	ln $^{210}Pb_{xs}$ (dpm/g)	Comments
PS-4	0-2	1	0.340	8.80	0.11	1.10 ±0.255	--	--	Mixed
PS-4	0-2	1	0.340	7.64	0.11	1.10 ±0.255	--	--	RPD = 14%
PS-4	8-10	9	3.39	7.86	0.10	1.10 ±0.255	--	--	Mixed
PS-4	18-20	19	8.04	7.34	0.12	1.10 ±0.255	6.24	1.83	
PS-4	28-30	29	12.9	6.26	0.10	1.10 ±0.255	5.16	1.64	
PS-4	38-40	39	17.7	6.14	0.10	1.10 ±0.255	5.04	1.62	
PS-4	48-50	49	22.8	5.85	0.11	1.10 ±0.255	4.75	1.56	
PS-4	55-60	57.5	27.2	5.84	0.12	1.10 ±0.255	4.74	1.56	
PS-4	65-70	67.5	32.3	5.88	0.12	1.10 ±0.255	4.78	1.56	
PS-4	75-80	77.5	37.3	4.40	0.11	1.10 ±0.255	3.30	1.19	
PS-4	85-90	87.5	42.6	4.13	0.10	1.10 ±0.255	3.03	1.11	
PS-4	95-100	97.5	49.2	4.10	0.12	1.10 ±0.255	3.00	1.10	
PS-4	110-115	112.5	55.7	3.38	0.11	1.10 ±0.255	2.28	0.820	
PS-4	125-130	127.5	63.6	2.81	0.13	1.10 ±0.255	1.71	0.540	
PS-4	140-145	142.5	71.9	2.04	0.13	1.10 ±0.255	0.940	-0.0658	
PS-4	155-160	157.5	80.4	1.96	0.13	1.10 ±0.255	0.860	-0.147	
PS-4	170-175	172.5	88.5	1.61	0.14	1.10 ±0.255	0.510	-0.680	
PS-4	180-185	182.5	94.0	1.15	0.17	1.10 ±0.255	--	--	Supported
PS-4	195-200	197.5	103	1.06	0.19	1.10 ±0.255	--	--	Supported
Check Standard				5.74	0.096	--	--	--	PR = 88%

Slope = -0.030
Correlation Factor = 0.937
Average Sediment Accumulation Rate ± 1 σ (g/cm^2/yr) = 1.05 ± 0.048
Lower 95% Confidence Limit = 1.07
Upper 95% Confidence Limit = 1.13
Sedimentation Rate (cm/yr) = 2.1 ± 0.2

Appendix A: Data and Calculations for Estimated Ages in the 2005 Sediment Cores

Core ID	Core Interval (cm)	Mid-Depth (cm)	Mid-Depth Total Dry Accumulation (g/cm^2)	Activity ^{210}Pb (dpm/g)	± Error	Supported ^{210}Pb Activity ± 1σ (dpm/g)	$^{210}Pb_{xs}$ Activity (dpm/g)	ln $^{210}Pb_{xs}$ (dpm/g)	Comments
HC-1	0-2	1	0.690	0.962	0.19	0.535 ± 0.401	--	--	Mixed
HC-1	6-8	7	5.13	1.16	0.25	0.535 ± 0.401	--	--	Mixed
HC-1	6-8	7	5.13	1.05	0.15	0.535 ± 0.401	--	--	RPD = 10%
HC-1	12-14	13	9.85	0.957	0.20	0.535 ± 0.401	--	--	Mixed
HC-1	18-20	19	14.6	1.03	0.17	0.535 ± 0.401	0.50	-0.70	
HC-1	28-30	29	23.0	0.887	0.21	0.535 ± 0.401	0.35	-1.04	
HC-1	38-40	39	31.7	0.791	0.18	0.535 ± 0.401	0.26	-1.36	
HC-1	48-50	49	40.6	0.551	0.19	0.535 ± 0.401	--	--	Supported
HC-1	60-65	62.5	52.8	0.568	0.20	0.535 ± 0.401	--	--	Supported
HC-1	75-80	77.5	67.0	0.585	0.18	0.535 ± 0.401	--	--	Supported
HC-1	90-95	92.5	81.3	0.436	0.23	0.535 ± 0.401	--	--	Supported
Check Standard				6.43	0.11	--	--	--	PR = 96%

Slope = -0.0387
Correlation Factor = 0.999
Average Sediment Accumulation Rate ± 1 σ (g/cm^2/yr) = 0.804 ± 0.42
Lower 95% Confidence Limit = 0.376
Upper 95% Confidence Limit = 1.22
Sedimentation Rate (cm/yr) = 0.90 ± 0.25

Core ID	Core Interval (cm)	Mid-Depth (cm)	Mid-Depth Total Dry Accumulation (g/cm^2)	Activity ^{210}Pb (dpm/g)	± Error	Supported ^{210}Pb Activity ± 1σ (dpm/g)	$^{210}Pb_{xs}$ Activity (dpm/g)	ln $^{210}Pb_{xs}$ (dpm/g)	Comments
HC-2	0-2	1	0.370	1.89	0.12	0.667 ± 0.37	--	--	Mixed
HC-2	2-4	3	1.13	1.90	0.14	0.667 ± 0.37	--	--	Mixed
HC-2	2-4	3	1.13	2.19	0.13	0.667 ± 0.37	--	--	RPD = 14%
HC-2	6-8	7	1.13	2.08	0.12	0.667 ± 0.37	--	--	Delta Slump
HC-2	10-12	11	1.13	2.16	0.12	0.667 ± 0.37	--	--	Delta Slump
HC-2	16-18	17	1.13	1.96	0.13	0.667 ± 0.37	--	--	Delta Slump
HC-2	22-24	23	1.13	2.17	0.12	0.667 ± 0.37	--	--	Delta Slump
HC-2	28-30	29	1.13	1.77	0.16	0.667 ± 0.37	--	--	Delta Slump
HC-2	32-34	33	1.13	2.05	0.12	0.667 ± 0.37	--	--	Delta Slump
HC-2	38-40	39	1.13	2.08	0.13	0.667 ± 0.37	--	--	Delta Slump
HC-2	42-44	43	3.81	1.81	0.13	0.667 ± 0.37	1.14	0.13	
HC-2	46-48	47	5.62	1.52	0.14	0.667 ± 0.37	0.85	-0.16	
HC-2	54-56	55	9.43	1.22	0.16	0.667 ± 0.37	0.56	-0.59	
HC-2	60-62	61	12.4	1.04	0.13	0.667 ± 0.37	0.37	-1.00	
HC-2	66-68	67	15.4	0.936	0.16	0.667 ± 0.37	0.27	-1.31	
HC-2	70-72	71	17.5	0.810	0.19	0.667 ± 0.37	0.14	-1.95	
HC-2	90-92	91	27.8	0.576	0.21	0.667 ± 0.37	--	--	Supported
HC-2	100-102	101	33.1	0.822	0.15	0.667 ± 0.37	--	--	Supported
HC-2	108-110	109	37.3	0.627	0.17	0.667 ± 0.37	--	--	Supported
HC-2	122-124	123	44.6	0.643	0.21	0.667 ± 0.37	--	--	Supported
Check Standard				6.17	0.098	--	--	--	PR = 92%

Slope = -0.140
Correlation Factor = 0.976
Average Sediment Accumulation Rate ± 1 σ (g/cm^2/yr) = 0.222 ±0.081
Lower 95% Confidence Limit = 0.167
Upper 95% Confidence Limit = 0.328
Sedimentation Rate (cm/yr) = 0.44 ± 0.10

Appendix A: Data and Calculations for Estimated Ages in the 2005 Sediment Cores

Core ID	Core Interval (cm)	Mid-Depth (cm)	Mid-Depth Total Dry Accumulation (g/cm^2)	Activity ^{210}Pb (dpm/g)	± Error	Supported ^{210}Pb Activity ± 1σ (dpm/g)	$^{210}Pb_{xs}$ Activity (dpm/g)	ln $^{210}Pb_{xs}$ (dpm/g)	Comments
HC-3	0-2	1	0.260	4.23	0.10	1.07 ± 0.286	--	--	Mixed
HC-3	0-2	1	0.260	4.21	0.11	1.07 ± 0.286	--	--	RPD = 0%
HC-3	4-6	5	1.47	3.71	0.11	1.07 ± 0.286	--	--	Mixed
HC-3	6-8	7	2.11	3.86	0.11	1.07 ± 0.286	--	--	Mixed
HC-3	8-10	9	2.76	3.09	0.13	1.07 ± 0.286	--	--	Mixed
HC-3	8-10	9	2.76	3.04	0.081	1.07 ± 0.286	--	--	RPD = 2%
HC-3	10-12	11	3.40	2.79	0.10	1.07 ± 0.286	1.72	0.54	
HC-3	18-20	19	6.03	2.24	0.14	1.07 ± 0.286	1.17	0.15	
HC-3	28-30	29	9.69	1.85	0.11	1.07 ± 0.286	0.77	-0.26	
HC-3	50-52	51	16.6	1.33	0.16	1.07 ± 0.286	0.26	-1.36	
HC-3	60-62	61	20.8	1.09	0.16	1.07 ± 0.286	--	--	Supported
HC-3	70-72	71	25.2	1.14	0.16	1.07 ± 0.286	--	--	Supported
HC-3	80-82	81	29.6	0.985	0.17	1.07 ± 0.286	--	--	Supported
Check Standard				7.09	0.093	--	--	--	PR = 106%

Slope = -0.143
Correlation Factor = 0.995
Average Sediment Accumulation Rate ± 1 σ (g/cm^2/yr) = 0.218 ± 0.030
Lower 95% Confidence Limit = 0.281
Upper 95% Confidence Limit = 0.222
Sedimentation Rate (cm/yr) = 0.49 ± 0.065

Core ID	Core Interval (cm)	Mid-Depth (cm)	Mid-Depth Total Dry Accumulation (g/cm^2)	Activity ^{210}Pb (dpm/g)	± Error	Supported ^{210}Pb Activity ± 1σ (dpm/g)	$^{210}Pb_{xs}$ Activity (dpm/g)	ln $^{210}Pb_{xs}$ (dpm/g)	Comments
HC-4	2-4	3	0.720	4.97	0.10	0.977 ±0.335	--	--	Mixed
HC-4	2-4	3	0.720	4.60	0.12	0.977 ±0.335	--	--	RPD = 8%
HC-4	10-12	11	3.09	4.37	0.11	0.977 ±0.335	3.40	1.22	
HC-4	20-22	21	6.54	3.16	0.11	0.977 ±0.335	2.18	0.78	
HC-4	30-32	31	10.2	2.14	0.13	0.977 ±0.335	1.16	0.15	
HC-4	42-44	43	14.8	1.46	0.12	0.977 ±0.335	0.49	-0.72	
HC-4	50-55	52.5	18.6	1.22	0.15	0.977 ±0.335	0.24	-1.42	
HC-4	60-65	62.5	22.7	1.07	0.13	0.977 ±0.335	0.10	-2.34	
HC-4	80-85	82.5	30.8	0.973	0.16	0.977 ±0.335	--	--	Supported
HC-4	90-95	92.5	35.0	1.05	0.16	0.977 ±0.335	--	--	Supported
HC-4	110-115	112.5	44.0	0.913	0.17	0.977 ±0.335	--	--	Supported
HC-4	130-135	132.5	53.0	0.976	0.18	0.977 ±0.335	--	--	Supported
Check Standard				5.90	0.094	--	--	--	PR = 88%

Slope = -0.183
Correlation Factor = 0.995
Average Sediment Accumulation Rate ± 1 σ (g/cm^2/yr) = 0.17 ± 0.027
Lower 95% Confidence Limit = 0.164
Upper 95% Confidence Limit = 0.218
Sedimentation Rate (cm/yr) = 0.43 ± 0.066

Appendix A: Data and Calculations for Estimated Ages in the 2005 Sediment Cores

Core ID	Core Interval (cm)	Mid-Depth (cm)	Mid-Depth Total Dry Accumulation (g/cm^2)	Activity ^{210}Pb (dpm/g)	± Error	Supported ^{210}Pb Activity ± 1σ (dpm/g)	$^{210}Pb_{xs}$ Activity (dpm/g)	ln $^{210}Pb_{xs}$ (dpm/g)	Comments
HC-5	2-4	3	0.980	6.11	0.12	0.851 ± 0.339	--	--	Mixed
HC-5	2-4	3	0.980	6.02	0.092	0.851 ± 0.339	--	--	RPD = 2%
HC-5	6-8	7	2.43	6.06	0.10	0.851 ± 0.339	--	--	Mixed
HC-5	10-12	11	3.97	6.36	0.10	0.851 ± 0.339	5.51	1.71	
HC-5	20-22	21	8.12	5.00	0.13	0.851 ± 0.339	4.15	1.42	
HC-5	30-32	31	12.4	3.63	0.10	0.851 ± 0.339	2.78	1.02	
HC-5	42-44	43	17.6	2.26	0.12	0.851 ± 0.339	1.413	0.35	
HC-5	50-52	51	21.3	2.09	0.12	0.851 ± 0.339	1.240	0.21	
HC-5	60-62	61	26.0	1.15	0.16	0.851 ± 0.339	--	--	Supported
HC-5	76-78	77	33.5	0.753	0.20	0.851 ± 0.339	--	--	Supported
HC-5	84-86	85	37.2	0.808	0.15	0.851 ± 0.339	--	--	Supported
HC-5	94-96	95	42.1	0.692	0.16	0.851 ± 0.339	--	--	Supported
Check Standard				5.62	0.11	--	--	--	PR = 84%

Slope = -0.092
Correlation Factor = 0.981
Average Sediment Accumulation Rate ± 1 σ ($g/cm^2/yr$) = 0.337 ± 0.018
Lower 95% Confidence Limit = 0.319
Upper 95% Confidence Limit = 0.354
Sedimentation Rate (cm/yr) = 0.73 ± 0.037

Appendix A: Data and Calculations for Estimated Ages in the 2005 Sediment Cores

^{137}Cs Data

Core ID	Core Interval Depth (cm)	Mid-Interval Depth (cm)	^{137}Cs (dpm/g)	± Counting Error	Estimated Date
PS-1	44-46	45	0.191	0.066	1968-1974
PS-1	48-50	49	0.242	0.069	1964-1970
PS-1	50-52	51	0.345	0.062	1962-1968
PS-1	52-54	53	0.426	0.077	1960-1968
PS-1	56-58	57	0.013	0.076	Not Detected
HC-3	28-30	29	0.177	0.17	1957-1965
HC-3	40-42	41	0.044	0.17	Not Detected
HC-4	20-22	21	0.444	0.051	1962-1972
HC-4	24-26	25	0.296	0.056	1952-1964
HC-4	30-32	31	0.006	0.041	Not Detected
HC-5	20-22	21	0.359	0.045	1980-1982
HC-5	24-26	25	0.644	0.088	1975-1977
HC-5	30-32	31	0.580	0.057	1966-1970
IAEA-135			42.8	0.48	PR = 88%
IAEA-135			42.1	0.48	PR = 86%
IAEA-135			42.8	0.48	PR = 88%

Appendix A: Data and Calculations for Estimated Ages in the 2005 Sediment Cores

Estimated Age for each core interval.

Core ID	Core Section Depth (cm)	Mid-Interval Depth (cm)	Percent Dry Weight	Porosity	Mid-Interval Total Dry Accumulation (g/cm^2)	Estimated Year (Mid-point)	Error 1 σ	Comments
Core PS-1 Sediment Accumulation Rate ($g/cm^2/yr$) = 0.556 ± 0.052								
PS-1	0-2	1	30.1	0.868	0.35	2004	0	
PS-1	2-4	3	29.3	0.873	1.04	2003	0	
PS-1	4-6	5	31.2	0.861	1.74	2002	0	
PS-1	6-8	7	32.4	0.853	2.49	2001	0	
PS-1	8-10	9	33.4	0.847	3.27	1999	1	
PS-1	10-12	11	34.2	0.841	4.09	1998	1	
PS-1	12-14	13	35.2	0.835	4.93	1996	1	
PS-1	14-16	15	35.6	0.832	5.79	1995	1	
PS-1	16-18	17	37.1	0.822	6.69	1993	1	
PS-1	18-20	19	36.2	0.829	7.60	1991	1	
PS-1	20-22	21	34.4	0.840	8.46	1990	1	
PS-1	22-24	23	34.8	0.838	9.30	1988	1	
PS-1	24-26	25	35.8	0.831	10.16	1987	2	
PS-1	26-28	27	34.8	0.838	11.02	1985	2	
PS-1	28-30	29	34.7	0.839	11.86	1984	2	
PS-1	30-32	31	35.0	0.836	12.71	1982	2	
PS-1	32-34	33	36.0	0.830	13.57	1981	2	
PS-1	34-36	35	37.0	0.823	14.47	1979	2	
PS-1	36-38	37	36.8	0.824	15.39	1977	2	
PS-1	38-40	39	37.4	0.820	16.31	1976	3	
PS-1	40-42	41	37.4	0.821	17.24	1974	3	
PS-1	42-44	43	38.0	0.816	18.18	1972	3	
PS-1	44-46	45	37.7	0.819	19.13	1971	3	
PS-1	46-48	47	37.7	0.818	20.07	1969	3	
PS-1	48-50	49	37.8	0.818	21.02	1967	3	
PS-1	50-52	51	38.1	0.815	21.97	1965	3	
PS-1	52-54	53	37.3	0.821	22.91	1964	4	
PS-1	54-56	55	38.0	0.816	23.85	1962	4	
PS-1	56-58	57	36.7	0.825	24.78	1960	4	
PS-1	58-60	59	36.7	0.825	25.69	1959	4	
PS-1	60-65	62.5	36.5	0.827	27.27	1956	4	
PS-1	65-70	67.5	36.9	0.824	29.54	1952	5	
PS-1	70-75	72.5	38.5	0.813	31.89	1948	5	
PS-1	75-80	77.5	39.2	0.808	34.34	1943	5	
PS-1	80-85	82.5	39.9	0.803	36.86	1939	6	
PS-1	85-90	87.5	39.8	0.804	39.40	1934	6	
PS-1	90-95	92.5	41.9	0.790	42.03	1929	7	
PS-1	95-100	97.5	40.3	0.800	44.68	1925	7	
PS-1	100-105	102.5	41.1	0.795	47.30	1920	8	
PS-1	105-110	107.5	41.7	0.791	49.98	1915	8	
PS-1	110-115	112.5	40.5	0.799	52.64	1910	8	
PS-1	115-120	117.5	41.9	0.790	55.30	1906	9	
PS-1	120-125	122.5	42.4	0.786	58.04	1901	9	
PS-1	125-130	127.5	42.0	0.789	60.80	1896	10	
PS-1	130-135	132.5	42.9	0.782	63.58	1891	10	
PS-1	135-140	137.5	42.4	0.786	66.38	1886	11	
PS-1	140-145	142.5	41.3	0.794	69.10	1881	11	Extrapolation
PS-1	145-150	147.5	40.6	0.799	71.74	1876	11	Extrapolation
PS-1	150-155	152.5	39.1	0.808	74.28	1871	12	Extrapolation
PS-1	155-160	157.5	40.2	0.801	76.81	1867	12	Extrapolation
PS-1	160-165	162.5	39.7	0.805	79.36	1862	13	Extrapolation

Appendix A: Data and Calculations for Estimated Ages in the 2005 Sediment Cores

Estimated Age for each core interval.

Core ID	Core Section Depth (cm)	Mid-Interval Depth (cm)	Percent Dry Weight	Porosity	Mid-Interval Total Dry Accumulation (g/cm^2)	Estimated Year (Mid-point)	Error 1 σ	Comments
PS-1	165-170	167.5	39.5	0.806	81.88	1858	13	Extrapolation
PS-1	170-175	172.5	39.1	0.809	84.38	1853	13	Extrapolation
PS-1	175-180	177.5	39.1	0.809	86.85	1849	14	Extrapolation
PS-1	180-185	182.5	39.2	0.808	89.3	1844	14	Extrapolation
PS-1	185-190	187.5	37.6	0.819	91.7	1840	15	Extrapolation
PS-1	190-195	192.5	37.9	0.817	94.1	1836	15	Extrapolation
PS-1	195-200	197.5	39.8	0.804	96.6	1831	15	Extrapolation
PS-1	200-205	202.5	41.0	0.796	99.1	1827	16	Extrapolation
PS-1	205-210	207.5	40.0	0.802	101.7	1822	16	Extrapolation
PS-1	210-215	212.5	39.9	0.804	104.3	1817	17	Extrapolation
PS-1	215-220	217.5	40.6	0.799	106.9	1813	17	Extrapolation
PS-1	220-225	222.5	40.4	0.799	109.5	1808	17	Extrapolation
PS-1	225-230	227.5	42.8	0.783	112.2	1803	18	Extrapolation
PS-1	230-235	232.5	42.5	0.785	115.0	1798	18	Extrapolation
PS-1	235-240	237.5	41.9	0.789	117.7	1793	19	Extrapolation
PS-1	240-245	242.5	41.8	0.790	120.5	1788	19	Extrapolation
PS-1	245-250	247.5	41.4	0.793	123.2	1784	20	Extrapolation
PS-1	250-255	252.5	39.1	0.809	125.7	1779	20	Extrapolation
PS-1	255-260	257.5	39.6	0.805	128.2	1774	20	Extrapolation
Core PS-2 Sediment Accumulation Rate ($g/cm^2/yr$) = 1.14 ± 0.065								
PS-2	0-2	1	28.9	0.876	0.33	2005	0	
PS-2	2-4	3	30.2	0.868	1.01	2004	0	
PS-2	4-6	5	31.1	0.862	1.72	2003	0	
PS-2	6-8	7	31.9	0.857	2.46	2003	0	
PS-2	8-10	9	32.8	0.851	3.23	2002	0	
PS-2	10-12	11	33.1	0.849	4.02	2001	0	
PS-2	12-14	13	32.3	0.854	4.80	2001	0	
PS-2	14-16	15	31.9	0.857	5.56	2000	0	
PS-2	16-18	17	32.3	0.854	6.32	1999	0	
PS-2	18-20	19	32.8	0.851	7.09	1999	0	
PS-2	20-22	21	33.1	0.849	7.87	1998	0	
PS-2	22-24	23	34.2	0.841	8.68	1997	0	
PS-2	24-26	25	34.6	0.839	9.51	1997	0	
PS-2	26-28	27	35.2	0.835	10.36	1996	1	
PS-2	28-30	29	33.6	0.845	11.20	1995	1	
PS-2	30-32	31	33.2	0.848	12.00	1994	1	
PS-2	32-34	33	31.6	0.859	12.77	1994	1	
PS-2	34-36	35	31.1	0.862	13.50	1993	1	
PS-2	36-38	37	32.0	0.856	14.24	1993	1	
PS-2	38-40	39	32.0	0.856	15.00	1992	1	
PS-2	40-42	41	32.5	0.853	15.76	1991	1	
PS-2	42-44	43	33.1	0.849	16.54	1990	1	
PS-2	44-46	45	32.3	0.854	17.32	1990	1	
PS-2	46-48	47	34.0	0.843	18.11	1989	1	
PS-2	48-50	49	34.6	0.839	18.94	1988	1	
PS-2	50-52	51	35.6	0.832	19.80	1988	1	
PS-2	52-54	53	35.3	0.834	20.67	1987	1	
PS-2	54-56	55	35.2	0.835	21.53	1986	1	
PS-2	56-58	57	35.6	0.832	22.39	1985	1	
PS-2	58-60	59	35.1	0.836	23.26	1985	1	
PS-2	60-62	61	35.1	0.836	24.11	1984	1	
PS-2	62-64	63	37.0	0.823	25.00	1983	1	

Appendix A: Data and Calculations for Estimated Ages in the 2005 Sediment Cores

Estimated Age for each core interval.

Core ID	Core Section Depth (cm)	Mid-Interval Depth (cm)	Percent Dry Weight	Porosity	Mid-Interval Total Dry Accumulation (g/cm^2)	Estimated Year (Mid-point)	Error 1 σ	Comments
PS-2	64-66	65	37.1	0.823	25.91	1982	1	
PS-2	66-68	67	36.1	0.829	26.82	1981	1	
PS-2	68-70	69	34.4	0.840	27.68	1981	1	
PS-2	70-72	71	35.3	0.834	28.52	1980	1	
PS-2	72-74	73	36.6	0.826	29.41	1979	1	
PS-2	74-76	75	35.8	0.831	30.30	1978	2	
PS-2	76-78	77	36.2	0.828	31.18	1978	2	
PS-2	78-80	79	36.4	0.827	32.08	1977	2	
PS-2	80-85	82.5	36.6	0.826	33.66	1975	2	
PS-2	85-90	87.5	36.5	0.826	35.92	1973	2	
PS-2	90-95	92.5	37.3	0.821	38.21	1971	2	
PS-2	95-100	97.5	36.8	0.825	40.51	1969	2	
PS-2	100-105	102.5	37.6	0.819	42.82	1967	2	
PS-2	105-110	107.5	36.7	0.825	45.12	1965	2	
PS-2	110-115	112.5	37.0	0.823	47.41	1963	2	
PS-2	115-120	117.5	37.4	0.820	49.72	1961	3	
PS-2	120-125	122.5	37.9	0.817	52.07	1959	3	
PS-2	125-130	127.5	37.6	0.819	54.43	1957	3	
PS-2	130-135	132.5	37.7	0.818	56.78	1955	3	
PS-2	135-140	137.5	37.9	0.817	59.14	1953	3	
PS-2	140-145	142.5	38.2	0.815	61.53	1951	3	
PS-2	145-150	147.5	38.5	0.813	63.94	1949	3	
PS-2	150-155	152.5	38.3	0.814	66.36	1947	3	
PS-2	155-160	157.5	39.4	0.807	68.81	1945	3	
PS-2	160-165	162.5	40.1	0.802	71.34	1942	4	
PS-2	165-170	167.5	40.6	0.798	73.93	1940	4	
PS-2	170-175	172.5	40.3	0.801	76.5	1938	4	
PS-2	175-180	177.5	39.2	0.808	79.1	1936	4	
PS-2	180-185	182.5	38.9	0.810	81.5	1933	4	
PS-2	185-190	187.5	40.1	0.802	84.0	1931	4	
PS-2	190-195	192.5	40.4	0.799	86.6	1929	4	
PS-2	195-200	197.5	40.6	0.799	89.2	1927	5	
PS-2	200-205	202.5	39.5	0.806	91.8	1924	5	
PS-2	205-210	207.5	42.4	0.786	94.4	1922	5	
PS-2	210-215	212.5	42.0	0.789	97.2	1920	5	
PS-2	215-220	217.5	40.5	0.799	99.9	1917	5	
PS-2	220-225	222.5	41.9	0.790	102.5	1915	5	
PS-2	225-230	227.5	41.5	0.792	105.2	1913	5	
PS-2	230-235	232.5	40.9	0.796	107.9	1910	5	
PS-2	235-240	237.5	41.0	0.796	110.5	1908	6	
PS-2	240-245	242.5	41.5	0.792	113.2	1906	6	
PS-2	245-250	247.5	40.3	0.801	115.8	1903	6	
Core PS-3 Sediment Accumulation Rate ($g/cm^2/yr$) = 0.914 ± 0.042								
PS-3	0-2	1	27.7	0.884	0.31	2005	0	
PS-3	2-4	3	30.0	0.869	0.97	2004	0	
PS-3	4-6	5	32.6	0.852	1.71	2003	0	
PS-3	6-8	7	34.4	0.840	2.51	2002	0	
PS-3	8-10	9	34.7	0.839	3.35	2001	0	
PS-3	10-12	11	35.6	0.833	4.20	2000	0	
PS-3	12-14	13	35.5	0.833	5.07	1999	0	
PS-3	14-16	15	36.7	0.825	5.96	1998	0	
PS-3	16-18	17	37.0	0.823	6.88	1997	0	

Appendix A: Data and Calculations for Estimated Ages in the 2005 Sediment Cores

Estimated Age for each core interval.

Core ID	Core Section Depth (cm)	Mid-Interval Depth (cm)	Percent Dry Weight	Porosity	Mid-Interval Total Dry Accumulation (g/cm^2)	Estimated Year (Mid-point)	Error 1 σ	Comments
PS-3	18-20	19	36.3	0.828	7.78	1996	0	
PS-3	20-22	21	36.7	0.825	8.68	1996	1	
PS-3	22-24	23	36.8	0.825	9.59	1995	1	
PS-3	24-26	25	35.7	0.832	10.48	1994	1	
PS-3	26-28	27	36.2	0.828	11.37	1993	1	
PS-3	28-30	29	36.4	0.827	12.26	1992	1	
PS-3	30-32	31	36.0	0.830	13.15	1991	1	
PS-3	32-34	33	37.5	0.820	14.06	1990	1	
PS-3	34-36	35	38.4	0.813	15.01	1989	1	
PS-3	36-38	37	37.8	0.818	15.97	1988	1	
PS-3	38-40	39	39.1	0.809	16.94	1986	1	
PS-3	40-42	41	40.1	0.802	17.94	1985	1	
PS-3	42-44	43	40.2	0.801	18.97	1984	1	
PS-3	44-48	46	40.8	0.797	20.54	1983	1	
PS-3	48-50	49	40.2	0.801	22.11	1981	1	
PS-3	50-55	52.5	41.9	0.789	23.99	1979	1	
PS-3	55-60	57.5	42.7	0.783	26.75	1976	2	
PS-3	60-65	62.5	42.9	0.782	29.57	1973	2	
PS-3	65-70	67.5	43.0	0.781	32.40	1970	2	
PS-3	70-75	72.5	42.5	0.785	35.21	1966	2	
PS-3	75-80	77.5	41.6	0.791	37.95	1963	2	
PS-3	80-85	82.5	41.1	0.795	40.63	1961	2	
PS-3	85-90	87.5	43.7	0.777	43.40	1958	3	
PS-3	90-95	92.5	44.1	0.774	46.32	1954	3	
PS-3	95-100	97.5	42.9	0.782	49.19	1951	3	
PS-3	100-105	102.5	43.6	0.777	52.04	1948	3	
PS-3	105-110	107.5	45.6	0.763	55.02	1945	3	
PS-3	110-115	112.5	48.7	0.739	58.26	1941	3	
PS-3	115-120	117.5	44.3	0.772	61.44	1938	4	
PS-3	120-125	122.5	44.7	0.770	64.41	1935	4	
PS-3	125-130	127.5	41.9	0.790	67.27	1931	4	
PS-3	130-135	132.5	43.7	0.777	70.08	1928	4	
PS-3	135-140	137.5	44.1	0.774	72.99	1925	4	
PS-3	140-145	142.5	44.6	0.770	75.95	1922	5	Extrapolation
PS-3	145-150	147.5	42.6	0.785	78.8	1919	5	Extrapolation
PS-3	150-155	152.5	42.4	0.786	81.6	1916	5	Extrapolation
PS-3	155-160	157.5	42.4	0.786	84.4	1913	5	Extrapolation
PS-3	160-165	162.5	41.6	0.792	87.1	1910	5	Extrapolation
PS-3	165-170	167.5	42.2	0.787	89.8	1907	5	Extrapolation
PS-3	170-175	172.5	41.4	0.793	92.6	1904	5	Extrapolation
PS-3	175-180	177.5	41.3	0.793	95.2	1901	6	Extrapolation
PS-3	180-185	182.5	40.8	0.797	97.9	1898	6	Extrapolation
PS-3	185-190	187.5	42.1	0.788	100.6	1895	6	Extrapolation
PS-3	190-195	192.5	40.5	0.799	103.3	1892	6	Extrapolation
PS-3	195-200	197.5	43.1	0.781	106.0	1889	6	Extrapolation
PS-3	200-205	202.5	42.8	0.783	108.8	1886	6	Extrapolation
Core PS-4 Sediment Accumulation Rate (g/cm^2/yr) = 1.05 ± 0.048								
PS-4	0-2	1	29.8	0.870	0.34	2005	0	
PS-4	2-4	3	30.8	0.864	1.05	2004	0	
PS-4	4-6	5	32.1	0.856	1.79	2003	0	
PS-4	6-8	7	33.4	0.847	2.57	2003	0	
PS-4	8-10	9	34.8	0.838	3.39	2002	0	

Appendix A: Data and Calculations for Estimated Ages in the 2005 Sediment Cores

Estimated Age for each core interval.

Core ID	Core Section Depth (cm)	Mid-Interval Depth (cm)	Percent Dry Weight	Porosity	Mid-Interval Total Dry Accumulation (g/cm^2)	Estimated Year (Mid-point)	Error 1 σ	Comments
PS-4	10-12	11	35.6	0.833	4.25	2001	0	
PS-4	12-14	13	37.3	0.821	5.15	2000	0	
PS-4	14-16	15	38.6	0.812	6.10	1999	0	
PS-4	16-18	17	38.5	0.813	7.07	1998	0	
PS-4	18-20	19	39.0	0.809	8.04	1997	0	
PS-4	20-22	21	38.8	0.811	9.03	1996	0	
PS-4	22-24	23	38.6	0.812	10.0	1995	0	
PS-4	24-26	25	38.9	0.810	11.0	1995	0	
PS-4	26-28	27	37.4	0.820	11.9	1994	0	
PS-4	28-30	29	38.1	0.816	12.9	1993	1	
PS-4	30-32	31	38.1	0.816	13.8	1992	1	
PS-4	32-34	33	38.9	0.810	14.8	1991	1	
PS-4	34-36	35	38.1	0.815	15.8	1990	1	
PS-4	36-38	37	37.3	0.821	16.7	1989	1	
PS-4	38-40	39	37.6	0.819	17.7	1988	1	
PS-4	40-42	41	39.5	0.806	18.6	1987	1	
PS-4	42-44	43	40.3	0.800	19.6	1986	1	
PS-4	44-46	45	41.4	0.793	20.7	1985	1	
PS-4	46-48	47	39.6	0.806	21.7	1984	1	
PS-4	48-50	49	40.7	0.798	22.8	1983	1	
PS-4	50-55	52.5	40.4	0.800	24.6	1982	1	
PS-4	55-60	57.5	41.4	0.793	27.2	1979	1	
PS-4	60-65	62.5	40.5	0.799	29.9	1977	1	
PS-4	65-70	67.5	37.8	0.817	32.3	1974	1	
PS-4	70-75	72.5	39.2	0.808	34.8	1972	1	
PS-4	75-80	77.5	39.7	0.805	37.3	1969	1	
PS-4	80-85	82.5	41.5	0.792	39.9	1967	2	
PS-4	85-90	87.5	42.1	0.788	42.6	1964	2	
PS-4	90-95	92.5	41.0	0.796	45.3	1962	2	
PS-4	95-100	97.5	40.6	0.798	47.9	1959	2	
PS-4	100-105	102.5	39.3	0.807	50.5	1957	2	
PS-4	105-110	107.5	41.1	0.795	53.0	1954	2	
PS-4	110-115	112.5	40.7	0.798	55.7	1952	2	
PS-4	115-120	117.5	42.0	0.788	58.4	1949	2	
PS-4	120-125	122.5	39.4	0.807	61.0	1947	2	
PS-4	125-130	127.5	41.6	0.791	63.6	1944	3	
PS-4	130-135	132.5	42.4	0.786	66.3	1942	3	
PS-4	135-140	137.5	41.8	0.790	69.1	1939	3	
PS-4	140-145	142.5	43.2	0.780	71.9	1937	3	
PS-4	145-150	147.5	44.1	0.774	74.7	1934	3	
PS-4	150-155	152.5	42.4	0.786	77.6	1931	3	
PS-4	155-160	157.5	42.1	0.788	80.4	1928	3	
PS-4	160-165	162.5	42.5	0.785	83.1	1926	3	
PS-4	165-170	167.5	40.6	0.798	85.8	1923	3	
PS-4	170-175	172.5	41.7	0.791	88.5	1921	4	
PS-4	175-180	177.5	42.5	0.785	91.2	1918	4	
PS-4	180-185	182.5	43.2	0.780	94.0	1915	4	
PS-4	185-190	187.5	43.1	0.781	96.9	1913	4	
PS-4	190-195	192.5	43.0	0.782	99.7	1910	4	
PS-4	195-200	197.5	43.8	0.776	102.6	1907	4	
PS-4	200-205	202.5	44.7	0.769	105.5	1904	4	
PS-4	205-210	207.5	45.4	0.765	108.6	1902	4	
PS-4	210-215	212.5	44.0	0.775	111.5	1899	4	

Appendix A: Data and Calculations for Estimated Ages in the 2005 Sediment Cores

Estimated Age for each core interval.

Core ID	Core Section Depth (cm)	Mid-Interval Depth (cm)	Percent Dry Weight	Porosity	Mid-Interval Total Dry Accumulation (g/cm^2)	Estimated Year (Mid-point)	Error 1 σ	Comments
PS-4	215-220	217.5	43.8	0.776	114.5	1896	5	
Core HC-1 Sediment Accumulation Rate ($g/cm^2/yr$) = 0.804 ± 0.42 - NOT A GOOD RECORD								
HC-1	0-2	1	49.1	0.737	0.69	2004	0	
HC-1	2-4	3	51.3	0.720	2.11	2002	1	
HC-1	4-6	5	52.3	0.712	3.60	2001	1	
HC-1	6-8	7	52.9	0.707	5.13	1999	2	
HC-1	8-10	9	53.0	0.706	6.67	1997	3	
HC-1	10-12	11	54.3	0.695	8.2	1995	3	
HC-1	12-14	13	54.0	0.698	9.8	1993	4	
HC-1	14-16	15	52.8	0.708	11.4	1991	5	
HC-1	16-18	17	54.6	0.693	13.0	1989	5	
HC-1	18-20	19	55.6	0.685	14.6	1987	6	
HC-1	20-22	21	55.6	0.684	16.3	1985	7	
HC-1	22-24	23	55.5	0.685	18.0	1983	7	
HC-1	24-26	25	56.2	0.679	19.7	1981	8	
HC-1	26-28	27	56.1	0.680	21.4	1978	9	
HC-1	28-30	29	55.8	0.682	23.0	1976	9	
HC-1	30-32	31	56.2	0.679	24.7	1974	10	
HC-1	32-34	33	57.8	0.665	26.5	1972	11	
HC-1	34-36	35	56.6	0.676	28.2	1970	12	
HC-1	36-38	37	57.0	0.672	29.9	1968	12	
HC-1	38-40	39	57.2	0.670	31.7	1966	13	
HC-1	40-42	41	57.4	0.669	33.4	1963	14	
HC-1	42-44	43	57.8	0.665	35.2	1961	14	
HC-1	44-46	45	58.2	0.662	37.0	1959	15	
HC-1	46-48	47	58.9	0.655	38.8	1957	16	
HC-1	48-50	49	58.5	0.659	40.6	1954	17	
HC-1	50-55	51	58.1	0.662	43.8	1951	18	
HC-1	55-60	57.5	58.3	0.661	48.3	1945	20	
HC-1	60-65	62.5	58.7	0.657	52.8	1939	22	Extrapolation
HC-1	65-70	67.5	59.6	0.649	57.4	1934	24	Extrapolation
HC-1	70-75	72.5	60.5	0.641	62.2	1928	25	Extrapolation
HC-1	75-80	77.5	60.4	0.642	67.0	1922	27	Extrapolation
HC-1	80-85	82.5	59.2	0.653	71.7	1916	29	Extrapolation
HC-1	85-90	87.5	60.4	0.642	76.4	1910	31	Extrapolation
HC-1	90-95	92.5	61.6	0.631	81.2	1904	33	Extrapolation
HC-1	95-100	97.5	60.4	0.642	86.1	1898	35	Extrapolation
HC-1	100-105	102.5	61.1	0.635	90.9	1892	37	Extrapolation
HC-1	105-110	107.5	62.5	0.622	95.9	1886	39	Extrapolation
HC-1	110-115	112.5	61.8	0.628	100.9	1879	41	Extrapolation
HC-1	115-120	117.5	62.7	0.619	106.0	1873	43	Extrapolation
HC-1	120-125	122.5	61.4	0.632	111.0	1867	45	Extrapolation
HC-1	125-130	127.5	59.9	0.646	115.8	1861	47	Extrapolation
HC-1	130-135	132.5	58.7	0.658	120.5	1855	49	Extrapolation
HC-1	135-140	137.5	60.4	0.641	125.1	1849	51	Extrapolation
HC-1	140-145	142.5	62.1	0.625	130.0	1843	53	Extrapolation
HC-1	145-150	147.5	59.4	0.651	134.9	1837	55	Extrapolation
HC-1	150-155	152.5	62.6	0.621	139.7	1831	57	Extrapolation
HC-1	155-160	157.5	60.4	0.642	144.7	1825	59	Extrapolation
HC-1	160-165	162.5	59.8	0.647	149.4	1819	61	Extrapolation
HC-1	165-170	167.5	63.5	0.612	154.4	1813	63	Extrapolation
HC-1	170-175	172.5	63.4	0.613	159.6	1807	65	Extrapolation

Appendix A: Data and Calculations for Estimated Ages in the 2005 Sediment Cores

Estimated Age for each core interval.

Core ID	Core Section Depth (cm)	Mid-Interval Depth (cm)	Percent Dry Weight	Porosity	Mid-Interval Total Dry Accumulation (g/cm^2)	Estimated Year (Mid-point)	Error 1 σ	Comments
HC-1	175-180	177.5	62.5	0.622	164.7	1800	67	Extrapolation
HC-1	180-185	182.5	60.6	0.640	169.6	1794	69	Extrapolation
HC-1	185-190	187.5	62.5	0.622	174.6	1788	71	Extrapolation
HC-1	190-195	192.5	63.6	0.611	179.7	1781	74	Extrapolation
HC-1	195-200	197.5	62.8	0.619	184.9	1775	76	Extrapolation
HC-1	200-205	202.5	62.7	0.620	190.0	1769	78	Extrapolation

Core HC-2 Sediment Accumulation Rate ($g/cm^2/yr$) = 0.222 ± 0.081 - NOT A GOOD RECORD

HC-2	0-2	1	31.2	0.861	0.37	2003	0	
HC-2	2-4	3	33.2	0.848	1.13	2000	1	
HC-2	4-6	5	32.4	0.854	1.91 slump	1996	2	
HC-2	6-8	7	33.4	0.847	1.91 slump	1996	2	
HC-2	8-10	9	33.2	0.848	1.91 slump	1996	2	
HC-2	10-12	11	34.1	0.842	1.91 slump	1996	2	
HC-2	12-14	13	34.2	0.842	1.91 slump	1996	2	
HC-2	14-16	15	34.2	0.842	1.91 slump	1996	2	
HC-2	16-18	17	35.6	0.833	1.91 slump	1996	2	
HC-2	18-20	19	36.4	0.827	1.91 slump	1996	2	
HC-2	20-22	21	36.9	0.824	1.91 slump	1996	2	
HC-2	22-24	23	37.7	0.818	1.91 slump	1996	2	
HC-2	24-26	25	36.4	0.827	1.91 slump	1996	2	
HC-2	26-28	27	35.9	0.830	1.91 slump	1996	2	
HC-2	28-30	29	36.6	0.825	1.91 slump	1996	2	
HC-2	30-32	31	36.7	0.825	1.91 slump	1996	2	
HC-2	32-34	33	37.9	0.817	1.91 slump	1996	2	
HC-2	34-36	35	37.2	0.821	1.91 slump	1996	2	
HC-2	36-38	37	38.0	0.817	1.91 slump	1996	2	
HC-2	38-40	39	38.9	0.810	1.91 slump	1996	2	
HC-2	40-42	41	38.1	0.816	2.88	1992	3	
HC-2	42-44	43	36.8	0.825	3.81	1988	4	
HC-2	44-46	45	36.6	0.826	4.72	1984	4	
HC-2	46-48	47	36.6	0.826	5.62	1980	5	
HC-2	48-50	49	37.8	0.817	6.55	1976	6	
HC-2	50-52	51	38.2	0.815	7.50	1971	7	
HC-2	52-54	53	38.0	0.816	8.46	1967	8	
HC-2	54-56	55	39.3	0.808	9.43	1963	9	
HC-2	56-58	57	39.3	0.808	10.43	1958	10	
HC-2	58-60	59	39.2	0.808	11.42	1954	11	
HC-2	60-62	61	38.1	0.815	12.40	1949	12	
HC-2	62-64	63	39.6	0.806	13.38	1945	13	
HC-2	64-66	65	40.1	0.802	14.40	1940	14	
HC-2	66-68	67	40.4	0.800	15.43	1936	15	
HC-2	68-70	69	39.9	0.803	16.45	1931	16	
HC-2	70-72	71	40.6	0.798	17.48	1926	17	
HC-2	72-74	73	39.3	0.807	18.51	1922	18	
HC-2	74-76	75	38.9	0.810	19.50	1917	18	
HC-2	76-78	77	39.3	0.808	20.49	1913	19	
HC-2	78-80	79	40.0	0.802	21.50	1908	20	
HC-2	80-82	81	39.8	0.804	22.52	1904	21	
HC-2	82-84	83	40.7	0.798	23.55	1899	22	
HC-2	84-86	85	40.2	0.801	24.58	1894	23	
HC-2	86-88	87	40.5	0.799	25.62	1890	24	
HC-2	88-90	89	41.8	0.790	26.68	1885	25	

Appendix A: Data and Calculations for Estimated Ages in the 2005 Sediment Cores

Estimated Age for each core interval.

Core ID	Core Section Depth (cm)	Mid-Interval Depth (cm)	Percent Dry Weight	Porosity	Mid-Interval Total Dry Accumulation (g/cm^2)	Estimated Year (Mid-point)	Error 1 σ	Comments
HC-2	90-92	91	41.8	0.790	27.77	1880	26	
HC-2	92-96	94	42.3	0.786	29.42	1872	28	
HC-2	96-98	97	40.4	0.800	31.04	1865	29	
HC-2	98-100	99	39.0	0.809	32.06	1861	30	
HC-2	100-102	101	39.5	0.806	33.05	1856	31	Extrapolation
HC-2	102-104	103	40.3	0.800	34.07	1852	32	Extrapolation
HC-2	104-106	105	41.5	0.792	35.13	1847	33	Extrapolation
HC-2	106-108	107	41.5	0.792	36.20	1842	34	Extrapolation
HC-2	108-110	109	41.4	0.793	37.28	1837	35	Extrapolation
HC-2	110-112	111	40.4	0.800	38.33	1832	36	Extrapolation
HC-2	112-114	113	40.6	0.799	39.37	1828	37	Extrapolation
HC-2	114-116	115	40.5	0.799	40.41	1823	38	Extrapolation
HC-2	116-118	117	40.7	0.797	41.45	1818	39	Extrapolation
HC-2	118-120	119	40.6	0.799	42.50	1814	40	Extrapolation
HC-2	120-122	121	41.2	0.794	43.55	1809	41	Extrapolation
HC-2	122-124	123	42.6	0.785	44.64	1804	42	Extrapolation
HC-2	124-126	125	41.8	0.790	45.75	1799	43	Extrapolation
HC-2	126-128	127	42.8	0.783	46.85	1794	44	Extrapolation
HC-2	128-130	129	42.0	0.789	47.96	1789	45	Extrapolation
HC-2	130-132	131	42.8	0.783	49.07	1784	46	Extrapolation
HC-2	132-134	133	42.1	0.788	50.18	1779	47	Extrapolation
HC-2	134-136	135	41.9	0.790	51.28	1774	49	Extrapolation
HC-2	136-138	137	42.2	0.787	52.37	1769	50	Extrapolation
HC-2	138-140	139	41.5	0.792	53.46	1764	51	Extrapolation
HC-2	140-142	141	41.1	0.795	54.53	1759	52	Extrapolation
HC-2	142-144	143	42.4	0.786	55.62	1754	53	Extrapolation
HC-2	144-146	145	41.6	0.791	56.71	1750	54	Extrapolation
HC-2	146-148	147	41.7	0.791	57.80	1745	55	Extrapolation
HC-2	148-150	149	41.2	0.795	58.87	1740	56	Extrapolation
HC-2	150-152	151	41.5	0.792	59.94	1735	57	Extrapolation
HC-2	152-154	153	41.0	0.795	61.01	1730	58	Extrapolation
HC-2	154-156	155	42.0	0.789	62.09	1725	59	Extrapolation
HC-2	156-158	157	43.3	0.780	63.21	1720	60	Extrapolation
HC-2	158-160	159	43.1	0.781	64.34	1715	61	Extrapolation
HC-2	160-162	161	43.6	0.777	65.49	1710	62	Extrapolation
HC-2	162-164	163	45.1	0.767	66.67	1705	63	Extrapolation
HC-2	164-166	165	47.4	0.749	67.93	1699	64	Extrapolation
HC-2	166-168	167	50.2	0.728	69.29	1693	66	Extrapolation
HC-2	168-170	169	48.7	0.740	70.68	1687	67	Extrapolation
HC-2	170-172	171	45.1	0.767	71.97	1681	68	Extrapolation
HC-2	172-174	173	42.9	0.782	73.14	1676	69	Extrapolation
HC-2	174-176	175	42.8	0.783	74.27	1670	70	Extrapolation
HC-2	176-178	177	43.2	0.780	75.40	1665	71	Extrapolation
HC-2	178-180	179	43.5	0.778	76.54	1660	72	Extrapolation
HC-2	180-182	181	43.4	0.778	77.69	1655	73	Extrapolation
HC-2	182-184	183	43.5	0.778	78.8	1650	75	Extrapolation
HC-2	184-186	185	43.4	0.778	80.0	1645	76	Extrapolation
HC-2	186-188	187	42.6	0.785	81.1	1640	77	Extrapolation
HC-2	188-190	189	43.8	0.776	82.3	1634	78	Extrapolation
HC-2	190-192	191	42.5	0.785	83.4	1629	79	Extrapolation
HC-2	192-194	193	42.1	0.788	84.5	1624	80	Extrapolation
HC-2	194-196	195	41.8	0.790	85.6	1619	81	Extrapolation
HC-2	196-198	197	42.8	0.783	86.7	1614	82	Extrapolation

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Core ID	Core Section Depth (cm)	Mid-Interval Depth (cm)	Percent Dry Weight	Porosity	Mid-Interval Total Dry Accumulation (g/cm^2)	Estimated Year (Mid-point)	Error 1 σ	Comments
HC-2	198-200	199	43.3	0.780	87.8	1609	83	Extrapolation
HC-2	200-202	201	43.5	0.778	89.0	1604	84	Extrapolation
HC-2	202-204	203	43.7	0.777	90.1	1599	85	Extrapolation
HC-2	204-206	205	43.7	0.776	91.3	1594	86	Extrapolation
HC-2	206-208	207	44.2	0.773	92.5	1588	87	Extrapolation
HC-2	208-210	209	43.4	0.779	93.6	1583	89	Extrapolation
HC-2	210-215	212.5	42.7	0.784	95.6	1574	90	Extrapolation
HC-2	215-220	217.5	43.5	0.778	98.4	1562	93	Extrapolation
HC-2	220-225	222.5	43.3	0.779	101.3	1549	96	Extrapolation
Core HC-3 Sediment Accumulation Rate ($g/cm^2/yr$) = 0.218 ± 0.030								
HC-3	0-2	1	24.1	0.906	0.26	2004	0	
HC-3	2-4	3	27.8	0.883	0.84	2001	0	
HC-3	4-6	5	28.0	0.882	1.47	1998	1	
HC-3	6-8	7	28.3	0.880	2.11	1995	1	
HC-3	8-10	9	28.5	0.878	2.76	1992	1	
HC-3	10-12	11	28.2	0.880	3.40	1989	2	
HC-3	12-14	13	28.0	0.882	4.04	1986	2	
HC-3	14-16	15	28.9	0.876	4.69	1983	2	
HC-3	16-18	17	29.0	0.875	5.35	1980	2	
HC-3	18-20	19	29.7	0.871	6.03	1977	3	
HC-3	20-22	21	30.7	0.864	6.73	1974	3	
HC-3	22-24	23	30.3	0.867	7.44	1971	3	
HC-3	24-26	25	32.2	0.855	8.17	1968	4	
HC-3	26-28	27	32.1	0.855	8.93	1964	4	
HC-3	28-30	29	31.7	0.858	9.69	1961	4	
HC-3	30-32	31	32.3	0.854	10.44	1957	5	
HC-3	32-34	33	32.6	0.852	11.21	1954	5	
HC-3	34-36	35	32.9	0.850	13.22	1944	6	
HC-3	36-38	37	34.1	0.842	13.22	1944	6	
HC-3	38-40	39	33.9	0.844	13.22	1944	6	
HC-3	40-42	41	34.0	0.843	13.22	1944	6	
HC-3	42-44	43	34.0	0.843	13.22	1944	6	
HC-3	44-46	45	34.8	0.838	14.05	1941	6	
HC-3	46-48	47	35.0	0.836	14.90	1937	7	
HC-3	48-50	49	34.8	0.838	15.75	1933	7	
HC-3	50-52	51	34.2	0.842	16.58	1929	8	
HC-3	52-54	53	35.0	0.836	17.42	1925	8	
HC-3	54-56	55	35.9	0.830	18.29	1921	8	
HC-3	56-58	57	34.8	0.838	19.15	1917	9	
HC-3	58-60	59	34.5	0.840	19.99	1913	9	
HC-3	60-62	61	35.0	0.836	20.84	1909	10	
HC-3	62-64	63	35.5	0.833	21.70	1905	10	
HC-3	64-66	65	35.7	0.832	22.57	1901	10	
HC-3	66-68	67	35.3	0.834	23.44	1897	11	
HC-3	68-70	69	36.4	0.827	24.32	1893	11	
HC-3	70-72	71	35.4	0.833	25.20	1889	12	Extrapolation
HC-3	72-74	73	36.1	0.829	26.08	1885	12	Extrapolation
HC-3	74-76	75	36.4	0.827	26.97	1881	12	Extrapolation
HC-3	76-78	77	36.0	0.830	27.86	1877	13	Extrapolation
HC-3	78-80	79	35.8	0.831	28.75	1873	13	Extrapolation
HC-3	80-82	81	35.5	0.833	29.62	1869	14	Extrapolation
HC-3	82-84	83	36.4	0.827	30.50	1865	14	Extrapolation

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Estimated Age for each core interval.

Core ID	Core Section Depth (cm)	Mid-Interval Depth (cm)	Percent Dry Weight	Porosity	Mid-Interval Total Dry Accumulation (g/cm^2)	Estimated Year (Mid-point)	Error 1 σ	Comments
HC-3	84-86	85	36.8	0.824	31.41	1861	14	Extrapolation
HC-3	86-88	87	36.1	0.829	32.31	1857	15	Extrapolation
HC-3	88-90	89	36.8	0.825	33.21	1853	15	Extrapolation
HC-3	90-92	91	36.4	0.827	34.11	1849	16	Extrapolation
HC-3	92-94	93	36.4	0.827	35.01	1844	16	Extrapolation
HC-3	94-96	95	37.6	0.819	35.93	1840	16	Extrapolation
HC-3	96-98	97	37.3	0.821	36.86	1836	17	Extrapolation
HC-3	98-100	99	35.7	0.832	37.77	1832	17	Extrapolation
HC-3	100-102	101	36.3	0.828	38.65	1828	18	Extrapolation
HC-3	102-104	103	36.1	0.829	39.54	1824	18	Extrapolation
HC-3	104-106	105	37.7	0.818	40.46	1819	19	Extrapolation
HC-3	106-108	107	38.2	0.815	41.41	1815	19	Extrapolation
HC-3	108-110	109	39.3	0.808	42.39	1811	19	Extrapolation
HC-3	110-112	111	39.4	0.807	43.39	1806	20	Extrapolation
HC-3	112-114	113	39.6	0.806	44.39	1801	20	Extrapolation
HC-3	114-116	115	39.9	0.803	45.40	1797	21	Extrapolation
HC-3	116-118	117	40.1	0.802	46.43	1792	21	Extrapolation
HC-3	118-120	119	40.5	0.799	47.46	1787	22	Extrapolation
HC-3	120-122	121	40.0	0.802	48.49	1783	22	Extrapolation
HC-3	122-124	123	39.8	0.804	49.51	1778	23	Extrapolation
HC-3	124-126	125	38.1	0.815	50.50	1773	23	Extrapolation
HC-3	126-128	127	38.1	0.815	51.45	1769	24	Extrapolation
HC-3	128-130	129	38.0	0.816	52.41	1765	24	Extrapolation
HC-3	130-132	131	37.8	0.818	53.36	1760	24	Extrapolation
HC-3	132-134	133	38.0	0.816	54.30	1756	25	Extrapolation
HC-3	134-136	135	39.7	0.805	55.29	1751	25	Extrapolation
HC-3	136-138	137	39.3	0.808	56.29	1747	26	Extrapolation
HC-3	138-140	139	39.4	0.807	57.29	1742	26	Extrapolation
HC-3	140-142	141	39.8	0.804	58.29	1738	27	Extrapolation
HC-3	142-144	143	40.0	0.802	59.31	1733	27	Extrapolation
HC-3	144-146	145	40.2	0.801	60.34	1728	28	Extrapolation
HC-3	146-148	147	39.3	0.807	61.35	1724	28	Extrapolation
HC-3	148-150	149	40.1	0.802	62.37	1719	29	Extrapolation
HC-3	150-152	151	40.4	0.800	63.40	1714	29	Extrapolation
HC-3	152-154	153	41.1	0.795	64.45	1709	29	Extrapolation
HC-3	154-156	155	41.1	0.795	65.51	1704	30	Extrapolation
HC-3	156-158	157	42.0	0.789	66.59	1700	30	Extrapolation
HC-3	158-160	159	40.5	0.799	67.66	1695	31	Extrapolation
HC-3	160-162	161	40.3	0.800	68.70	1690	31	Extrapolation
HC-3	162-164	163	40.6	0.799	69.73	1685	32	Extrapolation
HC-3	164-166	165	39.6	0.805	70.76	1680	32	Extrapolation
HC-3	166-168	167	39.4	0.807	71.76	1676	33	Extrapolation
HC-3	168-170	169	39.7	0.804	72.77	1671	33	Extrapolation
HC-3	170-172	171	40.4	0.800	73.79	1666	34	Extrapolation
HC-3	172-174	173	40.4	0.800	74.8	1662	34	Extrapolation
HC-3	174-176	175	41.1	0.795	75.9	1657	35	Extrapolation
HC-3	176-178	177	40.3	0.800	76.9	1652	35	Extrapolation
HC-3	178-180	179	40.1	0.802	78.0	1647	36	Extrapolation
HC-3	180-182	181	43.3	0.780	79.0	1642	36	Extrapolation
HC-3	182-184	183	42.8	0.783	80.2	1637	37	Extrapolation
HC-3	184-186	185	46.5	0.756	83.1	1624	38	Extrapolation
HC-3	186-188	187	57.7	0.666	83.1	1624	38	Extrapolation
HC-3	188-190	189	56.2	0.679	83.1	1624	38	Extrapolation

Appendix A: Data and Calculations for Estimated Ages in the 2005 Sediment Cores

Estimated Age for each core interval.

Core ID	Core Section Depth (cm)	Mid-Interval Depth (cm)	Percent Dry Weight	Porosity	Mid-Interval Total Dry Accumulation (g/cm^2)	Estimated Year (Mid-point)	Error 1 σ	Comments
HC-3	190-192	191	47.4	0.750	83.1	1624	38	Extrapolation
HC-3	192-194	193	42.4	0.786	84.3	1618	39	Extrapolation
HC-3	194-196	195	43.1	0.781	85.4	1613	39	Extrapolation
HC-3	196-198	197	43.2	0.780	86.6	1608	40	Extrapolation
HC-3	198-200	199	42.3	0.786	87.7	1603	40	Extrapolation
HC-3	200-205	201	42.3	0.787	89.6	1594	41	Extrapolation
HC-3	205-210	207.5	42.6	0.785	92.4	1581	42	Extrapolation
HC-3	210-215	212.5	41.7	0.791	95.2	1568	44	Extrapolation
Core HC-4 Sediment Accumulation Rate ($g/cm^2/yr$) = 0.170 ± 0.027								
HC-4	0-2	1	22.0	0.919	0.23	2004	0	
HC-4	2-4	3	23.7	0.909	0.72	2001	1	
HC-4	4-6	5	25.1	0.900	1.26	1998	1	
HC-4	6-8	7	26.8	0.889	1.83	1994	1	
HC-4	8-10	9	27.8	0.883	2.45	1991	2	
HC-4	10-12	11	29.0	0.876	3.09	1987	2	
HC-4	12-14	13	29.1	0.875	3.76	1983	3	
HC-4	14-16	15	29.5	0.872	4.43	1979	3	
HC-4	16-18	17	30.1	0.869	5.12	1975	4	
HC-4	18-20	19	30.7	0.865	5.83	1971	4	
HC-4	20-22	21	30.8	0.864	6.54	1967	5	
HC-4	22-24	23	30.5	0.866	7.26	1962	6	
HC-4	24-26	25	30.7	0.865	7.97	1958	6	
HC-4	26-28	27	31.4	0.860	8.70	1954	7	
HC-4	28-30	29	31.9	0.857	9.44	1949	7	
HC-4	30-32	31	32.0	0.856	10.19	1945	8	
HC-4	32-34	33	31.5	0.859	10.94	1941	8	
HC-4	34-36	35	31.5	0.859	11.68	1936	9	
HC-4	36-38	37	32.1	0.855	12.43	1932	9	
HC-4	38-40	39	31.8	0.857	13.19	1927	10	
HC-4	40-42	41	32.8	0.851	13.95	1923	11	
HC-4	42-44	43	33.7	0.845	14.75	1918	11	
HC-4	44-46	45	33.4	0.847	15.55	1914	12	
HC-4	46-48	47	33.8	0.844	16.36	1909	12	
HC-4	48-50	49	33.8	0.844	17.17	1904	13	
HC-4	50-55	52.5	33.3	0.847	18.58	1896	14	
HC-4	55-60	57.5	34.4	0.840	20.61	1884	16	
HC-4	60-65	62.5	35.0	0.837	22.72	1871	17	Extrapolation
HC-4	65-70	67.5	33.8	0.844	24.80	1859	19	Extrapolation
HC-4	70-75	72.5	33.7	0.845	26.83	1847	20	Extrapolation
HC-4	75-80	77.5	33.4	0.847	28.84	1835	22	Extrapolation
HC-4	80-85	82.5	33.2	0.848	30.83	1824	23	Extrapolation
HC-4	85-90	87.5	34.5	0.840	32.87	1812	25	Extrapolation
HC-4	90-95	92.5	35.7	0.832	35.00	1799	27	Extrapolation
HC-4	95-100	97.5	36.2	0.828	37.21	1786	28	Extrapolation
HC-4	100-105	102.5	37.4	0.820	39.49	1773	30	Extrapolation
HC-4	105-110	107.5	36.8	0.824	41.80	1759	32	Extrapolation
HC-4	110-115	112.5	35.0	0.836	44.00	1746	33	Extrapolation
HC-4	115-120	117.5	35.3	0.835	46.14	1734	35	Extrapolation
HC-4	120-125	122.5	35.5	0.833	48.31	1721	37	Extrapolation
HC-4	125-130	127.5	38.1	0.816	50.58	1707	38	Extrapolation
HC-4	130-135	132.5	39.0	0.809	53.01	1693	40	Extrapolation
HC-4	135-140	137.5	37.1	0.823	55.40	1679	42	Extrapolation

Appendix A: Data and Calculations for Estimated Ages in the 2005 Sediment Cores

Estimated Age for each core interval.

Core ID	Core Section Depth (cm)	Mid-Interval Depth (cm)	Percent Dry Weight	Porosity	Mid-Interval Total Dry Accumulation (g/cm^2)	Estimated Year (Mid-point)	Error 1 σ	Comments
HC-4	140-145	142.5	38.5	0.813	57.76	1665	44	Extrapolation
HC-4	145-150	147.5	36.8	0.824	60.11	1651	46	Extrapolation
HC-4	150-155	152.5	35.9	0.830	62.36	1638	47	Extrapolation
HC-4	155-160	157.5	36.3	0.828	64.58	1625	49	Extrapolation
HC-4	160-165	162.5	36.0	0.830	66.80	1612	51	Extrapolation
HC-4	165-170	167.5	34.6	0.839	68.96	1599	52	Extrapolation
HC-4	170-175	172.5	34.1	0.842	71.03	1587	54	Extrapolation
HC-4	175-180	177.5	33.0	0.849	73.05	1575	55	Extrapolation
HC-4	180-185	182.5	33.1	0.849	75.0	1564	57	Extrapolation
HC-4	185-190	187.5	34.2	0.842	77.0	1552	58	Extrapolation
HC-4	190-195	192.5	35.0	0.837	79.1	1540	60	Extrapolation
HC-4	195-200	197.5	36.4	0.827	81.3	1527	62	Extrapolation
HC-4	200-205	202.5	37.4	0.820	83.6	1513	63	Extrapolation
HC-4	205-210	207.5	37.5	0.820	85.9	1499	65	Extrapolation
HC-4	210-215	212.5	37.7	0.818	88.3	1486	67	Extrapolation
HC-4	215-220	217.5	36.7	0.825	90.6	1472	69	Extrapolation
HC-4	220-225	222.5	37.2	0.822	92.9	1459	70	Extrapolation
HC-4	225-230	227.5	38.0	0.816	95.2	1445	72	Extrapolation
HC-4	230-235	232.5	38.2	0.815	97.6	1431	74	Extrapolation
HC-4	235-240	237.5	35.7	0.832	99.9	1417	76	Extrapolation
HC-4	240-245	242.5	36.8	0.824	102.2	1404	77	Extrapolation
HC-4	245-250	247.5	36.8	0.825	104.4	1391	79	Extrapolation
HC-4	250-255	252.5	36.2	0.828	106.7	1377	81	Extrapolation
Core HC-5 Sediment Accumulation Rate ($g/cm^2/yr$) = 0.337 ± 0.018								
HC-5	0-2	1	28.2	0.880	0.32	2004	0	
HC-5	2-4	3	29.3	0.874	0.98	2002	0	
HC-5	4-6	5	31.2	0.861	1.68	2000	0	
HC-5	6-8	7	32.3	0.854	2.43	1998	0	
HC-5	8-10	9	32.0	0.856	3.19	1996	0	
HC-5	10-12	11	33.4	0.847	3.97	1993	1	
HC-5	12-14	13	34.2	0.842	4.78	1991	1	
HC-5	14-16	15	33.1	0.849	5.59	1988	1	
HC-5	16-18	17	34.0	0.843	6.39	1986	1	
HC-5	18-20	19	35.8	0.831	7.24	1984	1	
HC-5	20-22	21	35.8	0.831	8.12	1981	1	
HC-5	22-24	23	35.7	0.832	8.99	1978	1	
HC-5	24-26	25	34.9	0.837	9.85	1976	1	
HC-5	26-28	27	35.3	0.835	10.71	1973	2	
HC-5	28-30	29	35.0	0.836	11.56	1971	2	
HC-5	30-32	31	34.5	0.840	12.41	1968	2	
HC-5	32-34	33	35.3	0.834	13.26	1966	2	
HC-5	34-36	35	35.0	0.836	14.11	1963	2	
HC-5	36-38	37	35.1	0.836	14.97	1961	2	
HC-5	38-40	39	35.4	0.834	15.83	1958	2	
HC-5	40-42	41	36.7	0.825	16.71	1955	3	
HC-5	42-44	43	36.5	0.827	17.62	1953	3	
HC-5	44-46	45	36.6	0.825	18.52	1950	3	
HC-5	46-48	47	37.1	0.823	19.43	1947	3	
HC-5	48-50	49	38.0	0.816	20.37	1945	3	
HC-5	50-52	51	37.9	0.817	21.32	1942	3	
HC-5	52-54	53	37.7	0.818	22.27	1939	3	
HC-5	54-56	55	38.0	0.816	23.21	1936	4	

Appendix A: Data and Calculations for Estimated Ages in the 2005 Sediment Cores

Estimated Age for each core interval.

Core ID	Core Section Depth (cm)	Mid-Interval Depth (cm)	Percent Dry Weight	Porosity	Mid-Interval Total Dry Accumulation (g/cm^2)	Estimated Year (Mid-point)	Error 1 σ	Comments
HC-5	56-58	57	37.8	0.818	24.16	1933	4	
HC-5	58-60	59	36.9	0.824	25.09	1931	4	
HC-5	60-62	61	36.5	0.826	26.00	1928	4	
HC-5	62-64	63	38.3	0.814	26.93	1925	4	
HC-5	64-66	65	37.2	0.822	27.88	1922	4	
HC-5	66-68	67	37.6	0.819	28.81	1920	4	
HC-5	68-70	69	37.9	0.817	29.75	1917	5	
HC-5	70-72	71	37.2	0.821	30.69	1914	5	
HC-5	72-74	73	37.6	0.819	31.62	1911	5	
HC-5	74-76	75	37.5	0.820	32.56	1908	5	
HC-5	76-78	77	37.3	0.821	33.49	1906	5	
HC-5	78-80	79	36.6	0.826	34.40	1903	5	
HC-5	80-82	81	37.3	0.821	35.32	1900	5	
HC-5	82-84	83	37.3	0.821	36.25	1897	6	
HC-5	84-86	85	37.9	0.817	37.19	1895	6	Extrapolation
HC-5	86-88	87	38.1	0.816	38.14	1892	6	Extrapolation
HC-5	88-90	89	38.1	0.815	39.09	1889	6	Extrapolation
HC-5	90-92	91	38.9	0.810	40.06	1886	6	Extrapolation
HC-5	92-94	93	39.0	0.810	41.05	1883	6	Extrapolation
HC-5	94-96	95	39.5	0.806	42.04	1880	6	Extrapolation
HC-5	96-100	98	38.6	0.812	43.52	1876	7	Extrapolation
HC-5	100-105	102.5	39.5	0.806	45.75	1869	7	Extrapolation
HC-5	105-110	107.5	39.4	0.807	48.26	1862	7	Extrapolation
HC-5	110-115	112.5	39.6	0.806	50.77	1854	8	Extrapolation
HC-5	115-120	117.5	41.6	0.791	53.38	1847	8	Extrapolation
HC-5	120-125	122.5	39.5	0.806	55.99	1839	9	Extrapolation
HC-5	125-130	127.5	37.3	0.821	58.40	1832	9	Extrapolation
HC-5	130-135	132.5	36.9	0.823	60.71	1825	9	Extrapolation
HC-5	135-140	137.5	36.3	0.828	62.97	1818	10	Extrapolation
HC-5	140-145	142.5	38.5	0.813	65.30	1811	10	Extrapolation
HC-5	145-150	147.5	38.0	0.816	67.70	1804	10	Extrapolation
HC-5	150-155	152.5	37.3	0.821	70.05	1797	11	Extrapolation
HC-5	155-160	157.5	36.1	0.829	72.32	1790	11	Extrapolation
HC-5	160-165	162.5	35.8	0.831	74.53	1784	11	Extrapolation
HC-5	165-170	167.5	37.3	0.821	76.79	1777	12	Extrapolation
HC-5	170-175	172.5	38.1	0.816	79.14	1770	12	Extrapolation
HC-5	175-180	177.5	42.5	0.785	81.7	1762	12	Extrapolation
HC-5	180-185	182.5	42.0	0.789	84.5	1754	13	Extrapolation
HC-5	185-190	187.5	43.0	0.781	87.3	1746	13	Extrapolation
HC-5	190-195	192.5	40.6	0.799	90.0	1738	14	Extrapolation
HC-5	195-200	197.5	40.3	0.801	92.6	1730	14	Extrapolation
HC-5	200-205	202.5	40.8	0.797	95.2	1723	14	Extrapolation
HC-5	205-210	207.5	41.5	0.792	97.8	1715	15	Extrapolation
HC-5	210-215	212.5	42.4	0.786	100.6	1707	15	Extrapolation
HC-5	215-220	217.5	48.0	0.745	103.6	1698	16	Extrapolation
HC-5	220-225	222.5	45.7	0.762	106.8	1688	16	Extrapolation
HC-5	225-230	227.5	42.8	0.783	109.8	1679	17	Extrapolation
HC-5	230-235	232.5	40.8	0.797	112.5	1671	17	Extrapolation
HC-5	235-240	237.5	41.4	0.793	115.2	1663	17	Extrapolation
HC-5	240-245	242.5	42.6	0.784	117.9	1655	18	Extrapolation
HC-5	245-250	247.5	41.9	0.789	120.7	1647	18	Extrapolation
HC-5	250-255	252.5	42.2	0.787	123.4	1639	19	Extrapolation
HC-5	255-260	257.5	38.2	0.815	126.0	1631	19	Extrapolation

Appendix B: Metal Data for Hood Canal Core HC-3

Core Segment	Mid-depth (cm)	Al (%)	Ti (%)	Ti/Al (x 10^2)	Fe (%)	Fe/Al	Mn (μg/g)	Mn/Al (x 10^2)	Mo (μg/g)	Mo/Al (x 10^6)	U (μg/g)	U/Al (x 10^6)	Re (ng/g)	Re SD	Re/Al (x 10^6)
0-2	1	5.67	0.578	10.2	5.85	1.03	4333	7.65	1.40	24.7	1.40	24.7	3.49	0.78	61.6
2-4	3	6.06	0.611	10.1	6.14	1.01	3050	5.03	0.959	15.8	1.51	24.9			
4-6	5	6.14	0.628	10.2	6.23	1.01	3036	4.94	0.837	13.6	1.51	24.6	3.33	0.64	54.2
6-8	7	6.16	0.624	10.1	6.28	1.02	2999	4.87	0.859	13.9	1.55	25.1	3.01	0.59	48.8
8-10	9	6.06	0.610	10.1	6.18	1.02	2677	4.42	0.862	14.2	1.47	24.2	5.56	1.47	91.7
10-12	11	5.93	0.603	10.2	5.92	1.00	2488	4.20	1.22	20.6	1.68	28.3	4.23	1.13	71.3
12-14	13	6.03	0.602	10.0	6.01	1.00	2446	4.05	1.39	23.0	2.02	33.5			
14-16	15	6.07	0.611	10.1	6.09	1.00	2378	3.92	1.54	25.4	2.40	39.6			
16-18	17	6.18	0.629	10.2	6.14	0.993	2307	3.73	1.18	19.1	2.25	36.4	2.10	0.47	
18-20	19	6.18	0.626	10.1	6.11	0.989	2353	3.81	1.34	21.7	2.40	38.8	4.69	0.79	75.9
20-22	21	6.19	0.615	9.95	6.15	0.994	2275	3.68	1.54	24.9	2.57	41.5			
22-24	23	6.28	0.623	9.93	6.17	0.983	2432	3.87	1.70	27.1	2.34	37.3			
24-26	25	6.23	0.626	10.0	5.97	0.958	2147	3.44	1.60	25.7	2.39	38.3			
26-28	27	6.26	0.628	10.0	6.04	0.965	2033	3.25	1.43	22.8	2.43	38.8			
28-30	29	6.09	0.613	10.1	6.04	0.992	2009	3.30	4.81	79.0	2.92	48.0			
30-32	31	6.32	0.619	9.79	6.14	0.971	1980	3.13	1.42	22.5	2.83	44.8	5.07	0.39	80.2
32-34	33	6.16	0.604	9.80	5.96	0.968	1904	3.09	1.33	21.6	2.82	45.8			
34-36	35	6.37	0.622	9.76	6.21	0.974	1942	3.05	1.61	25.3	2.93	46.0	6.11	1.74	95.9
36-38	37	6.27	0.623	9.94	6.12	0.976	1982	3.16	2.08	33.2	2.88	45.9			
38-40	39	6.22	0.616	9.91	6.01	0.967	1963	3.16	2.14	34.4	2.78	44.7			
40-42	41	6.38	0.635	10.0	6.24	0.978	1978	3.10	2.52	39.5	3.02	47.4	6.06	1.72	95.0
42-44	43	6.35	0.622	9.80	6.22	0.979	1997	3.14	2.91	45.8	2.98	46.9	4.09	0.37	64.4
44-46	45	6.26	0.622	9.94	6.10	0.975	1881	3.00	2.76	44.1	2.83	45.2	4.63	1.23	
46-48	47	6.32	0.617	9.76	6.14	0.971	1917	3.03	2.91	46.0	2.94	46.5			
48-50	49	6.22	0.615	9.89	6.17	0.993	1879	3.02	2.86	46.0	3.22	51.8	8.41	2.04	135
50-52	51	6.30	0.626	9.92	6.20	0.983	1939	3.08	3.29	52.2	3.61	57.3	8.31	1.58	132
52-54	53	6.41	0.630	9.82	6.26	0.977	1884	2.94	3.53	55.0	3.46	53.9			
54-56	55	6.32	0.630	10.0	6.23	0.985	1813	2.87	3.18	50.3	3.37	53.3	7.78	0.53	123
56-58	57	6.28	0.629	10.0	6.20	0.988	1729	2.76	3.37	53.7	3.73	59.4	12.2	2.61	194
58-60	59	6.39	0.640	10.0	6.32	0.989	1848	2.89	4.28	67.0	3.81	59.6			
60-62	61	6.42	0.637	9.92	6.37	0.992	1796	2.80	4.80	74.7	4.50	70.1	12.1	0.75	188
62-64	63	6.39	0.633	9.91	6.35	0.994	1781	2.79	5.65	88.4	4.76	74.5	16.0	0.85	250
64-66	65	6.31	0.626	9.92	6.31	1.00	1771	2.81	5.64	89.3	4.46	70.7	12.0	1.32	190
66-68	67	6.30	0.633	10.0	6.21	0.985	1772	2.81	5.84	92.7	4.59	72.9	9.46	2.51	150
68-70	69	6.38	0.630	9.88	6.34	0.993	1833	2.87	6.52	102	4.63	72.6			
70-72	71	6.30	0.617	9.78	6.28	1.00	1880	2.98	6.30	99.9	4.87	77.2	20.3	2.90	322
72-74	73	6.48	0.633	9.76	6.35	0.98	1881	2.90	7.09	109	4.39	67.8	13.3	3.26	205
74-76	75	6.49	0.633	9.77	6.34	0.98	1899	2.93	9.23	142	4.05	62.4	10.2	1.39	157
76-78	77	6.38	0.618	9.69	6.14	0.963	1883	2.95	6.44	101	3.79	59.4	8.64	1.18	136
78-80	79	6.42	0.620	9.65	6.25	0.973	1912	2.98	5.62	87.5	3.88	60.4	9.55	2.10	149
80-82	81	6.13	0.637	10.4	6.10	1.00	1835	2.99	4.38	71.4	2.93	47.8	6.87	0.25	112
82-84	83	6.24	0.662	10.6	6.42	1.03	1911	3.06	4.86	77.9	3.12	50.0			
84-86	85	6.28	0.662	10.5	6.29	1.00	1831	2.91	3.58	57.0	3.12	49.7	6.34	1.36	101
86-88	87	6.34	0.664	10.5	6.25	0.986	1845	2.91	3.64	57.5	3.20	50.5			
88-90	89	6.38	0.672	10.5	5.76	0.903	1847	2.90	4.44	69.6	3.60	56.5			
90-92	91	6.15	0.649	10.5	6.13	1.00	1751	2.84	5.72	92.9	3.84	62.4	13.6	1.31	221
92-94	93	6.24	0.656	10.5	6.35	1.02	1805	2.89	8.80	141	3.87	62.1	10.8	3.08	173
94-96	95	6.19	0.654	10.6	6.23	1.01	1860	3.00	6.50	105	3.58	57.8			
96-98	97	6.30	0.662	10.5	6.26	0.993	1940	3.08	7.70	122	4.00	63.5	7.80	2.29	124
98-100	99	6.31	0.674	10.7	6.37	1.01	1862	2.95	7.72	122	3.94	62.4	8.76	0.65	139
100-102	101	6.31	0.667	10.6	6.29	1.00	1904	3.02	5.29	83.8	3.68	58.3	10.9	1.73	173
102-104	103	5.95	0.625	10.5	5.96	1.00	1810	3.05	5.65	95.0	3.59	60.4	9.81	2.30	165
104-106	105	6.52	0.683	10.5	6.54	1.00	1778	2.73	7.27	112	3.97	60.9	14.1	1.42	216
106-108	107	6.43	0.686	10.7	6.51	1.01	1682	2.61	7.17	111	3.84	59.7	8.71	1.85	135
108-110	109	6.51	0.688	10.6	6.56	1.01	1771	2.72	5.69	87.5	3.31	50.9	5.50	0.98	84.5
110-112	111	6.51	0.682	10.5	6.48	1.00	1751	2.69	5.46	83.9	3.31	50.9	6.73	0.23	103
112-114	113	6.58	0.685	10.4	6.60	1.00	1717	2.61	5.38	81.8	3.37	51.2			
114-116	115	6.45	0.666	10.3	6.35	0.984	1710	2.65	5.59	86.7	3.31	51.3			
116-118	117	6.39	0.671	10.5	6.34	0.993	1776	2.78	7.07	111	3.23	50.6	8.21	1.99	129
118-120	119	6.40	0.690	10.8	6.42	1.00	1767	2.76	5.64	88.1	3.10	48.4	8.57	1.92	134
120-122	121	6.48	0.672	10.4	6.41	0.989	1675	2.59	4.75	73.4	3.46	53.4	8.86	1.72	137
122-124	123	6.46	0.681	10.5	6.65	1.03	1689	2.61	5.20	80.5	3.66	56.6	12.7	2.54	197

Appendix B: Metal Data for Hood Canal Core HC-3

Core Segment	Mid-depth (cm)	Al (%)	Ti (%)	Ti/Al (x 10^2)	Fe (%)	Fe/Al	Mn (µg/g)	Mn/Al (x 10^2)	Mo (µg/g)	Mo/Al (x 10^6)	U (µg/g)	U/Al (x 10^6)	Re (ng/g)	Re SD	Re/Al (x 10^6)
124-126	125	6.33	0.657	10.4	6.48	1.02	1745	2.75	5.52	87.1	3.64	57.5	9.85	1.12	155
126-128	127	6.43	0.662	10.3	6.55	1.02	1820	2.83	6.38	99.2	3.59	55.8	8.52	1.43	132
128-130	129	6.42	0.669	10.4	6.60	1.03	1899	2.96	6.29	97.9	3.36	52.3	7.00	0.90	109
130-132	131	6.42	0.663	10.3	6.58	1.03	1917	2.99	6.27	97.7	3.15	49.1	9.89	0.43	154
132-134	133	6.55	0.665	10.2	6.53	1.00	2014	3.08	7.36	112	2.99	45.7	9.62	2.23	147
134-136	135	6.34	0.665	10.5	6.49	1.02	2064	3.25	7.27	115	3.01	47.4	6.77	1.37	107
136-138	137	6.51	0.680	10.4	6.60	1.01	2063	3.17	4.88	75.0	3.29	50.5	8.35	1.69	128
138-140	139	6.40	0.674	10.5	6.51	1.02	1934	3.02	3.08	48.2	3.22	50.3	5.53	0.15	86.5
140-142	141	6.58	0.678	10.3	6.61	1.00	1922	2.92	2.17	33.0	3.12	47.4			
142-144	143	6.77	0.698	10.3	6.75	1.00	1950	2.88	1.87	27.6	2.89	42.7	7.71	0.55	114
144-146	145	6.54	0.685	10.5	6.49	0.993	1928	2.95	2.79	42.7	2.91	44.5			
146-148	147	6.54	0.682	10.4	6.60	1.01	1882	2.88	2.83	43.3	2.98	45.5	5.84	1.41	89.3
148-150	149	6.50	0.674	10.4	6.60	1.01	1894	2.91	3.34	51.4	3.08	47.4			
150-152	151	6.48	0.665	10.3	6.55	1.01	1818	2.81	4.69	72.4	3.24	50.0	9.44	2.47	146
152-154	153	6.49	0.673	10.4	6.65	1.03	1860	2.87	5.06	78.0	3.59	55.3	7.53	1.94	116
154-156	155	6.49	0.678	10.5	6.69	1.03	1670	2.57	4.42	68.1	4.35	67.1	11.8	0.08	182
156-158	157	6.57	0.679	10.3	6.84	1.04	1733	2.64	5.14	78.3	4.67	71.1	12.9	2.84	196
158-160	159	6.51	0.669	10.3	6.79	1.04	1763	2.71	5.48	84.2	4.83	74.2	12.9	2.54	198
160-162	161	6.58	0.659	10.0	6.53	0.992	1701	2.58	5.91	89.8	4.69	71.2	13.5	1.94	205
162-164	163	6.60	0.650	9.85	6.51	0.986	1737	2.63	6.29	95.3	4.55	68.9			
164-166	165	6.76	0.675	10.0	6.79	1.00	1792	2.65	7.59	112	4.84	71.6	15.8	1.94	234
166-168	167	6.71	0.672	10.0	6.77	1.01	1814	2.70	9.96	148	4.89	72.9	12.6	1.25	188
168-170	169	6.75	0.664	9.83	6.75	1.00	1797	2.66	12.8	190	5.02	74.4	17.7	1.40	262
170-172	171	6.59	0.646	9.81	6.45	0.979	1679	2.55	18.1	275	4.94	75.0	11.0	2.11	167
172-174	173	6.82	0.663	9.72	6.67	0.978	1833	2.69	16.2	238	4.72	69.2	9.17	1.68	134
174-176	175	6.72	0.646	9.62	6.61	0.984	1889	2.81	12.0	179	4.10	61.0	9.10	0.91	135
176-178	177	6.79	0.656	9.65	6.67	0.983	1990	2.93	11.1	163	3.97	58.5	10.1	1.30	149
178-180	179	6.11	0.612	10.0	6.09	1.00	1866	3.05	11.3	185	3.46	56.6	7.39	1.42	121
180-182	181	6.60	0.646	9.79	6.47	0.980	1906	2.89	6.71	102	3.26	49.4			
182-184	183	6.69	0.669	10.0	6.55	0.979	1822	2.72	5.33	79.7	3.07	45.9	7.44	1.00	111
184-186	185	6.58	0.660	10.0	6.52	0.991	1800	2.73	5.14	78.1	3.01	45.7	5.94	1.37	90.2
186-188	187	6.49	0.674	10.4	6.44	0.992	1792	2.76	3.08	47.4	2.87	44.2	6.10	1.10	93.9
188-190	189	6.61	0.705	10.7	6.30	0.952	1489	2.25	2.18	33.0	2.30	34.8			
190-192	191	6.52	0.675	10.3	6.38	0.978	1674	2.57	3.89	59.6	2.62	40.2	5.43	0.23	83.3
192-194	193	6.65	0.630	9.47	6.52	0.980	1860	2.80	5.44	81.8	2.96	44.5	8.41	1.17	126
194-196	195	6.57	0.626	9.53	6.51	0.990	1805	2.75	6.47	98.4	3.08	46.9			
196-198	197	6.55	0.620	9.48	6.35	0.970	1814	2.77	3.64	55.6	3.12	47.7			
198-200	199	6.54	0.627	9.58	6.31	0.965	1888	2.89	2.89	44.2	2.93	44.8	8.05	1.96	123
200-205	201	6.61	0.644	9.74	6.71	1.01	1824	2.76	2.74	41.4	2.44	36.9	8.68	1.27	131
205-210	207.5	6.60	0.643	9.74	6.73	1.02	1985	3.01	2.54	38.5	2.54	38.5	4.26	0.97	
210-215	212.5	6.53	0.630	9.65	6.44	0.987	2311	3.54	2.51	38.4	2.36	36.2	7.06	1.28	108
CV		3%	4%		4%		18%		64%		25%		40%		

Appendix B: Metal Data for Hood Canal Core HC-3

Core Segment	Mid-depth (cm)	Cd (µg/g)	Cd/Al ($x10^6$)	Pb (µg/g)	Pb/Al ($x10^4$)	As (µg/g)	Zn (µg/g)	Ni (µg/g)	V (µg/g)	Cr (µg/g)	Cu (µg/g)	Ba (µg/g)	Be (µg/g)	Ca (%)	Mg (%)	P (µg/g)	BSi as SiO_2 (%)	SD
0-2	1	0.313	5.52	10.7	1.89	10.2	111	60.2	196	97	90.2	214	1.04	2.32	2.59	968	9.83	0.20
2-4	3	0.320	5.28	12.0	1.98	9.72	114	62.3	199	102	94.2	223	1.13	2.37	2.59			
4-6	5	0.320	5.21	12.0	1.95	9.56	117	64.3	205	104	97.4	222	1.10	2.40	2.62	828		
6-8	7	0.346	5.61	12.1	1.96	9.24	119	64.6	208	106	98.3	222	1.09	2.41	2.63			
8-10	9	0.311	5.13	11.8	1.95	8.99	114	62.5	199	101	94.5	220	1.14	2.39	2.61	812		
10-12	11	0.355	5.99	12.0	2.02	9.20	112	61.2	195	100	91.0	218	1.11	2.30	2.57	778	9.87	0.50
12-14	13	0.367	6.08	12.8	2.12	9.84	116	62.6	201	102	93.9	220	1.12	2.34	2.59	792		
14-16	15	0.356	5.87	13.8	2.28	10.5	120	63.0	204	105	94.3	221	1.11	2.39	2.59			
16-18	17	0.331	5.35	13.5	2.18	9.45	121	63.9	204	105	95.3	223	1.13	2.40	2.63	739		
18-20	19	0.356	5.76	13.4	2.17	9.61	120	63.8	204	104	95.1	222	1.15	2.38	2.63	779	10.30	0.48
20-22	21	0.354	5.72	14.5	2.34	10.1	123	63.7	203	103	93.7	222	1.18	2.39	2.58	753		
22-24	23	0.357	5.68	15.3	2.44	10.2	127	64.6	208	106	95.4	225	1.17	2.38	2.62	807		
24-26	25	0.354	5.68	14.8	2.37	9.79	121	63.5	205	105	93.4	221	1.24	2.31	2.56			
26-28	27	0.377	6.02	13.0	2.08	10.2	116	64.5	205	106	93.2	228	1.25	2.34	2.57	665		
28-30	29	0.378	6.21	12.0	1.97	11.7	111	62.7	202	104	90.1	224	1.15	2.48	2.53	696	10.50	0.21
30-32	31	0.406	6.42	11.2	1.77	11.7	109	64.2	204	105	91.4	233	1.17	2.37	2.60	712		
32-34	33	0.420	6.82	10.2	1.66	10.5	104	62.7	200	104	89.5	231	1.15	2.32	2.54			
34-36	35	0.428	6.71	9.98	1.57	11.0	104	65.3	206	107	91.9	241	1.19	2.40	2.61			
36-38	37	0.447	7.13	9.04	1.44	11.2	99.3	64.1	203	105	89.3	236	1.16	2.36	2.58	723		
38-40	39	0.422	6.79	9.10	1.46	10.8	100	64.4	205	106	89.3	236	1.19	2.35	2.60			
40-42	41	0.517	8.11	8.85	1.39	10.2	102	66.5	214	111	93.1	259	1.16	2.44	2.61	703	10.60	0.21
42-44	43	0.496	7.81	8.16	1.28	11.1	100	64.9	209	110	90.5	258	1.18	2.44	2.61			
44-46	45	0.514	8.21	7.87	1.26	10.3	100	64.1	207	109	89.0	251	1.15	2.65	2.60			
46-48	47	0.501	7.92	7.87	1.24	10.2	100	64.6	209	109	89.9	251	1.19	2.42	2.58			
48-50	49	0.510	8.20	7.58	1.22	10.7	100	63.8	205	108	89.9	249	1.15	2.42	2.54	718		
50-52	51	0.549	8.71	7.82	1.24	10.9	102	65.5	209	110	91.3	251	1.15	2.44	2.60	725	10.50	0.46
52-54	53	0.613	9.56	7.26	1.13	10.6	101	65.5	207	111	90.7	258	1.19	2.48	2.61	682		
54-56	55	0.552	8.73	7.22	1.14	11.3	99.1	64.3	204	111	89.9	251	1.14	2.44	2.56			
56-58	57	0.641	10.2	7.23	1.2	11.0	99.1	64.6	207	109	88.4	248	1.18	2.48	2.60			
58-60	59	0.598	9.36	7.68	1.20	10.2	103	66.1	210	112	90.1	254	1.20	2.56	2.64	723		
60-62	61	0.644	10.0	7.56	1.2	11.4	102	66.5	216	113	92.3	254	1.17	2.52	2.65	705	10.20	0.44
62-64	63	0.620	9.71	7.20	1.13	11.7	100	65.5	218	110	91.8	248	1.17	2.50	2.65			
64-66	65	0.604	9.57	7.10	1.12	11.4	98.8	65.6	211	110	89.7	249	1.13	2.47	2.63			
66-68	67	0.587	9.32	6.99	1.11	10.9	97.6	65.2	208	108	89.0	244	1.15	2.50	2.61			
68-70	69	0.639	10.0	7.22	1.1	12.3	100	65.9	213	109	89.3	245	1.15	2.49	2.67	672		
70-72	71	0.720	11.4	7.09	1.1	11.7	100	65.3	209	107	87.5	248	1.15	2.59	2.62			
72-74	73	0.660	10.2	7.54	1.2	10.9	101	66.7	210	109	88.4	253	1.21	2.47	2.69	672		
74-76	75	0.678	10.5	7.82	1.2	10.3	102	66.6	212	110	89.9	255	1.19	2.46	2.68	695	10.20	0.34
76-78	77	0.612	9.60	7.29	1.14	9.79	100	65.4	206	108	88.6	247	1.17	2.42	2.61	685		
78-80	79	0.618	9.62	7.25	1.13	10.3	101	65.9	207	108	87.6	253	1.17	2.49	2.68	664		
80-82	81	0.514	8.38	6.84	1.12	8.11	99.3	62.1	204	106	87.4	256	1.05	2.41	2.53			
82-84	83	0.610	9.77	7.33	1.17	9.32	103	64.3	210	109	91.2	268	1.07	2.53	2.59	687		
84-86	85	0.568	9.04	7.30	1.16	8.80	101	63.6	207	107	89.5	262	1.07	2.46	2.58	726	10.10	0.31
86-88	87	0.622	9.82	7.36	1.16	9.18	102	64.4	211	110	91.0	261	1.07	2.72	2.59			
88-90	89	0.558	8.75	7.34	1.15	10.1	103	65.1	212	109	92.4	241	1.10	2.23	2.61			
90-92	91	0.540	8.77	7.06	1.15	10.1	98.3	62.2	203	106	87.0	256	1.07	2.39	2.50	681		
92-94	93	0.632	10.1	7.27	1.2	10.1	100	63.6	207	106	88.4	264	1.09	2.50	2.56	716	9.38	0.20
94-96	95	0.571	9.22	7.07	1.14	9.49	99.4	62.8	205	107	88.1	259	1.07	2.42	2.53	674		
96-98	97	0.620	9.84	7.36	1.17	9.40	100	63.5	205	107	88.6	264	1.08	2.42	2.59	677		
98-100	99	0.629	9.97	7.39	1.17	10.6	102	64.9	209	108	90.2	266	1.11	2.46	2.60			
100-102	101	0.560	8.88	7.14	1.13	11.3	99.5	62.9	204	106	88.3	259	1.07	2.42	2.60	705	9.21	0.07
102-104	103	0.554	9.32	6.89	1.16	10.3	95.4	60.6	195	102	85.0	248	1.04	2.33	2.44			
104-106	105	0.509	7.81	7.39	1.13	11.1	103	64.4	210	110	93.6	279	1.14	2.47	2.62			
106-108	107	0.493	7.66	7.68	1.19	9.74	103	64.9	211	113	93.9	283	1.12	2.45	2.62	695	9.22	0.17
108-110	109	0.515	7.92	7.65	1.18	9.52	104	65.4	211	111	94.2	278	1.12	2.55	2.63			
110-112	111	0.491	7.55	7.46	1.15	8.78	104	64.8	208	109	92.5	279	1.12	2.47	2.63	682	9.68	0.30
112-114	113	0.479	7.28	7.69	1.17	9.14	106	66.4	213	112	95.4	286	1.15	2.52	2.61			
114-116	115	0.484	7.50	7.42	1.15	9.67	103	65.0	207	109	92.2	272	1.12	2.41	2.60			
116-118	117	0.476	7.45	7.39	1.16	9.58	102	63.8	204	108	89.4	273	1.08	2.40	2.62	730		
118-120	119	0.494	7.72	7.41	1.16	10.6	104	65.5	209	111	91.8	275	1.11	2.46	2.64	722		
120-122	121	0.525	8.11	7.25	1.12	10.1	104	65.3	212	111	94.0	275	1.12	2.48	2.64	697	9.59	0.02
122-124	123	0.552	8.54	7.32	1.13	10.8	103	65.7	215	111	96.1	277	1.12	2.55	2.64			

Appendix B: Metal Data for Hood Canal Core HC-3

Core Segment	Mid-depth (cm)	Cd (µg/g)	Cd/Al ($x10^6$)	Pb (µg/g)	Pb/Al ($x10^4$)	As (µg/g)	Zn (µg/g)	Ni (µg/g)	V (µg/g)	Cr (µg/g)	Cu (µg/g)	Ba (µg/g)	Be (µg/g)	Ca (%)	Mg (%)	P (µg/g)	BSi as SiO_2 (%)	SD
124-126	125	0.540	8.52	7.15	1.13	10.7	102	64.9	212	108	94.7	269	1.08	2.67	2.63			
126-128	127	0.567	8.81	7.09	1.10	9.90	103	65.9	215	110	96.0	271	1.11	2.56	2.67			
128-130	129	0.543	8.45	7.32	1.14	9.21	104	65.8	213	110	96.8	275	1.13	2.48	2.69			
130-132	131	0.523	8.15	7.20	1.12	10.2	105	66.9	215	110	96.4	277	1.10	2.53	2.71	714		
132-134	133	0.481	7.34	7.17	1.09	10.1	104	66.1	213	112	95.9	276	1.13	2.47	2.68			
134-136	135	0.446	7.03	7.21	1.14	8.93	102	64.9	209	108	94.5	276	1.09	2.49	2.68	680	8.97	0.20
136-138	137	0.473	7.26	7.29	1.12	10.7	104	66.8	214	110	98.3	282	1.15	2.49	2.72			
138-140	139	0.474	7.41	7.23	1.13	11.0	102	65.4	212	108	97.1	279	1.11	2.45	2.69	668		
140-142	141	0.461	7.00	7.38	1.12	10.4	105	67.9	216	112	100	283	1.17	2.49	2.73	676	8.17	0.03
142-144	143	0.460	6.79	7.56	1.12	8.88	108	69.0	221	114	101	290	1.18	2.57	2.81	651		
144-146	145	0.505	7.72	7.37	1.13	9.20	104	66.4	214	110	98.2	278	1.15	2.45	2.74			
146-148	147	0.490	7.49	7.59	1.16	9.60	105	67.6	215	111	98.7	284	1.14	2.54	2.72			
148-150	149	0.486	7.47	7.54	1.16	9.57	104	66.5	212	109	97.4	285	1.16	2.43	2.70			
150-152	151	0.496	7.66	7.44	1.15	11.0	105	67.0	211	111	95.2	274	1.13	2.46	2.70	630	8.90	
152-154	153	0.518	7.98	7.64	1.18	10.6	106	67.4	211	111	95.0	270	1.13	2.49	2.68			
154-156	155	0.599	9.23	7.44	1.15	13.2	108	69.1	213	111	94.0	263	1.12	2.41	2.68	686		
156-158	157	0.617	9.40	7.03	1.07	13.5	105	68.4	211	111	92.4	260	1.07	2.50	2.70			
158-160	159	0.568	8.73	7.12	1.09	12.1	104	68.2	210	112	93.7	258	1.12	2.53	2.70			
160-162	161	0.556	8.45	7.35	1.12	11.1	100	67.6	213	114	94.4	263	1.15	2.45	2.67	621	8.58	0.22
162-164	163	0.504	7.64	7.05	1.07	9.93	101	67.8	212	114	95.5	264	1.17	2.47	2.66			
164-166	165	0.546	8.08	6.79	1.00	11.1	103	70.0	222	119	98.6	265	1.19	2.68	2.79			
166-168	167	0.509	7.59	7.03	1.05	12.0	103	69.5	217	118	98.7	268	1.19	2.60	2.73			
168-170	169	0.642	9.51	7.35	1.09	13.3	103	68.8	215	116	97.3	273	1.24	2.52	2.71	663	8.53	0.13
170-172	171	0.575	8.73	7.00	1.06	13.7	100	68.0	209	115	92.4	270	1.24	2.43	2.60	589	8.52	0.19
172-174	173	0.581	8.52	7.40	1.09	12.8	104	69.4	215	118	95.9	279	1.26	2.51	2.71	686	8.76	0.08
174-176	175	0.543	8.08	7.35	1.09	12.0	101	67.8	206	114	93.5	278	1.25	2.46	2.67			
176-178	177	0.590	8.69	7.57	1.11	11.2	103	68.1	215	113	94.3	277	1.28	2.47	2.71	668		
178-180	179	0.544	8.90	6.76	1.11	10.7	94.2	63.6	193	107	85.0	243	1.08	2.33	2.46			
180-182	181	0.504	7.64	6.68	1.01	10.3	100	67.6	204	113	90.2	260	1.22	2.47	2.66	636	9.73	0.32
182-184	183	0.459	6.86	6.42	0.96	9.66	100	70.8	209	121	91.8	258	1.16	2.74	2.71			
184-186	185	0.473	7.18	6.64	1.01	9.8	97.5	67.8	208	130	89.7	257	1.19	2.77	2.65			
186-188	187	0.374	5.76	5.90	0.91	9.13	93.2	67.8	206	121	90.7	239	1.09	2.92	2.65	513		
188-190	189	0.332	5.02	4.56	0.69	8.19	89.4	57.7	222	96.3	71.2	211	1.16	3.40	2.34	632	7.49	0.12
190-192	191	0.412	6.32	6.03	0.92	8.62	93.9	66.8	209	121	85.1	285	1.12	2.83	2.66	680		
192-194	193	0.482	7.25	7.53	1.13	8.45	102	68.7	202	112	88.1	268	1.21	2.41	2.73			
194-196	195	0.536	8.15	8.08	1.23	9.14	102	68.5	200	111	86.7	268	1.19	2.38	2.70	725	9.41	0.47
196-198	197	0.502	7.67	7.71	1.18	8.33	102	68.0	201	111	85.3	264	1.18	2.36	2.72			
198-200	199	0.494	7.55	7.47	1.14	8.95	102	69.4	202	111	86.0	260	1.17	2.60	2.73	684		
200-205	201	0.418	6.32	6.93	1.05	8.33	103	69.9	201	112	88.9	265	1.18	2.50	2.79	678		
205-210	207.5	0.412	6.24	6.99	1.06	8.79	102	69.4	202	111	89.0	261	1.19	2.52	2.79			
210-215	212.5	0.422	6.46	7.19	1.10	9.83	101	68.7	198	110	88.5	257	1.19	3.00	2.77			
CV		19%		26%		11%	6%	4%	3%	4%	5%	8%	4%	6%	3%	9%	9%	

Appendix B: Metal Data for Hood Canal Core HC-5

Core Segment	Mid-depth (cm)	Al (%)	Ti (%)	Ti/Al (x 10^2)	Fe (%)	Fe/Al	Mn (µg/g)	Mn/Al (x 10^2)	Mo (µg/g)	Mo/Al (x 10^6)	U (µg/g)	U/Al (x 10^6)	Re (ng/g)	Re SD	Re/Al (x 10^6)
0-2	1	6.27	0.438	6.98	4.45	0.709	1380	2.20	1.17	18.7	2.1	33.5	4.69	0.03	
2-4	3	6.25	0.448	7.17	4.31	0.690	999	1.60	0.989	15.8	2.00	32.0			
4-6	5	6.45	0.454	7.04	4.58	0.710	881	1.37	1.03	16.0	2.14	33.2	4.00	0.64	62.0
6-8	7	6.51	0.451	6.92	4.55	0.700	852	1.31	0.991	15.2	1.99	30.6			
8-10	9	6.56	0.460	7.02	4.60	0.702	889	1.36	1.23	18.7	2.11	32.2	5.88	0.77	89.6
10-12	11	6.35	0.452	7.11	4.48	0.706	855	1.35	1.34	21.1	2.13	33.5			
12-14	13	6.72	0.461	6.86	4.53	0.674	804	1.20	1.65	24.6	2.24	33.3			
14-16	15	6.62	0.466	7.04	4.48	0.677	784	1.18	1.38	20.9	2.16	32.6			
16-18	17	6.57	0.466	7.09	4.51	0.686	761	1.16	1.66	25.3	2.31	35.1			
18-20	19	6.68	0.458	6.85	4.45	0.667	752	1.13	2.08	31.1	2.44	36.5	5.00	0.51	74.8
20-22	21	6.67	0.464	6.96	4.55	0.682	739	1.11	2.19	32.9	2.86	42.9			
22-24	23	6.76	0.473	7.00	4.69	0.693	749	1.11	2.73	40.4	3.07	45.4	3.28	0.89	48.5
24-26	25	6.46	0.453	7.01	4.37	0.676	710	1.10	1.74	26.9	2.88	44.6	6.17	0.83	95.5
26-28	27	6.67	0.464	6.95	4.47	0.669	732	1.10	1.99	29.8	2.86	42.9			
28-30	29	6.50	0.453	6.97	4.65	0.715	714	1.10	1.99	30.6	2.77	42.6	5.68	1.49	87.4
30-32	31	6.76	0.457	6.77	4.51	0.668	725	1.07	2.09	30.9	2.89	42.8	6.03	1.09	89.2
32-34	33	6.58	0.451	6.86	4.45	0.677	710	1.08	2.09	31.8	2.55	38.8	4.76	0.76	72.4
34-36	35	6.74	0.459	6.80	4.45	0.660	739	1.10	2.19	32.5	2.61	38.7			
36-38	37	6.93	0.471	6.79	4.51	0.650	757	1.09	2.19	31.6	2.56	36.9			
38-40	39	6.88	0.465	6.75	4.49	0.653	721	1.05	2.03	29.5	2.63	38.2			
40-42	41	7.05	0.479	6.79	4.62	0.655	736	1.04	2.21	31.3	2.75	39.0			
42-44	43	6.88	0.466	6.77	4.40	0.640	701	1.02	2.11	30.7	3.01	43.7			
44-46	45	7.03	0.465	6.62	4.38	0.624	705	1.00	2.02	28.7	2.87	40.8			
46-48	47	6.83	0.464	6.80	4.49	0.658	692	1.01	1.99	29.1	2.75	40.3	4.78	0.56	
48-50	49	6.16	0.452	7.34	4.38	0.711	711	1.15	1.96	31.8	2.60	42.2	5.21	0.37	84.6
50-52	51	6.19	0.452	7.29	4.35	0.703	709	1.15	1.77	28.6	2.63	42.5			
52-54	53	7.05	0.474	6.72	4.59	0.650	732	1.04	1.76	25.0	2.53	35.9			
54-56	55	6.98	0.467	6.69	4.48	0.642	722	1.03	1.96	28.1	2.34	33.5			
56-58	57	7.04	0.475	6.74	4.49	0.637	724	1.03	1.93	27.4	2.35	33.4			
58-60	59	6.76	0.467	6.91	4.43	0.656	715	1.06	2.00	29.6	2.33	34.5	9.01	2.37	133
60-62	61	6.61	0.450	6.80	4.33	0.655	677	1.02	2.17	32.8	2.52	38.1			
62-64	63	7.05	0.476	6.75	4.50	0.638	714	1.01	2.19	31.1	2.95	41.8	5.81	1.62	82.4
64-66	65	7.02	0.477	6.79	4.51	0.642	705	1.00	2.55	36.3	3.45	49.1	7.46	0.68	106
66-68	67	6.96	0.475	6.82	4.43	0.636	688	0.988	1.98	28.4	3.38	48.5	6.39	1.82	91.7
68-70	69	7.00	0.476	6.80	4.44	0.634	693	0.990	2.31	33.0	2.84	40.6	6.09	1.36	87.0
70-72	71	7.01	0.477	6.80	4.51	0.642	688	0.981	2.02	28.8	2.81	40.1			
72-74	73	6.37	0.432	6.78	4.10	0.643	587	0.920	2.33	36.6	3.09	48.5			
74-76	75	7.35	0.506	6.88	4.87	0.662	740	1.01	2.44	33.2	3.25	44.2			
76-78	77	6.61	0.448	6.78	4.28	0.648	635	0.961	2.48	37.5	3.05	46.2	7.71	2.00	117
78-80	79	6.69	0.459	6.86	4.36	0.651	634	0.948	2.40	35.9	3.15	47.1	5.92	1.39	88.5
80-82	81	6.89	0.474	6.88	4.51	0.654	642	0.933	2.54	36.9	3.38	49.1	6.79	0.71	98.6
82-84	83	6.73	0.462	6.86	4.31	0.640	624	0.926	2.34	34.7	3.18	47.2			
84-86	85	6.25	0.446	7.12	4.47	0.715	606	0.969	2.58	41.3	3.65	58.4	8.98	1.98	144
86-88	87	6.30	0.455	7.23	4.62	0.733	612	0.970	2.69	42.7	4.19	66.5	11.2	0.52	178
88-90	89	6.38	0.452	7.09	4.49	0.703	600	0.940	2.72	42.6	3.69	57.8			
90-92	91	6.37	0.456	7.17	4.66	0.732	606	0.951	2.79	43.8	3.90	61.3	11.8	1.79	185
92-94	93	6.35	0.454	7.15	4.57	0.720	595	0.937	2.64	41.6	4.17	65.7			
94-96	95	6.37	0.445	6.98	4.43	0.695	571	0.896	2.27	35.6	4.48	70.3	12.6	1.76	198
96-100	98	6.56	0.457	6.97	4.57	0.696	586	0.893	2.33	35.5	4.51	68.8	10.7	0.76	163
100-105	102.5	6.45	0.456	7.07	4.50	0.698	564	0.875	2.13	33.0	4.59	71.2	12.7	1.44	197
105-110	107.5	6.30	0.449	7.12	4.54	0.720	579	0.919	2.49	39.5	4.22	67.0	13.4	0.98	213
110-115	112.5	6.33	0.441	6.96	4.45	0.703	598	0.945	2.52	39.8	3.06	48.4			
115-120	117.5	6.51	0.450	6.92	4.59	0.706	641	0.984	2.97	45.6	3.51	53.9	12.3	1.75	189
120-125	122.5	6.29	0.436	6.94	4.46	0.710	617	0.981	3.71	59.0	3.08	49.0	8.78	0.88	140
125-130	127.5	6.23	0.426	6.83	4.27	0.686	613	0.984	4.13	66.3	2.65	42.5			
130-135	132.5	6.36	0.448	7.04	4.51	0.709	681	1.07	3.58	56.3	2.54	39.9	6.06	0.88	95.3
135-140	137.5	6.07	0.429	7.07	4.49	0.740	675	1.11	4.02	66.2	2.69	44.3	6.89	0.96	114
140-145	142.5	6.38	0.447	7.00	4.44	0.696	641	1.00	2.91	45.6	3.31	51.9			
145-150	147.5	6.39	0.446	6.97	4.42	0.692	632	0.990	3.25	50.9	3.37	52.7	9.75	1.07	153
150-155	152.5	6.35	0.437	6.89	4.30	0.677	623	0.981	3.19	50.3	3.04	47.9	7.25	0.02	114

Appendix B: Metal Data for Hood Canal Core HC-5

Core Segment	Mid-depth (cm)	Al (%)	Ti (%)	Ti/Al (x 10^2)	Fe (%)	Fe/Al	Mn (µg/g)	Mn/Al (x 10^2)	Mo (µg/g)	Mo/Al (x 10^6)	U (µg/g)	U/Al (x 10^6)	Re (ng/g)	Re SD	Re/Al (x 10^6)
155-160	157.5	6.08	0.420	6.91	4.28	0.704	605	1.00	4.20	69.1	3.09	50.8	10.4	1.36	171
160-165	162.5	6.09	0.421	6.92	4.27	0.702	619	1.02	4.46	73.3	2.88	47.3			
165-170	167.5	5.98	0.431	7.21	4.46	0.747	639	1.07	3.44	57.6	2.66	44.5	5.35	0.54	89.5
170-175	172.5	6.02	0.428	7.11	4.16	0.692	633	1.05	3.31	55.0	2.50	41.6			
175-180	177.5	6.13	0.437	7.13	4.42	0.720	650	1.06	2.94	47.9	2.42	39.5			
180-185	182.5	6.21	0.437	7.04	4.40	0.710	691	1.11	2.76	44.5	2.26	36.4	11.8	2.51	190
185-190	187.5	6.13	0.433	7.07	4.38	0.715	696	1.14	2.30	37.5	2.06	33.6	5.80	0.36	94.7
190-195	192.5	6.43	0.448	6.97	4.51	0.701	653	1.02	2.26	35.1	2.42	37.6			
195-200	197.5	6.41	0.447	6.97	4.35	0.678	638	1.00	2.24	34.9	2.55	39.8	5.4	1.35	73.6
200-205	202.5	6.43	0.447	6.96	4.33	0.673	640	1.00	2.76	42.9	2.80	43.6			
205-210	207.5	6.38	0.438	6.85	4.39	0.687	625	0.980	3.45	54.0	2.70	42.3			
210-215	212.5	6.31	0.427	6.76	4.29	0.681	655	1.04	3.82	60.6	2.46	39.0	7.65	2.19	121
215-220	217.5	6.56	0.440	6.71	4.28	0.652	722	1.10	2.65	40.4	1.97	30.0			
220-225	222.5	6.51	0.432	6.64	4.20	0.645	644	0.989	4.24	65.2	3.02	46.4	6.69		103
225-230	227.5	6.23	0.440	7.06	4.42	0.710	679	1.09	4.44	71.3	3.07	49.3			
230-235	232.5	6.01	0.430	7.15	4.40	0.732	666	1.11	4.13	68.7	3.17	52.7	16.4	2.12	273
235-240	237.5	5.95	0.437	7.35	4.48	0.753	718	1.21	3.03	50.9	2.28	38.3	5.01	1.04	84.1
240-245	242.5	5.99	0.439	7.33	4.57	0.762	777	1.30	3.41	56.9	2.31	38.5	3.64	1.06	60.7
245-250	247.5	5.77	0.429	7.44	4.40	0.762	783	1.36	2.69	46.6	2.23	38.6			
250-255	252.5	6.06	0.443	7.32	4.58	0.756	735	1.21	2.14	35.3	2.53	41.8			
255-260	257.5	5.94	0.446	7.51	4.60	0.776	714	1.20							
CV		5%	4%		3%		16%		32%		21%		40%		

Appendix B: Metal Data for Hood Canal Core HC-5

Core Segment	Mid-depth (cm)	Cd (µg/g)	Cd/Al ($x10^6$)	Pb (µg/g)	Pb/Al ($x10^4$)	As (µg/g)	Zn (µg/g)	Ni (µg/g)	V (µg/g)	Cr (µg/g)	Cu (µg/g)	Ba (µg/g)	Be (µg/g)	Ca (%)	Mg (%)	P (µg/g)	BSi as SiO_2 (%)	SD
0-2	1	0.281	4.48	16.6	2.65	10.9	98.6	47.0	139	85.2	46.8	369	1.02	1.42	1.76	993	12.0	0.15
2-4	3	0.275	4.40	16.1	2.58	8.47	99.4	46.7	140	84.7	47.1	360	1.05	1.37	1.73			
4-6	5	0.269	4.17	17.1	2.65	9.25	103	48.0	144	86.4	49.4	380	1.05	1.48	1.76			
6-8	7	0.275	4.22	15.6	2.40	8.31	103	48.2	144	87.1	48.8	369	1.07	1.45	1.75	771		
8-10	9	0.286	4.36	17.8	2.71	9.14	104	48.4	145	87.3	49.5	376	1.07	1.43	1.77			
10-12	11	0.249	3.92	18.0	2.83	8.90	102	47.7	142	85.6	48.2	369	1.07	1.41	1.74	747		
12-14	13	0.246	3.66	18.3	2.72	9.51	105	49.0	145	88.1	49.3	378	1.11	1.45	1.77	773		
14-16	15	0.262	3.96	18.2	2.75	8.81	106	49.6	148	89.3	50.6	377	1.10	1.43	1.78	672		
16-18	17	0.282	4.29	19.1	2.91	9.31	105	48.5	146	87.5	50.0	375	1.12	1.43	1.76			
18-20	19	0.277	4.15	19.5	2.92	8.87	106	48.9	145	87.8	49.3	367	1.12	1.41	1.77			
20-22	21	0.282	4.23	20.8	3.12	10.4	111	50.3	147	90.4	51.1	383	1.12	1.42	1.78	659		
22-24	23	0.314	4.65	22.6	3.34	11.2	115	51.0	151	91.3	52.0	385	1.14	1.46	1.82	657	11.5	0.02
24-26	25	0.283	4.38	21.6	3.34	9.41	109	48.6	142	86.2	49.0	369	1.07	1.39	1.74	673		
26-28	27	0.277	4.15	22.9	3.43	9.92	114	50.0	146	89.4	51.2	373	1.13	1.38	1.76			
28-30	29	0.282	4.34	22.8	3.51	11.8	115	49.6	142	86.5	50.1	380	1.10	1.43	1.75			
30-32	31	0.295	4.36	23.8	3.52	12.1	117	50.1	145	87.9	50.5	370	1.13	1.39	1.78	611		
32-34	33	0.289	4.39	23.2	3.53	11.8	116	49.2	143	87.8	50.1	370	1.13	1.39	1.75			
34-36	35	0.275	4.08	23.6	3.50	11.4	115	49.1	143	87.6	49.6	385	1.15	1.36	1.74			
36-38	37	0.283	4.08	22.6	3.26	11.3	118	51.3	148	90.1	50.9	394	1.16	1.41	1.83	605		
38-40	39	0.270	3.92	21.3	3.10	11.2	115	50.1	144	88.0	49.5	387	1.17	1.40	1.81	662		
40-42	41	0.287	4.07	21.5	3.05	11.7	115	51.4	148	91.0	50.6	396	1.22	1.43	1.81			
42-44	43	0.306	4.45	20.8	3.02	11.6	109	49.4	143	88.6	47.7	388	1.19	1.38	1.77	639		
44-46	45	0.283	4.03	20.0	2.85	10.6	109	50.0	144	89.9	47.7	394	1.21	1.36	1.76			
46-48	47	0.275	4.03	18.5	2.71	10.2	108	49.6	143	88.6	47.1	383	1.20	1.36	1.75	660	9.90	0.08
48-50	49	0.273	4.43	18.7	3.04	9.78	105	47.2	138	84.1	46.1	341	1.31	1.37	1.73			
50-52	51	0.277	4.47	18.7	3.02	10.1	105	47.9	141	85.0	46.5	347	1.30	1.37	1.75	651		
52-54	53	0.236	3.35	17.0	2.41	10.6	102	50.1	146	88.7	46.5	391	1.22	1.38	1.79	627		
54-56	55	0.236	3.38	16.3	2.33	10.5	102	50.3	144	87.6	46.4	384	1.23	1.38	1.78	649		
56-58	57	0.288	4.09	16.9	2.40	9.42	102	50.3	147	90.1	46.6	385	1.27	1.52	1.78			
58-60	59	0.260	3.85	15.6	2.31	8.70	100	49.2	143	86.9	46.7	370	1.22	1.36	1.80			
60-62	61	0.281	4.25	16.2	2.45	8.85	94.6	48.2	139	83.9	44.1	359	1.17	1.33	1.74	635		
62-64	63	0.324	4.60	14.4	2.04	10.6	97.6	50.8	148	89.3	47.2	384	1.28	1.48	1.82			
64-66	65	0.389	5.54	15.5	2.21	12.0	95.9	50.5	149	89.1	46.6	383	1.26	1.39	1.82	663		
66-68	67	0.364	5.23	14.3	2.05	11.7	94.4	50.3	148	87.9	46.1	382	1.26	1.38	1.81	651		
68-70	69	0.345	4.93	13.0	1.86	10.9	93.7	50.3	147	89.7	45.6	384	1.24	1.42	1.81			
70-72	71	0.311	4.43	12.4	1.77	9.47	92.9	50.4	146	89.8	44.6	381	1.26	1.39	1.79	659		
72-74	73	0.326	5.12	12.3	1.93	9.84	84.6	47.6	134	83.8	39.9	335	2.96	1.34	1.65	655		
74-76	75	0.334	4.54	13.0	1.77	10.9	98.5	54.0	155	94.5	47.5	402	1.29	1.49	1.96	670		
76-78	77	0.334	5.06	11.2	1.70	9.83	87.3	48.4	139	84.8	41.3	356	1.16	1.33	1.74			
78-80	79	0.335	5.01	10.4	1.56	10.3	89.1	49.2	141	87.3	41.3	363	1.17	1.37	1.76	638	12.9	0.14
80-82	81	0.358	5.20	10.6	1.54	11.4	90.3	50.4	144	90.3	41.8	371	1.21	1.42	1.81	617		
82-84	83	0.340	5.05	10.1	1.50	9.33	88.9	49.5	140	87.5	41.0	366	1.17	1.53	1.77			
84-86	85	0.381	6.09	10.3	1.65	9.42	92.6	47.5	140	86.1	42.1	378	1.08	1.45	1.70			
86-88	87	0.398	6.32	10.7	1.70	10.2	89.5	47.6	141	86.2	42.6	379	1.11	1.48	1.70	607		
88-90	89	0.384	6.02	10.3	1.61	9.40	88.7	47.4	141	86.2	42.0	378	1.14	1.44	1.71	623	13.4	0.25
90-92	91	0.394	6.19	10.4	1.63	9.79	90.4	47.7	143	87.0	43.1	383	1.11	1.47	1.72	661		
92-94	93	0.392	6.17	10.2	1.61	9.93	89.7	48.0	142	86.3	42.8	379	1.11	1.45	1.72			
94-96	95	0.425	6.67	10.6	1.66	9.47	89.3	47.4	141	85.3	41.8	376	1.12	1.41	1.70	649		
96-100	98	0.442	6.74	10.7	1.63	10.2	91.9	49.1	145	87.8	42.5	391	1.16	1.46	1.72			
100-105	102.5	0.480	7.45	11.0	1.71	8.68	93.5	48.7	145	88.0	43.3	392	1.14	1.45	1.70	626	12.6	0.00
105-110	107.5	0.408	6.47	10.4	1.65	10.1	91.3	48.1	141	87.9	42.3	385	1.12	1.43	1.69			
110-115	112.5	0.343	5.42	10.2	1.61	9.04	89.3	47.0	137	85.3	41.0	371	1.14	1.42	1.69	620		
115-120	117.5	0.373	5.73	13.4	2.06	10.5	98.0	48.8	143	87.1	44.2	389	1.15	1.45	1.74	666	13.8	0.17
120-125	122.5	0.363	5.77	10.3	1.64	9.38	90.2	47.5	139	85.2	39.5	378	1.15	1.44	1.70	639		
125-130	127.5	0.343	5.51	9.83	1.58	8.10	86.2	45.6	133	81.5	38.4	362	1.11	1.40	1.68	638	13.5	0.13
130-135	132.5	0.346	5.44	10.3	1.62	8.97	90.2	49.4	142	87.4	42.3	374	1.14	1.46	1.74	625		
135-140	137.5	0.346	5.70	9.76	1.61	8.28	83.6	45.3	135	81.5	40.3	363	1.13	1.47	1.67			
140-145	142.5	0.409	6.41	10.1	1.58	9.98	89.5	48.8	140	89.0	40.4	367	1.12	1.46	1.73	652	13.4	0.22
145-150	147.5	0.392	6.14	10.1	1.58	8.57	89.1	47.5	139	86.9	40.0	375	1.16	1.51	1.74			
150-155	152.5	0.370	5.83	9.74	1.53	8.37	87.5	47.4	136	85.4	38.8	366	1.15	1.47	1.75			

Appendix B: Metal Data for Hood Canal Core HC-5

Core Segment	Mid-depth (cm)	Cd (µg/g)	Cd/Al ($x10^6$)	Pb (µg/g)	Pb/Al ($x10^4$)	As (µg/g)	Zn (µg/g)	Ni (µg/g)	V (µg/g)	Cr (µg/g)	Cu (µg/g)	Ba (µg/g)	Be (µg/g)	Ca (%)	Mg (%)	P (µg/g)	BSi as SiO_2 (%)	SD
155-160	157.5	0.428	7.04	9.74	1.60	9.06	85.0	46.5	133	82.6	37.7	350	1.12	1.50	1.70	599	14.7	0.28
160-165	162.5	0.360	5.91	9.50	1.56	8.48	83.8	46.0	133	83.1	38.0	358	1.13	1.43	1.71	626	15.6	0.26
165-170	167.5	0.334	5.59	9.37	1.57	8.24	86.4	46.5	133	84.5	39.0	349	1.12	1.46	1.74	585	15.0	0.07
170-175	172.5	0.334	5.55	9.34	1.55	7.05	84.3	45.8	132	84.4	38.0	334	1.18	1.39	1.73	660		
175-180	177.5	0.355	5.79	9.72	1.58	7.50	88.5	47.4	134	84.6	39.9	354	1.14	1.46	1.73			
180-185	182.5	0.339	5.46	9.74	1.57	7.11	89.0	47.7	138	86.0	40.0	352	1.16	1.44	1.75			
185-190	187.5	0.278	4.54	9.55	1.56	6.94	87.0	47.3	135	83.8	39.1	348	1.14	1.42	1.73			
190-195	192.5	0.305	4.74	9.95	1.55	8.89	89.6	48.2	138	85.6	40.9	370	1.22	1.44	1.78			
195-200	197.5	0.301	4.69	9.62	1.50	8.84	89.3	48.1	140	87.2	40.9	356	1.19	1.66	1.79	618	12.4	0.27
200-205	202.5	0.335	5.21	9.95	1.55	9.62	88.2	48.1	136	85.5	40.1	348	1.18	1.44	1.79			
205-210	207.5	0.333	5.22	9.71	1.52	10.0	88.3	48.0	133	83.4	38.9	357	1.16	1.48	1.76			
210-215	212.5	0.319	5.06	9.83	1.56	10.8	85.7	46.7	130	82.4	37.7	349	1.21	1.41	1.72	636	14.5	0.33
215-220	217.5	0.253	3.86	9.22	1.41	5.74	87.8	46.9	133	84.2	37.8	359	1.26	1.39	1.74	625	14.3	0.58
220-225	222.5	0.373	5.73	10.4	1.60	9.32	86.4	47.6	135	86.9	37.3	358	1.22	1.42	1.71	591	14.5	0.52
225-230	227.5	0.387	6.21	9.91	1.59	9.09	90.7	49.6	137	86.9	40.5	348	1.18	1.48	1.73	620	14.5	0.23
230-235	232.5	0.473	7.87	10.2	1.70	8.69	87.6	48.4	135	86.4	39.6	347	1.12	1.45	1.70	613	14.5	0.07
235-240	237.5	0.278	4.67	9.22	1.55	6.78	88.3	48.2	132	86.6	39.4	356	1.12	1.50	1.73			
240-245	242.5	0.251	4.19	9.51	1.59	7.44	89.5	48.5	134	84.7	41.0	345	1.12	1.46	1.76			
245-250	247.5	0.246	4.26	9.31	1.61	7.49	87.3	47.6	132	82.3	39.8	331	1.14	1.41	1.73			
250-255	252.5	0.314	5.18	9.88	1.63	9.05	90.4	48.8	136	85.7	41.2	357	1.12	1.48	1.77	600		
255-260	257.5						89.9	49.3	137	85.4	41.9	346	1.14	1.47	1.80			
CV		17%		34%		14%	10%	3%	4%	3%	10%	4%	18%	4%	3%	3%	3%	

Appendix B: Metal Data for Hood Canal Core HC-4

Core Segment	Mid-depth (cm)	Al (%)	Ti (%)	Ti/Al (x 10^2)	Fe (%)	Fe/Al	Mn (µg/g)	Mn/Al (x 10^2)	Mo (µg/g)	Mo/Al (x 10^6)	U (µg/g)	U/Al (x 10^6)	Re (ng/g)	Re SD	Re/Al (x 10^6)
0-2	1	5.67	0.494	8.72	5.01	0.884	6174	10.9	1.83	32.3	1.58	27.9			
10-12	11	6.37	0.548	8.59	5.50	0.862	2463	3.86	2.52	39.5	2.58	40.5			
20-22	21	6.38	0.547	8.57	5.53	0.867	2657	4.16	7.54	118	3.48	54.5	4.27	0.41	66.9
30-32	31	6.22	0.528	8.49	5.34	0.858	2537	4.08	4.30	69.2	3.24	52.1	6.74	1.35	108
40-42	41	6.54	0.556	8.49	5.49	0.839	2323	3.55	3.93	60.1	3.32	50.7	6.11	0.27	93.4
50-55	52.5	6.58	0.560	8.52	5.54	0.843	2334	3.55	4.22	64.2	3.14	47.7	3.31	0.94	50.3
60-65	62.5	6.62	0.562	8.50	5.58	0.844	2025	3.06	4.01	60.6	2.85	43.1	5.87	1.71	88.7
80-85	82.5	6.50	0.541	8.33	5.39	0.829	2086	3.21	3.15	48.4	2.82	43.4			
90-95	92.5	6.54	0.546	8.34	5.40	0.826	2066	3.16	2.63	40.2	3.32	50.7			
100-105	102.5	6.64	0.556	8.37	5.58	0.841	2817	4.24	2.79	42.0	3.60	54.2	7.93	0.99	119
105-110	107.5	6.55	0.553	8.44	5.50	0.840	2589	3.95	2.72	41.5	4.04	61.7	8.80	2.38	134
110-115	112.5	6.50	0.546	8.40	5.44	0.838	2262	3.48	2.68	41.2	3.52	54.2	7.24	1.58	111
115-120	117.5	6.47	0.540	8.35	5.37	0.831	2374	3.67	2.64	40.8	3.51	54.3	7.36	2.19	114
120-125	122.5	6.53	0.546	8.37	5.45	0.835	2893	4.43	3.09	47.3	3.48	53.3			
125-130	127.5	6.60	0.546	8.27	5.45	0.826	2696	4.08	3.39	51.4	3.03	45.9			
130-135	132.5	6.82	0.568	8.33	5.49	0.805	1853	2.72	1.96	28.8	3.38	49.6	6.00	0.47	88.0
135-140	137.5	6.72	0.576	8.57	5.60	0.833	1785	2.66	2.05	30.5	3.30	49.1			
140-145	142.5	6.73	0.581	8.64	5.63	0.837	1716	2.55	2.49	37.0	4.26	63.3	9.03	1.20	134
145-150	147.5	6.59	0.558	8.46	5.56	0.843	1895	2.87	3.10	47.0	3.96	60.0	10.2	0.74	155
150-155	152.5	6.66	0.557	8.36	5.49	0.823	1795	2.69	3.68	55.2	3.75	56.3	8.07	0.27	121
155-160	157.5	6.66	0.554	8.32	5.46	0.820	1831	2.75	3.90	58.6	3.88	58.3	8.94	1.03	134
160-165	162.5	6.71	0.554	8.26	5.47	0.815	1829	2.72	3.89	58.0	4.22	62.9	11.3	3.40	168
165-170	167.5	6.59	0.543	8.25	5.42	0.823	1944	2.95	4.75	72.1	4.25	64.5	7.62	1.74	116
170-175	172.5	6.42	0.530	8.26	5.26	0.819	1822	2.84	4.91	76.5	4.42	68.8	13.3	2.22	207
175-180	177.5	6.41	0.526	8.21	5.22	0.815	2082	3.25	4.96	77.4	4.09	63.8	10.7	3.15	167
180-185	182.5	6.54	0.541	8.27	5.39	0.823	2575	3.93	5.56	85.0	3.60	55.0	4.22	0.97	64.5
200-205	202.5	6.77	0.557	8.23	5.49	0.811	2306	3.41	2.42	35.8	3.54	52.3	7.23	0.09	107
205-210	207.5	6.89	0.565	8.20	5.58	0.809	2383	3.46	2.55	37.0	3.60	52.2	8.58	1.60	124
210-215	212.5	6.78	0.558	8.23	5.51	0.812	2217	3.27	2.73	40.3	3.69	54.4			
215-220	217.5	6.68	0.551	8.25	5.48	0.821	2584	3.87	3.73	55.9	3.75	56.2	8.69	1.74	130
220-225	222.5	6.56	0.538	8.20	5.40	0.824	2851	4.35	5.00	76.3	3.49	53.2	7.65	1.42	117
230-235	232.5	6.72	0.557	8.30	5.52	0.822	2392	3.56	4.17	62.1	3.03	45.1	6.10	0.40	90.8
235-240	237.5	6.67	0.560	8.40	5.55	0.832	2183	3.27	5.80	86.9	3.26	48.9			
240-245	242.5	6.79	0.571	8.41	5.62	0.829	2107	3.10	4.51	66.4	4.07	60.0			
245-250	247.5	6.71	0.562	8.38	5.55	0.827	2216	3.30	4.66	69.4	4.22	62.9	9.17	2.25	137
250-255	252.5	6.47	0.539	8.34	5.36	0.829	2328	3.60	4.68	72.4	4.25	65.7	13.2	3.38	204
CV		3%	3%		2%		31%		34%		16%		31%		

Appendix B: Metal Data for Hood Canal Core HC-4

Core Segment	Mid-depth (cm)	Cd (µg/g)	Cd/Al ($x10^6$)	Pb (µg/g)	Pb/Al ($x10^4$)	As (µg/g)	Zn (µg/g)	Ni (µg/g)	V (µg/g)	Cr (µg/g)	Cu (µg/g)	Ba (µg/g)	Be (µg/g)	Ca (%)	Mg (%)
0-2	1	0.403	7.11	12.7	2.24	9.83	107	53.4	173	86.9	72.8	253	0.934	1.94	2.39
10-12	11	0.446	7.00	17.8	2.79	5.74	125	58.9	190	96.0	79.5	282	1.08	1.98	2.41
20-22	21	0.452	7.08	18.7	2.93	10.5	128	59.6	187	97.1	78.7	283	1.13	1.94	2.35
30-32	31	0.451	7.25	16.0	2.57	11.0	115	56.8	178	93.3	74.4	280	1.08	2.13	2.30
40-42	41	0.537	8.21	13.7	2.09	10.9	112	59.9	190	98.1	75.7	299	1.12	1.94	2.32
50-55	52.5	0.528	8.03	10.6	1.61	9.96	99.0	60.6	187	98.5	74.4	297	1.16	2.09	2.39
60-65	62.5	0.623	9.41	9.91	1.50	9.82	95.4	59.2	185	98.3	70.8	298	1.10	2.00	2.40
80-85	82.5	0.562	8.64	8.06	1.24	8.57	94.2	58.8	180	96.5	68.9	302	1.11	1.92	2.37
90-95	92.5	0.623	9.52	8.21	1.25	8.54	95.0	58.6	181	96.9	69.2	303	1.16	1.94	2.34
100-105	102.5	0.619	9.32	8.73	1.31	9.94	95.1	59.9	188	98.2	71.3	305	1.16	1.97	2.35
105-110	107.5	0.656	10.0	8.15	1.24	10.8	96.6	60.5	189	98.0	69.8	301	1.12	1.95	2.39
110-115	112.5	0.589	9.07	8.23	1.27	10.5	94.7	59.0	180	96.3	67.7	294	1.16	1.90	2.36
115-120	117.5	0.515	7.96	8.41	1.30	9.50	94.2	59.1	177	96.1	66.5	294	1.13	1.89	2.36
120-125	122.5	0.611	9.36	8.09	1.24	10.7	94.4	59.7	178	96.0	66.7	294	1.16	1.93	2.38
125-130	127.5	0.532	8.06	7.97	1.21	10.0	94.1	59.2	179	94.3	66.5	298	1.15	1.86	2.31
130-135	132.5	0.681	9.99	8.34	1.22	8.15	97.7	60.9	189	97.7	70.2	306	1.19	1.89	2.39
135-140	137.5	0.617	9.18	8.14	1.21	9.04	96.1	60.7	187	98.7	70.6	300	1.21	1.96	2.40
140-145	142.5	0.507	7.54	8.04	1.19	10.4	95.2	61.1	188	98.9	73.1	296	1.20	2.02	2.38
145-150	147.5	0.587	8.90	7.92	1.20	11.0	95.8	61.1	186	95.7	71.1	294	1.18	1.99	2.37
150-155	152.5	0.654	9.81	8.14	1.22	9.25	95.2	60.4	184	95.7	69.2	302	1.20	2.06	2.36
155-160	157.5	0.666	10.0	7.93	1.19	8.23	97.8	60.6	182	95.6	68.8	298	1.20	2.10	2.37
160-165	162.5	0.701	10.4	8.04	1.20	10.1	98.6	60.2	180	92.7	66.8	299	1.17	1.89	2.37
165-170	167.5	0.600	9.11	7.91	1.20	10.3	91.2	59.0	178	91.9	67.2	294	1.13	1.88	2.34
170-175	172.5	0.685	10.7	7.76	1.21	9.20	91.1	58.9	177	91.3	67.1	290	1.15	1.95	2.28
175-180	177.5	0.756	11.8	7.67	1.20	8.98	90.3	58.0	176	91.5	65.4	292	1.13	2.11	2.34
180-185	182.5	0.611	9.34	7.92	1.21	8.42	92.7	60.0	179	92.3	67.4	295	1.16	1.89	2.37
200-205	202.5	0.612	9.05	8.09	1.20	8.68	95.2	61.5	188	96.1	71.0	311	1.19	1.88	2.41
205-210	207.5	0.583	8.46	8.22	1.19	9.52	96.4	62.0	187	95.9	70.8	317	1.17	1.94	2.46
210-215	212.5	0.527	7.78	8.12	1.20	9.79	94.4	60.7	183	94.6	69.0	310	1.21	1.89	2.39
215-220	217.5	0.606	9.08	7.99	1.20	11.8	93.6	60.2	180	92.6	68.9	304	1.14	1.90	2.37
220-225	222.5	0.536	8.18	7.92	1.21	10.5	93.1	59.4	177	90.7	66.8	297	1.16	1.89	2.34
230-235	232.5	0.560	8.34	8.03	1.20	8.93	94.2	60.7	186	95.4	70.1	301	1.19	1.85	2.42
235-240	237.5	0.675	10.1	7.93	1.19	9.43	93.9	61.0	186	95.0	70.4	295	1.14	1.96	2.44
240-245	242.5	0.643	9.47	8.11	1.19	9.09	96.5	62.5	191	98.2	72.4	298	1.20	1.96	2.48
245-250	247.5	0.667	9.94	8.00	1.19	9.02	96.2	61.3	186	96.3	71.0	296	1.19	1.97	2.41
250-255	252.5	0.706	10.9	7.30	1.13	9.95	90.1	59.7	180	91.9	69.2	288	1.13	3.13	2.36
CV		14%		31%		12%	9%	3%	3%	3%	5%	4%	4%	11%	2%

Appendix B: Metal Data for Hood Canal Core HC-1

Core Segment	Mid-depth (cm)	Al (%)	Ti (%)	Ti/Al (x 10^2)	Fe (%)	Fe/Al	Mn (µg/g)	Mn/Al (x 10^2)	Mo (µg/g)	Mo/Al (x 10^6)	U (µg/g)	U/Al (x 10^6)	Re (ng/g)	Re SD	Re/Al (x 10^6)
0-2	1	6.37	0.855	13.41	6.75	1.059	942	1.5	0.874	13.7	1.63	25.6			
6-8	7	6.47	0.856	13.24	6.79	1.050	946	1.46	1.45	22.4	1.69	26.1	3.90	1.13	60.3
10-12	11	6.49	0.858	13.21	6.84	1.053	942	1.45	1.46	22	1.80	27.7			
16-18	17	6.48	0.851	13.13	6.75	1.042	945	1.46	1.12	17.3	1.78	27.5			
20-22	21	6.58	0.862	13.11	6.79	1.032	956	1.45	0.96	14.6	1.73	26.3			
26-28	27	6.56	0.866	13.20	6.77	1.033	953	1.45	0.896	13.7	1.65	25.2			
30-32	31	6.39	0.835	13.07	6.65	1.041	923	1.44	1.08	16.9	1.69	26.4			
36-38	37	6.44	0.850	13.20	6.72	1.044	941	1.46	0.860	13.4	1.80	27.9			
40-42	41	6.44	0.841	13.06	6.65	1.032	933	1.45	0.965	15.0	1.83	28.4	9.18	1.68	143
44-46	45	6.51	0.852	13.10	6.70	1.030	938	1.44	0.920	14.1	1.73	26.6			
50-55	51	6.53	0.857	13.12	6.71	1.028	947	1.45	0.998	15.3	1.69	25.9	5.39	0.81	83
60-65	62.5	6.51	0.846	13.00	6.66	1.024	947	1.46	0.954	14.7	1.70	26.1			
70-75	72.5	6.52	0.845	12.96	6.71	1.029	945	1.45	1.14	17.5	1.79	27.5	7.54	1.83	116
80-85	82.5	6.51	0.841	12.91	6.66	1.023	937	1.44	0.944	14.5	1.97	30.2			
90-95	92.5	6.55	0.851	12.99	6.80	1.038	951	1.45	1.23	18.8	2.08	31.8	6.86	1.06	105
100-105	102.5	6.49	0.850	13.10	6.75	1.040	942	1.45	1.18	18.2	2.40	37.0	10.6	1.43	163
110-115	112.5	6.69	0.863	12.90	6.92	1.034	967	1.44	1.20	17.9	1.83	27.3			
120-125	122.5	6.64	0.862	12.99	6.79	1.023	960	1.45	0.960	14.5	1.77	26.7			
130-135	132.5	6.57	0.850	12.95	6.69	1.019	941	1.43	0.922	14.0	1.83	27.9	6.98	2.05	106
140-145	142.5	6.45	0.825	12.79	6.56	1.017	913	1.42	1.30	20.2	1.75	27.1			
150-155	152.5	6.64	0.844	12.71	6.61	0.996	926	1.39	1.33	20.0	2.15	32.4	5.16	0.53	78
160-165	162.5	6.55	0.840	12.83	6.63	1.012	917	1.40	1.01	15.4	1.89	28.9	3.69	1.29	56
170-175	172.5	6.57	0.846	12.87	6.72	1.022	923	1.40	1.11	16.9	1.78	27.1	5.73	0.46	87
180-185	182.5	6.47	0.837	12.94	6.58	1.018	905	1.40	0.886	13.7	1.78	27.5	5.43	0.38	84
190-195	192.5	6.64	0.853	12.85	6.80	1.024	923	1.39	0.997	15.0	1.90	28.6			
200-205	202.5	6.55	0.840	12.82	6.58	1.005	906	1.38	0.929	14.2	1.80	27.5			
CV		1%	1%		1%		2%		16%		9%		33%		

Appendix B: Metal Data for Hood Canal Core HC-1

Core Segment	Mid-depth (cm)	Cd (µg/g)	Cd/Al ($x10^6$)	Pb (µg/g)	Pb/Al ($x10^4$)	As (µg/g)	Zn (µg/g)	Ni (µg/g)	V (µg/g)	Cr (µg/g)	Cu (µg/g)	Ba (µg/g)	Be (µg/g)	Ca (%)	Mg (%)
0-2	1	0.406	6.4	5.41	0.849	10.5	92.6	66.8	256	177	108	167	0.789	4.53	2.99
6-8	7	0.326	5.0	5.43	0.839	11.5	94.4	68.3	261	180	109	171	0.828	4.56	3.01
10-12	11	0.337	5.2	5.47	0.842	11.2	95.3	68.5	262	180	111	170	0.787	4.56	3.01
16-18	17	0.309	4.8	5.49	0.847	10.6	92.3	67.8	259	182	105	171	0.804	4.64	3.03
20-22	21	0.321	4.9	5.31	0.807	11.2	93.2	68.6	262	184	106	172	0.834	4.63	3.06
26-28	27	0.318	4.8	5.12	0.781	10.3	91.9	67.9	262	185	105	173	0.821	4.71	3.05
30-32	31	0.301	4.7	5.45	0.853	11.5	90.4	66.6	256	179	104	170	0.811	4.83	2.96
36-38	37	0.296	4.6	5.36	0.832	11.0	90.2	67.2	261	182	104	175	0.798	4.67	3.02
40-42	41	0.291	4.5	5.14	0.798	10.4	88.6	66.5	258	182	103	173	0.807	4.63	3.00
44-46	45	0.319	4.9	4.79	0.736	10.3	88.7	67.0	260	186	102	174	0.811	4.69	3.01
50-55	51	0.338	5.2	4.71	0.721	11.2	90.4	67.7	263	185	103	178	0.814	4.74	3.01
60-65	62.5	0.356	5.5	4.58	0.704	10.7	85.9	66.5	258	190	99.6	173	0.800	4.85	3.03
70-75	72.5	0.463	7.1	3.95	0.606	10.8	85.1	67.2	259	185	99.3	179	0.790	4.72	3.01
80-85	82.5	0.398	6.1	4.27	0.656	10.2	86.8	67.0	259	185	102	177	0.856	4.86	2.97
90-95	92.5	0.366	5.6	4.00	0.611	10.6	87.0	66.8	261	184	105	182	0.811	4.75	3.02
100-105	102.5	0.415	6.4	4.07	0.627	9.91	88.0	67.9	264	184	107	180	0.773	4.66	3.02
110-115	112.5	0.348	5.2	4.18	0.624	10.6	86.6	69.4	267	179	113	186	0.842	4.59	3.05
120-125	122.5	0.339	5.1	4.01	0.604	8.89	84.5	68.1	268	184	108	182	0.817	4.73	3.06
130-135	132.5	0.410	6.2	4.23	0.644	9.69	85.6	67.6	258	179	104	184	0.828	4.68	3.03
140-145	142.5	0.387	6.0	3.86	0.598	10.4	82.5	65.9	253	178	97.2	179	0.805	4.73	2.96
150-155	152.5	0.378	5.7	3.74	0.563	10.5	82.8	66.4	254	181	95.1	185	0.826	4.60	3.00
160-165	162.5	0.371	5.7	4.07	0.622	8.88	83.9	66.7	256	180	101	186	0.790	4.52	2.98
170-175	172.5	0.320	4.9	3.89	0.592	9.41	84.5	67.2	260	177	104	184	0.798	4.50	2.99
180-185	182.5	0.327	5.1	3.72	0.575	8.54	81.7	65.4	254	181	97.3	182	0.781	4.96	2.96
190-195	192.5	0.334	5.0	4.04	0.608	9.19	84.3	66.8	261	177	106	186	0.803	4.49	3.00
200-205	202.5	0.339	5.2	4.08	0.623	7.65	81.3	66.2	256	178	101	190	0.827	4.74	2.92
CV		12%		14%		9%	5%	1%	1%	2%	4%	4%	2%	3%	1%

Appendix B: Metal Data for Puget Sound Core PS-4

Core Segment	Mid-depth (cm)	Al (%)	Ti (%)	Ti/Al (x 10^2)	Fe (%)	Fe/Al	Mn (µg/g)	Mn/Al (x 10^2)	Mo (µg/g)	Mo/Al (x 10^6)	U (µg/g)	U/Al (x 10^6)	Re (ng/g)	Re SD	Re/Al (x 10^6)
0-2	1	5.92	0.379	6.40	0.601	3.56	563	0.950	0.994	16.8	1.73	29.2			
2-4	3	6.00	0.383	6.39	0.606	3.63	555	0.925	1.10	18.3	1.80	30.0			
6-8	7	5.57	0.366	6.57	0.605	3.37	599	1.07	1.10	19.7	1.63	29.3			
8-10	9	6.13	0.393	6.41	0.614	3.76	621	1.01	1.23	20.1	1.78	29.0			
10-12	11	6.17	0.395	6.41	0.610	3.76	656	1.06	1.17	19.0	1.81	29.3			
12-14	13	6.18	0.397	6.43	0.607	3.75	653	1.06	1.13	18.3	1.82	29.5			
14-16	15	6.25	0.405	6.48	0.614	3.83	644	1.03	1.18	18.9	1.82	29.1			
16-18	17	6.22	0.403	6.49	0.612	3.80	590	0.950	1.37	22.0	1.85	29.8	6.68	1.32	107
18-20	19	6.13	0.396	6.47	0.612	3.75	551	0.898	1.42	23.2	1.95	31.8			
20-22	21	6.25	0.402	6.42	0.602	3.76	552	0.883	1.47	23.5	2.02	32.3			
22-24	23	6.25	0.400	6.40	0.606	3.78	545	0.873	1.74	27.9	2.12	33.9			
24-26	25	6.27	0.403	6.42	0.605	3.79	541	0.864	1.77	28.2	2.08	33.2			
26-28	27	6.22	0.399	6.41	0.608	3.78	528	0.848	1.53	24.6	2.01	32.3	6.00	0.97	96.4
28-30	29	6.13	0.392	6.39	0.606	3.72	513	0.836	1.46	23.8	2.02	32.9			
30-32	31	6.28	0.406	6.46	0.604	3.79	524	0.835	1.40	22.3	1.96	31.2			
32-34	33	6.22	0.400	6.42	0.599	3.73	505	0.811	1.55	24.9	2.00	32.1			
34-36	35	6.24	0.402	6.45	0.603	3.76	495	0.794	1.47	23.6	1.90	30.4			
36-38	37	6.20	0.401	6.47	0.604	3.74	486	0.784	1.21	19.5	1.85	29.9			
38-40	39	6.23	0.405	6.49	0.603	3.76	486	0.780	1.25	20.1	1.93	31.0			
40-42	41	6.29	0.404	6.43	0.616	3.87	492	0.782	1.34	21.3	1.88	29.9			
42-44	43	6.19	0.398	6.43	0.615	3.81	482	0.777	1.38	22.3	1.8	29.1			
44-46	45	6.45	0.413	6.40	0.610	3.94	502	0.778	1.37	21.2	1.91	29.6			
46-48	47	6.33	0.406	6.42	0.618	3.91	495	0.782	1.48	23.4	1.96	31.0	3.46	0.62	54.7
48-50	49	6.31	0.405	6.42	0.603	3.80	486	0.770	1.52	24.1	1.94	30.7	4.13	1.28	65.4
50-55	52.5	6.47	0.420	6.49	0.606	3.92	495	0.765	1.64	25.3	2.10	32.5	5.74	0.58	88.7
55-60	57.5	6.38	0.415	6.50	0.610	3.89	489	0.766	1.50	23.5	1.91	29.9	4.28	1.28	56.9
60-65	62.5	6.43	0.418	6.50	0.609	3.91	474	0.736	1.45	22.5	2.00	31.1			
65-70	67.5	6.25	0.406	6.49	0.610	3.82	460	0.736	1.47	23.5	1.96	31.3	4.57	1.16	73.1
70-75	72.5	6.43	0.414	6.44	0.596	3.83	463	0.721	1.43	22.2	1.99	31.0			
75-80	77.5	6.40	0.412	6.44	0.610	3.90	468	0.732	1.45	22.7	2.06	32.2			
80-85	82.5	6.45	0.416	6.45	0.622	4.01	477	0.740	1.96	30.4	2.10	32.6			
85-90	87.5	6.37	0.412	6.46	0.634	4.04	477	0.748	1.94	30.4	2.03	31.9	6.29	1.06	98.7
90-95	92.5	6.40	0.415	6.49	0.630	4.03	481	0.752	1.86	29.1	2.10	32.8			
95-100	97.5	6.31	0.412	6.53	0.637	4.02	472	0.748	1.84	29.2	2.14	33.9			
100-105	102.5	6.46	0.421	6.52	0.611	3.95	483	0.748	1.26	19.5	2.04	31.6	4.74	0.82	73.4
105-110	107.5	6.46	0.423	6.54	0.624	4.03	499	0.773	1.72	26.6	2.19	33.9			
110-115	112.5	6.51	0.425	6.52	0.629	4.10	501	0.768	1.53	23.5	2.06	31.6			
115-120	117.5	6.64	0.432	6.51	0.621	4.12	504	0.758	1.59	23.9	2.09	31.5			
120-125	122.5	6.53	0.427	6.54	0.612	4.00	496	0.759	1.54	23.6	2.09	32.0	6.69	0.56	102
125-130	127.5	6.55	0.426	6.50	0.620	4.06	504	0.770	1.64	25.0	2.06	31.4			
130-135	132.5	6.62	0.428	6.47	0.613	4.06	500	0.756	1.56	23.6	2.02	30.5			
135-140	137.5	6.58	0.425	6.45	0.618	4.07	487	0.741	1.64	24.9	2.13	32.4			
140-145	142.5	6.55	0.426	6.50	0.615	4.03	475	0.725	1.35	20.6	2.03	31.0			
145-150	147.5	6.67	0.433	6.49	0.607	4.05	471	0.707	1.29	19.3	2.15	32.2			
150-155	152.5	6.70	0.435	6.49	0.607	4.07	478	0.714	1.33	19.8	2.17	32.4			
155-160	157.5	6.61	0.432	6.53	0.601	3.98	466	0.704	1.39	21.0	2.18	33.0			
160-165	162.5	6.64	0.433	6.52	0.604	4.01	474	0.714	1.57	23.6	2.22	33.4			
165-170	167.5	6.58	0.429	6.51	0.617	4.06	480	0.730	1.39	21.1	2.14	32.5			
170-175	172.5	6.56	0.423	6.44	0.607	3.99	499	0.761	1.68	25.6	2.22	33.8			
175-180	177.5	6.48	0.417	6.44	0.608	3.94	505	0.780	1.75	27.0	2.14	33.0			
180-185	182.5	6.42	0.415	6.46	0.615	3.95	504	0.784	1.79	27.9	1.98	30.8			
185-190	187.5	6.51	0.418	6.43	0.603	3.92	513	0.789	1.85	28.4	1.96	30.1			
190-195	192.5	6.56	0.419	6.38	0.601	3.94	521	0.794	1.38	21.0	1.93	29.4			
195-200	197.5	6.60	0.423	6.41	0.610	4.02	517	0.784	1.52	23.0	1.95	29.5			
200-205	202.5	6.65	0.426	6.40	0.605	4.03	511	0.769	1.31	19.7	1.91	28.7			
205-210	207.5	6.64	0.423	6.37	0.607	4.03	511	0.770	1.18	17.8	1.75	26.4			
210-215	212.5	6.69	0.429	6.42	0.600	4.01	519	0.777	1.23	18.4	1.94	29.0			
215-220	217.5	6.58	0.420	6.38	0.600	3.95	520	0.790	1.33	20.2	1.91	29.0			
CV		3%	4%			4%	9%		15%		7%		22%		

Appendix B: Metal Data for Puget Sound Core PS-4

Core Segment	Mid-depth (cm)	Cd (µg/g)	Cd/Al ($x10^6$)	Pb (µg/g)	Pb/Al ($x10^4$)	As (µg/g)	Zn (µg/g)	Ni (µg/g)	V (µg/g)	Cr (µg/g)	Cu (µg/g)	Ba (µg/g)	Be (µg/g)	Ca (%)	Mg (%)
0-2	1	0.275	4.64	21.7	3.67	7.24	96.2	39.8	107	79.3	37.3	377	0.976	1.49	1.49
2-4	3	0.293	4.89	22.6	3.77	7.53	97.2	40.6	108	80.3	38.0	381	0.989	1.58	1.51
6-8	7	0.325	5.83	20.1	3.61	7.09	90.5	37.9	99.3	72.0	35.2	352	0.938	1.42	1.37
8-10	9	0.343	5.60	22.4	3.66	7.97	100	41.6	110	80.9	38.5	389	1.01	1.56	1.49
10-12	11	0.373	6.05	23.1	3.74	8.06	100	41.9	109	81.5	39.0	387	1.03	1.54	1.50
12-14	13	0.357	5.78	23.2	3.76	8.20	100	41.9	110	80.3	39.0	388	1.02	1.54	1.47
14-16	15	0.346	5.54	24.0	3.84	8.56	102	42.1	111	83.2	39.3	397	1.02	1.56	1.47
16-18	17	0.348	5.60	23.8	3.83	7.99	102	42.6	111	83.6	39.2	394	1.02	1.55	1.47
18-20	19	0.335	5.47	24.0	3.92	8.32	102	42.3	110	82.4	38.9	390	1.01	1.54	1.45
20-22	21	0.329	5.26	24.2	3.87	7.91	102	41.9	112	82.9	39.6	397	1.03	1.57	1.48
22-24	23	0.349	5.59	23.9	3.83	8.42	102	42.6	111	83.4	39.7	391	1.03	1.65	1.49
24-26	25	0.374	5.97	23.5	3.75	8.97	102	41.7	112	83.0	39.8	396	1.03	1.57	1.49
26-28	27	0.330	5.30	23.1	3.71	8.87	101	42.2	111	84.0	39.2	391	1.03	1.57	1.49
28-30	29	0.326	5.31	23.1	3.77	8.79	99.0	41.4	109	81.5	38.7	387	1.02	1.54	1.47
30-32	31	0.305	4.86	23.8	3.79	8.93	100	46.2	113	89.1	40.3	385	1.02	1.67	1.54
32-34	33	0.341	5.48	24.5	3.94	9.18	101	42.7	111	83.9	40.2	388	1.02	1.52	1.49
34-36	35	0.316	5.06	24.7	3.96	9.20	102	42.5	111	83.5	40.0	391	1.02	1.53	1.48
36-38	37	0.284	4.58	25.5	4.12	8.97	103	43.0	112	83.4	39.8	391	1.01	1.53	1.48
38-40	39	0.311	4.99	25.6	4.11	9.70	102	42.7	111	84.4	40.5	392	1.00	1.51	1.48
40-42	41	0.312	4.96	25.3	4.02	9.62	106	42.7	115	83.9	41.3	414	1.09	1.59	1.51
42-44	43	0.314	5.07	25.0	4.04	8.71	103	41.4	111	80.7	40.8	405	1.05	1.56	1.47
44-46	45	0.255	3.95	26.3	4.08	9.90	105	42.9	115	83.8	42.4	417	1.09	1.62	1.51
46-48	47	0.297	4.69	26.4	4.17	9.43	107	42.1	114	84.1	41.7	415	1.08	1.65	1.51
48-50	49	0.328	5.20	26.7	4.23	9.94	105	42.0	113	82.1	41.3	405	1.08	1.59	1.49
50-55	52.5	0.306	4.73	28.2	4.36	9.55	110	43.8	118	86.1	42.7	428	1.08	1.62	1.54
55-60	57.5	0.379	5.94	29.4	4.61	9.66	109	43.3	115	86.4	42.2	414	1.06	1.61	1.51
60-65	62.5	0.329	5.11	30.8	4.79	10.2	111	44.3	117	85.4	44.3	422	1.10	1.59	1.54
65-70	67.5	0.344	5.50	30.3	4.85	9.63	107	42.2	113	84.1	42.5	406	1.06	1.58	1.51
70-75	72.5	0.368	5.73	31.7	4.93	10.3	110	42.9	116	85.4	44.2	419	1.10	1.58	1.54
75-80	77.5	0.365	5.70	35.5	5.55	11.9	113	43.4	116	86.5	46.7	416	1.08	1.59	1.51
80-85	82.5	0.320	4.96	39.9	6.19	13.5	117	44.7	118	86.0	49.9	424	1.06	1.59	1.52
85-90	87.5	0.346	5.43	40.5	6.35	12.8	117	44.0	116	86.9	49.3	421	1.10	1.61	1.51
90-95	92.5	0.361	5.64	41.3	6.46	14.1	118	44.2	117	85.9	49.0	418	1.07	1.62	1.51
95-100	97.5	0.311	4.93	41.9	6.64	14.2	117	44.3	116	86.5	49.1	413	1.07	1.61	1.50
100-105	102.5	0.341	5.28	40.0	6.19	12.8	119	45.2	119	88.0	49.2	422	1.10	1.59	1.55
105-110	107.5	0.352	5.45	45.3	7.01	16.0	123	45.0	118	87.2	50.6	430	1.10	1.62	1.55
110-115	112.5	0.349	5.36	42.4	6.51	15.1	120	45.1	118	87.4	49.0	442	1.09	1.63	1.55
115-120	117.5	0.351	5.28	42.5	6.40	13.8	120	45.4	120	88.0	48.9	439	1.13	1.63	1.58
120-125	122.5	0.386	5.91	40.2	6.16	13.1	118	45.9	119	89.4	47.4	424	1.09	1.60	1.57
125-130	127.5	0.385	5.88	42.4	6.47	14.9	117	45.5	119	85.1	47.1	428	1.19	1.61	1.59
130-135	132.5	0.352	5.32	41.6	6.28	15.4	118	45.9	121	83.0	48.2	429	1.24	1.62	1.59
135-140	137.5	0.385	5.85	42.7	6.49	14.7	118	46.3	121	85.5	49.0	429	1.18	1.60	1.59
140-145	142.5	0.317	4.84	40.9	6.24	14.9	116	44.9	120	84.9	47.0	427	1.23	1.59	1.56
145-150	147.5	0.382	5.73	40.0	6.00	15.3	116	46.1	122	84.3	46.2	436	1.22	1.59	1.55
150-155	152.5	0.360	5.37	39.7	5.92	16.1	115	46.3	121	83.2	45.9	432	1.27	1.59	1.59
155-160	157.5	0.344	5.20	38.7	5.85	14.0	114	45.1	120	84.0	45.0	424	1.18	1.56	1.55
160-165	162.5	0.361	5.43	38.0	5.72	13.5	114	45.1	119	83.8	43.9	441	1.21	1.59	1.56
165-170	167.5	0.368	5.59	40.1	6.09	14.1	112	45.8	120	83.0	44.9	432	1.22	1.60	1.56
170-175	172.5	0.354	5.39	37.2	5.67	13.3	107	44.8	119	82.1	44.4	426	1.22	1.62	1.55
175-180	177.5	0.376	5.80	41.0	6.33	12.5	107	44.1	118	79.9	45.0	418	1.22	1.61	1.53
180-185	182.5	0.352	5.48	37.2	5.79	11.6	100	43.3	116	77.9	44.5	414	1.21	1.59	1.51
185-190	187.5	0.326	5.01	31.7	4.87	11.9	98.0	44.0	117	79.6	41.8	420	1.22	1.62	1.52
190-195	192.5	0.352	5.37	30.6	4.67	11.4	97.1	43.5	117	78.8	41.9	421	1.21	1.61	1.53
195-200	197.5	0.352	5.33	24.5	3.71	10.7	95.5	43.5	119	80.2	40.8	427	1.25	1.63	1.54
200-205	202.5	0.296	4.45	20.1	3.02	10.8	91.8	43.7	118	79.1	38.2	426	1.24	1.63	1.53
205-210	207.5	0.268	4.04	18.0	2.71	8.93	89.5	44.2	117	80.1	35.6	426	1.23	1.63	1.52
210-215	212.5	0.306	4.57	19.2	2.87	9.79	88.5	44.5	118	80.8	33.5	430	1.24	1.67	1.55
215-220	217.5	0.292	4.44	18.9	2.87	9.34	86.2	44.0	115	79.6	32.3	421	1.23	1.64	1.53
CV		9%		27%		24%	9%	4%	4%	4%	10%	5%	8%	3%	3%

Appendix B: Metal Data for Puget Sound Core PS-1

Core Segment	Mid-depth (cm)	Al (%)	Ti (%)	Ti/Al (x 10^2)	Fe (%)	Fe/Al	Mn (µg/g)	Mn/Al (x 10^2)	Mo (µg/g)	Mo/Al (x 10^6)	U (µg/g)	U/Al (x 10^6)	Re (ng/g)	Re SD	Re/Al (x 10^6)	Cd (µg/g)	Cd/Al (x10^6)
0-2	1	6.35	0.361	5.69	3.71	0.585	523	0.825	1.22	19.2	2.49	39.2	3.87	0.23		0.307	4.84
2-4	3	6.49	0.370	5.71	3.83	0.590	531	0.819	1.73	26.7	2.11	32.5	2.65	0.72	40.9	0.330	5.09
4-6	5	6.65	0.377	5.67	3.87	0.582	543	0.816	1.87	28.1	2.44	36.7				0.292	4.39
6-8	7	6.79	0.387	5.70	4.00	0.589	570	0.839	1.52	22.4	2.62	38.6				0.281	4.14
8-10	9	6.64	0.379	5.71	3.85	0.580	590	0.889	1.35	20.3	2.29	34.5				0.278	4.18
10-12	11	6.74	0.384	5.69	3.90	0.579	548	0.813	1.26	18.7	2.41	35.8	2.65	0.35	39.3	0.270	4.01
12-14	13	6.69	0.378	5.65	3.92	0.585	544	0.814	1.37	20.5	2.39	35.7				0.278	4.16
14-16	15	6.63	0.375	5.66	3.80	0.574	530	0.799	1.52	22.9	2.39	36.1				0.282	4.26
16-18	17	6.78	0.381	5.62	3.88	0.573	538	0.794	1.69	24.9	2.49	36.8				0.273	4.03
18-20	19	6.60	0.373	5.65	3.79	0.574	525	0.796	1.53	23.2	2.40	36.4				0.258	3.91
20-22	21	6.71	0.378	5.64	3.88	0.579	525	0.783	1.54	23.0	2.34	34.9	3.16		47.1	0.234	3.49
22-24	23	6.71	0.378	5.63	3.83	0.571	536	0.799	1.84	27.4	2.40	35.8	4.78	0.37	71.3	0.256	3.82
24-26	25	6.47	0.364	5.63	3.76	0.582	527	0.815	1.89	29.2	2.37	36.6				0.305	4.72
26-28	27	6.45	0.364	5.65	3.76	0.583	527	0.816	1.84	28.5	2.30	35.7	4.03	0.44	62.5	0.283	4.39
28-30	29	6.70	0.378	5.65	3.85	0.575	535	0.799	1.73	25.8	2.31	34.5				0.301	4.49
30-32	31	6.79	0.385	5.67	3.88	0.571	538	0.792	1.39	20.5	2.24	33.0				0.281	4.14
32-34	33	6.65	0.381	5.72	3.86	0.581	540	0.811	1.53	23.0	2.13	32.0				0.228	3.43
34-36	35	6.86	0.391	5.70	3.98	0.581	530	0.773	1.92	28.0	2.28	33.2				0.283	4.13
36-38	37	6.94	0.392	5.65	4.01	0.579	530	0.764	2.22	32.0	2.36	34.0				0.289	4.17
38-40	39	6.75	0.379	5.62	3.88	0.575	513	0.761	1.82	27.0	2.26	33.5				0.233	3.45
40-42	41	6.93	0.388	5.60	4.07	0.587	525	0.758	1.92	27.7	2.37	34.2				0.264	3.81
42-44	43	6.68	0.381	5.71	3.89	0.583	513	0.768	2.03	30.4	2.22	33.3				0.234	3.51
44-46	45	6.56	0.380	5.78	3.81	0.581	509	0.776	1.88	28.6	2.19	33.4				0.277	4.22
46-48	47	6.68	0.387	5.79	3.99	0.598	532	0.796	2.04	30.6	2.30	34.4				0.305	4.57
48-50	49	6.57	0.379	5.78	3.98	0.606	531	0.808	2.00	30.5	2.18	33.2				0.252	3.84
50-52	51	6.51	0.376	5.77	3.96	0.607	506	0.777	1.94	29.8	2.08	31.9				0.224	3.44
52-54	53	6.64	0.386	5.81	4.03	0.606	531	0.799	1.65	24.8	1.98	29.8				0.276	4.16
54-56	55	6.75	0.393	5.82	3.95	0.586	496	0.735	1.92	28.5	2.46	36.5				0.259	3.84
56-58	57	6.52	0.380	5.82	3.93	0.603	496	0.761	2.14	32.8	2.38	36.5				0.257	3.94
58-60	59	6.70	0.388	5.79	4.05	0.605	516	0.770	2.55	38.1	2.29	34.2				0.246	3.67
60-65	62.5	6.55	0.379	5.79	3.85	0.587	504	0.769	2.25	34.3	2.36	36.0				0.253	3.86
65-70	67.5	6.84	0.397	5.81	3.99	0.583	521	0.762	1.53	22.4	2.27	33.2				0.287	4.20
70-75	72.5	6.74	0.390	5.79	3.88	0.576	529	0.785	1.67	24.8	2.29	34.0				0.258	3.83
75-80	77.5	6.74	0.389	5.77	3.94	0.586	530	0.787	1.51	22.4	2.17	32.2				0.262	3.89
80-85	82.5	6.71	0.387	5.77	3.94	0.587	533	0.794	1.97	29.3	2.15	32.0				0.222	3.31
85-90	87.5	6.64	0.380	5.72	3.97	0.597	529	0.797	2.04	30.7	2.05	30.9	3.95	1.52	59.5	0.265	3.99
90-95	92.5	6.95	0.400	5.75	4.07	0.585	548	0.788	1.64	23.6	2.10	30.2				0.235	3.38
95-100	97.5	6.87	0.390	5.67	4.05	0.590	564	0.821	1.73	25.2	2.15	31.3				0.227	3.31
100-105	102.5	6.77	0.385	5.69	3.89	0.575	503	0.744	1.46	21.6	2.15	31.8				0.235	3.47
105-110	107.5	6.97	0.394	5.66	3.96	0.569	512	0.735	1.74	25.0	2.26	32.4				0.249	3.57
110-115	112.5	6.87	0.394	5.73	3.92	0.570	509	0.741	1.56	22.7	2.54	37.0				0.304	4.42
115-120	117.5	6.78	0.384	5.67	3.79	0.560	504	0.744	1.44	21.3	2.44	36.0				0.259	3.82
120-125	122.5	6.86	0.393	5.72	3.88	0.566	504	0.735	1.67	24.3	2.53	36.9				0.311	4.53
125-130	127.5	6.79	0.386	5.68	3.89	0.573	504	0.742	1.79	26.4	2.32	34.2	3.66	0.00	53.9	0.279	4.11
130-135	132.5	6.90	0.395	5.72	3.97	0.576	526	0.762	1.82	26.4	2.32	33.6				0.259	3.75
135-140	137.5	6.42	0.369	5.76	3.69	0.574	498	0.777	1.74	27.1	2.09	32.6				0.274	4.27
140-145	142.5	6.62	0.374	5.65	3.88	0.586	522	0.789	2.19	33.1	2.27	34.3	3.42	0.84	51.7	0.313	4.73
145-150	147.5	6.48	0.364	5.62	3.78	0.584	515	0.794	2.79	43.0	2.43	37.5				0.349	5.38
150-155	152.5	6.65	0.372	5.60	3.83	0.577	531	0.798	2.30	34.6	2.64	39.7	5.68	0.93	85.5		0.00
155-160	157.5	6.65	0.371	5.58	3.84	0.577	527	0.792	2.74	41.2	3.22	48.4				0.359	5.40
160-165	162.5	6.63	0.370	5.57	3.84	0.579	524	0.790	3.14	47.4	3.13	47.2				0.385	5.81
165-170	167.5	6.47	0.360	5.56	3.77	0.583	533	0.823	3.37	52.1	2.55	39.4	1.76	0.40	27.2	0.350	5.41
170-175	172.5	6.60	0.368	5.58	3.84	0.582	523	0.793	3.31	50.1	2.81	42.6	5.96	1.30	90.3	0.370	5.61
175-180	177.5	6.58	0.368	5.59	3.92	0.597	525	0.799	3.46	52.6	3.09	47.0	5.01	0.86	76.2	0.382	5.81
180-185	182.5	6.59	0.368	5.59	3.77	0.572	517	0.784	2.99	45.4	2.74	41.6				0.363	5.51
185-190	187.5	6.50	0.363	5.58	3.73	0.573	498	0.767	3.24	49.8	2.98	45.8	7.34	2.36	113	0.376	5.78
190-195	192.5	6.70	0.376	5.62	3.88	0.579	519	0.775	3.73	55.7	3.02	45.1				0.397	5.93
195-200	197.5	6.45	0.357	5.54	3.63	0.563	489	0.759	2.65	41.1	2.31	35.8				0.313	4.85
CV		2%	3%		2%		3%		30%		11%		36%			16%	

Appendix B: Metal Data for Puget Sound Core PS-1

Core Segment	Mid-depth (cm)	Pb (µg/g)	Pb/Al ($x10^4$)	As (µg/g)	Zn (µg/g)	Ni (µg/g)	V (µg/g)	Cr (µg/g)	Cu (µg/g)	Ba (µg/g)	Be (µg/g)	Ca (%)	Mg (%)	P (µg/g)	BSi as SiO_2 (%)	SD
0-2	1	35.5	5.59	10.3	102	37.8	107	66.7	48.2	373	1.01	1.89	1.55	787	12.8	0.12
2-4	3	35.9	5.53	12.3	106	38.3	109	66.6	49.8	379	1.10	1.84	1.54			
4-6	5	37.7	5.67	13.1	107	40.7	112	71.3	49.7	386	1.06	1.83	1.58	739	12.6	0.34
6-8	7	37.9	5.58	12.4	108	40.8	113	71.7	51.5	394	1.11	1.90	1.61			
8-10	9	37.0	5.57	11.7	107	40.2	112	70.3	49.9	382	1.01	1.85	1.57	841	12.2	0.03
10-12	11	38.3	5.68	11.8	108	40.9	113	72.4	51.0	390	1.07	1.86	1.58			
12-14	13	39.3	5.87	12.8	109	40.1	113	73.1	50.9	391	1.05	1.84	1.55			
14-16	15	39.1	5.90	13.8	106	39.9	111	71.1	52.6	384	1.05	1.79	1.53		12.0	0.72
16-18	17	40.6	5.99	13.1	108	40.3	114	72.1	53.0	399	1.10	1.83	1.56			
18-20	19	40.4	6.12	13.6	105	39.3	111	69.9		389	1.08	1.81	1.53	717	12.4	0.03
20-22	21	41.2	6.14	13.6	107	39.5	112	69.7	52.0	396	1.08	1.85	1.57			
22-24	23	41.2	6.14	13.4	108	40.3	113	72.4	52.1	388	1.06	1.80	1.56			
24-26	25	40.1	6.20	14.2	109	39.0	108	70.0	50.3	378	0.995	1.76	1.52	620	12.6	0.14
26-28	27	41.2	6.39	14.7	104	39.3	107	69.7	51.6	379	1.03	1.75	1.52			
28-30	29	42.6	6.36	14.4	111	41.3	113	73.7	53.3	394	1.09	1.79	1.58			
30-32	31	44.9	6.62	15.6	111	41.3	114	72.4	55.5	395	1.10	1.82	1.60	719		
32-34	33	43.6	6.55	15.3	111	41.1	113	73.3	54.0	388	1.03	1.77	1.56		12.2	
34-36	35	47.5	6.92	16.2	115	41.9	116	73.0	56.8	397	1.08	1.83	1.58			
36-38	37	50.3	7.25	18.1		43.1	118	76.4	59.1	404	1.11	1.86	1.60	724		
38-40	39	50.8	7.53	17.5	114	41.0	114	72.9	57.9	398	1.08	1.81	1.54			
40-42	41	53.8	7.77	18.4	117	41.8	116	73.2	61.1	412	1.12	1.89	1.60	711	12.2	0.51
42-44	43	54.6	8.18	19.7	116	40.3	113	70.4	61.4	388	1.12	1.81	1.50			
44-46	45	54.4	8.29	19.3	119	40.4	112	68.7	60.4	386	1.09	1.72	1.48			
46-48	47	57.2	8.57	22.0	120	41.9	115	71.6	63.0	397	1.17	1.78	1.53			
48-50	49	57.5	8.76	22.9	119	42.3	113	72.0	62.6	389	1.18	1.74	1.54			
50-52	51	58.6	9.00	22.5	118	41.0	111	70.6	62.3	385	1.13	1.69	1.48	737	13.3	0.40
52-54	53	56.1	8.45	22.1	119	42.1	113	71.4	62.6	389	1.17	1.74	1.52			
54-56	55	59.8	8.86	25.0	123	42.9	116	74.2	65.7	390	1.18	1.75	1.53		12.7	0.70
56-58	57	59.4	9.11	24.7	121	41.2	111	71.6	63.8	387	1.16	1.74	1.50		13.1	0.28
58-60	59	62.8	9.38	28.4	124	42.7	113	72.5	65.8	392	1.18	1.79	1.55	720	12.8	0.50
60-65	62.5	60.6	9.25	25.7	120	41.5	111	70.7	64.4	382	1.14	1.73	1.51		11.6	0.28
65-70	67.5	59.9	8.76	23.2	118	42.0	113	71.0	63.4	398	1.18	1.82	1.55	689		
70-75	72.5	54.9	8.15	21.8	115	41.9	112	71.0	59.0	385	1.18	1.77	1.51			
75-80	77.5	55.0	8.17	21.5	114	41.6	113	71.8	58.8	392	1.19	1.83	1.51	675		
80-85	82.5	55.0	8.19	21.8	112	41.3	111	70.6	61.7	386	1.17	1.78	1.49		11.5	0.35
85-90	87.5	52.9	7.97	20.7	107	38.8	109	67.4	58.0	388	1.13	1.85	1.45	738		
90-95	92.5	49.9	7.18	19.9	85.7	41.4	113	71.1	35.3	401	1.20	1.93	1.55	750		
95-100	97.5	52.4	7.63	18.3	107	41.1	112	67.7	79.3	403	1.17	1.92	1.49		10.7	0.60
100-105	102.5	52.2	7.71	17.8	81.9	39.6	108	65.9	35.5	388	1.17	1.93	1.47		11.2	0.27
105-110	107.5	54.0	7.75	20.2	84.9	39.5	109	66.6	37.0	399	1.21	1.97	1.49		11.6	0.33
110-115	112.5	54.6	7.95	17.1	102	39.8	113	67.0	55.8	398	1.17	1.92	1.46			
115-120	117.5	42.6	6.29	14.8	96.3	38.5	109	64.5	55.9	391	1.19	1.88	1.44	717	11.2	0.49
120-125	122.5	29.5	4.30	15.0	91.6	38.4	112	67.0	50.6	398	1.18	1.95	1.45			
125-130	127.5	23.3	3.43	11.7	83.9	38.1	109	65.0	38.9	400	1.18	1.94	1.46			
130-135	132.5	21.7	3.14	9.93	104	40.7	113	66.6	54.6	401	1.21	1.94	1.48	663	13.9	0.93
135-140	137.5	16.3	2.54	9.64	97.9	38.2	104	62.7	52.3	365	1.13	1.75	1.40			
140-145	142.5	12.2	1.84	9.74	80.7	38.4	108	66.3	34.5	390	1.14	1.89	1.49		12.3	1.32
145-150	147.5	10.7	1.65	8.77	77.9	37.6	105	64.7	33.4	385	1.11	1.83	1.46	618	11.9	2.09
150-155	152.5			11.5	84.6	38.5	108	64.8	38.9	390	1.13	1.84	1.48			
155-160	157.5	12.3	1.85	10.0	81.0	37.8	107	65.4	36.5	391	1.15	1.84	1.50		14.2	0.13
160-165	162.5	9.88	1.49	7.24	80.4	39.1	108	68.5	34.1	394	1.13	1.83	1.50			
165-170	167.5	10.2	1.58	7.36	79.4	38.4	105	66.8	33.2	390	1.13	1.79	1.50	675	14.7	0.39
170-175	172.5	9.95	1.51	8.76	81.1	39.5	107	66.9	33.6	390	1.13	1.81	1.51			
175-180	177.5	11.4	1.73	10.3	80.7	38.9	107	66.2	34.2	391	1.15	1.84	1.51			
180-185	182.5	10.0	1.52	7.76	79.5	38.6	106	65.8	33.1	388	1.16	1.81	1.52			
185-190	187.5	12.0	1.85	8.39	79.7	37.5	104	64.9	33.8	381	1.11	1.82	1.48			
190-195	192.5			10.7	84.7	39.7	109	66.8	38.7	390	1.14	1.88	1.51	642	12.8	0.52
195-200	197.5	9.65	1.50	6.63	76.9	36.0	100	63.2	31.8	370	1.09	1.80	1.45			
CV		42%		35%	14%	4%	3%	5%	22%	2%	5%	3%	3%	8%	8%	

Appendix B: Quality Control Metals Data

Sample ID		Al (%)	Ti (%)	Fe (%)	Mn (µg/g)	Mo (µg/g)	U (µg/g)	Re (ng/g)	Cd (µg/g)	Pb (µg/g)	As (µg/g)
Method Blanks											
Blank 062106 r1		<0.001	<0.001	<0.001	<0.03	0.146	0.00423	<0.2	0.00529	0.0409	0.0725
Blank 062006 r5		<0.001	<0.001	<0.001	<0.03	0.0536	0.00296	<0.2	<0.004	0.0791	0.0291
Blank 062806 r1		<0.001	<0.001	<0.001	<0.03	0.0389	<0.001	0.396	<0.004	0.117	<0.02
Blank 062806 r2		<0.001	<0.001	<0.001	<0.03	<0.013	<0.001	0.747	<0.004	<0.006	<0.02
Blank 062706 r1		<0.001	<0.001	<0.001	<0.03	0.070	<0.001	<0.2	0.00704	0.0342	0.173
Blank 062706 r2		<0.001	<0.001	<0.001	<0.03	<0.013	<0.001	<0.2	0.00711	0.0691	<0.02
Blank 060606r1		<0.001	<0.001	<0.001	0.0981	0.0948	<0.001	<0.2	0.00711	0.0532	0.142
Blank 060606r2		<0.001	<0.001	<0.001	0.0926	<0.013	<0.001	<0.2	0.00711	0.0529	0.0625
Blank 060606r3		<0.001	<0.001	<0.001	0.136	<0.013	<0.001	<0.2	0.00711	0.0199	<0.02
Blank 061406		<0.001	<0.001	<0.001	<0.03	0.174	0.00313	<0.2	0.00821	0.143	<0.02
Blank 062006 r4		<0.001	<0.001	<0.001	<0.03	0.0411	0.00158	0.866	<0.004	<0.006	<0.02
Blank 091106		<0.001	<0.001	<0.001	0.405	0.0416	0.00185	<0.2	0.020	0.0255	<0.02
Blank 083106		<0.001	<0.001	<0.001	0.457996	0.0186	<0.001	<0.2	0.010	0.020	0.168
Blank 032306r1		<0.001	<0.001	<0.001	0.219	0.0441	<0.001	<0.2	<0.004	<0.006	<0.02
Blank 032306r2		<0.001	<0.001	<0.001	<0.03	<0.013	<0.001	<0.2	<0.004	<0.006	0.161
Blank 032706r1		<0.001	<0.001	<0.001	<0.03	0.0742	<0.001	<0.2	0.011	0.0418	<0.02
Blank 030806r1		<0.001	<0.001	<0.001	<0.03	0.0459	<0.001	<0.2	<0.004	<0.006	<0.02
Blank 030806r2		<0.001	<0.001	<0.001	<0.03	0.020	<0.001	<0.2	<0.004	<0.006	0.0790
Matrix Spikes											
HC-3	**Percent recovery**										
HC-3	**Percent recovery**					**84%**	**94%**	**93%**	**90%**	**94%**	**88%**
HC-3	**Percent recovery**					**92%**	**96%**	**100%**	**98%**	**85%**	**97%**
HC-3	**Percent recovery**					**106%**	**113%**	**103%**	**103%**	**95%**	**105%**
HC-3	**Percent recovery**					**115%**	**105%**	**97%**	**96%**	**102%**	**105%**
HC-3	**Percent recovery**					**101%**	**101%**	**100%**	**96%**	**105%**	**107%**
HC-5	**Percent recovery**				**92%**	**105%**	**97%**	**95%**	**99%**	**107%**	**98%**
HC-5	**Percent recovery**				**92%**	**99%**	**102%**	**98%**	**94%**	**99%**	**94%**
HC-5	**Percent recovery**				**88%**	**95%**	**96%**	**94%**	**99%**	**89%**	**89%**
HC-5	**Percent recovery**				**99%**	**101%**	**97%**	**98%**	**92%**	**89%**	**105%**
HC-4	**Percent recovery**				**90%**	**84%**	**104%**	**101%**	**97%**	**98%**	**93%**
HC-1	**Percent recovery**				**102%**	**92%**	**105%**	**96%**	**96%**	**124%**	**104%**
PS-4	**Percent recovery**			**114%**	**95%**	**90%**	**89%**	**99%**	**90%**	**98%**	**90%**
PS-4	**Percent recovery**				**83%**	**96%**	**100%**	**99%**	**97%**	**96%**	**94%**
PS-4	**Percent recovery**				**94%**	**89%**	**96%**	**93%**	**93%**	**95%**	**99%**
PS-1	**Percent recovery**			**110%**	**89%**	**93%**	**88%**	**86%**	**95%**	**95%**	**98%**
PS-1	**Percent recovery**			**89%**	**88%**	**94%**	**102%**	**85%**	**92%**	**97%**	**97%**

Appendix B: Quality Control Metals Data

Sample ID	Al (%)	Ti (%)	Fe (%)	Mn (µg/g)	Mo (µg/g)	U (µg/g)	Re (ng/g)	Cd (µg/g)	Pb (µg/g)	As (µg/g)
Standard Reference Material										
Mess3 062706 r1	7.87	0.426	4.22	307	2.73	3.55		0.218	22.5	17.8
Mess3 062706 r2	7.81	0.428	4.22	303	2.64	3.56		0.226	21.5	18.0
Mess3 062806 r1	7.91	0.411	4.12	300	2.66	3.69		0.209	22.1	20.5
Mess3 062806 r2	8.01	0.412	4.32	307	2.49	3.56		0.196	21.2	19.7
Mess3 062106 r1	7.68	0.397	3.91	294	2.69	3.61		0.239	21.0	19.3
Mess3 062006 r2	7.92	0.409	4.11	299	2.65	3.68		0.219	21.9	19.8
Mess3 060606r1	8.02	0.410	4.11	294	2.87	3.78		0.226	22.0	21.6
Mess3 060606r2	8.43	0.411	4.09	298	2.71	3.75		0.251	22.2	20.9
Mess3 060606r3	8.20	0.417	4.03	299	2.49	3.53		0.214	21.2	19.4
Mess3 061406	7.67	0.399	4.07	293	2.92	3.80		0.231	22.7	20.0
Mess3 062006 r1	7.59	0.406	4.27	303	2.81	3.64		0.222	22.6	19.1
MESS-3 091106	8.12	0.410	4.08	298	2.65	3.72		0.237	20.6	21.0
MESS-3 083106	7.83	0.403	4.02	290	2.85	3.50		0.245	21.7	22.5
Mess3 032306r1	7.58	0.392	3.91	281	2.67	3.46		0.233	22.0	16.6
Mess3 032306r2	7.65	0.396	3.98	288	2.60	3.61		0.210	21.8	19.1
Mess3 032706r1	7.85	0.410	4.09	298	2.54	3.75		0.231	21.9	20.8
Mess3 030806r1	7.60	0.390	3.97	288	2.58	3.68		0.217	22.4	19.9
Mess3 030806r2	7.63	0.398	3.99	295	2.57	3.90		0.211	22.0	19.4
certified value	8.59	0.44	4.34	324	2.78	4	NC	0.24	21.1	21.1
range	*0.23*	*0.06*	*0.11*	*12*	*0.07*	*REF*		*0.01*	*0.7*	*1.1*
percent recovery	**92%**	**97%**	**97%**	**95%**	**98%**	**89%**		**91%**	**107%**	**84%**
percent recovery	**91%**	**97%**	**97%**	**94%**	**95%**	**89%**		**94%**	**102%**	**85%**
percent recovery	**92%**	**93%**	**95%**	**93%**	**96%**	**92%**		**87%**	**105%**	**97%**
percent recovery	**93%**	**94%**	**100%**	**95%**	**90%**	**89%**		**82%**	**100%**	**93%**
percent recovery	**89%**	**90%**	**90%**	**91%**	**97%**	**90%**		**100%**	**100%**	**91%**
percent recovery	**92%**	**93%**	**95%**	**92%**	**95%**	**92%**		**91%**	**104%**	**94%**
percent recovery	**93%**	**93%**	**95%**	**91%**	**103%**	**95%**		**94%**	**104%**	**102%**
percent recovery	**98%**	**93%**	**94%**	**92%**	**97%**	**94%**		**105%**	**105%**	**99%**
percent recovery	**95%**	**95%**	**93%**	**92%**	**90%**	**88%**		**89%**	**100%**	**92%**
percent recovery	**89%**	**91%**	**94%**	**90%**	**105%**	**95%**		**96%**	**108%**	**95%**
percent recovery	**88%**	**92%**	**98%**	**93%**	**101%**	**91%**		**93%**	**107%**	**91%**
percent recovery	**95%**	**93%**	**94%**	**92%**	**95%**	**93%**		**99%**	**98%**	**100%**
percent recovery	**91%**	**92%**	**93%**	**90%**	**103%**	**88%**		**102%**	**103%**	**107%**
percent recovery	**88%**	**89%**	**90%**	**87%**	**96%**	**87%**		**97%**	**104%**	**79%**
percent recovery	**89%**	**90%**	**92%**	**89%**	**94%**	**90%**		**88%**	**103%**	**91%**
percent recovery	**91%**	**93%**	**94%**	**92%**	**91%**	**94%**		**96%**	**104%**	**99%**
percent recovery	**88%**	**89%**	**91%**	**89%**	**93%**	**92%**		**90%**	**106%**	**94%**
percent recovery	**89%**	**91%**	**92%**	**91%**	**92%**	**98%**		**88%**	**104%**	**92%**

Appendix B: Quality Control Metals Data

Sample ID	Al (%)	Ti (%)	Fe (%)	Mn (µg/g)	Mo (µg/g)	U (µg/g)	Re (ng/g)	Cd (µg/g)	Pb (µg/g)	As (µg/g)
Standard Reference Material										
2702 062706 r1	7.61	0.862	7.33	1602	9.77	8.20		0.656	126	35.4
2702 062706 r2	7.65	0.872	7.23	1623	9.97	8.38		0.653	128	36.5
2702 062806 r1	7.95	0.826	7.32	1633	9.74	8.57		0.732	129	43.0
2702 062806 r2	8.14	0.840	7.76	1678	9.59	8.55		0.702	130	42.6
2702 062106 r1	8.00	0.844	7.26	1624	9.83	8.16		0.652	122	41.4
2702 062006 r3	7.89	0.822	7.21	1595	9.45	8.10		0.689	121	40.3
2702 060606r1	7.75	0.804	7.11	1523	10.1	8.12		0.651	120	43.6
2702 060606r2	7.90	0.816	6.93	1553	9.20	8.05		0.586	120	41.1
2702 060606r3	8.01	0.828	7.08	1592	9.33	7.96		0.688	120	41.7
2702 061406	7.55	0.790	7.05	1552	10.5	8.65		0.730	129	43.2
2702 062006 r2	7.38	0.808	7.24	1600	10.0	8.31		0.767	132	41.9
2702 091106	7.90	0.813	7.30	1582	9.91	8.42		0.613	120	43.2
2702 083106	7.82	0.820	7.28	1576	9.68	7.73		0.731	132	48.4
2702 032306r1	7.40	0.773	6.94	1532	9.55	7.79		0.635	124	37.9
2702 032306r2	7.27	0.778	6.88	1519	9.64	7.98		0.694	126	42.6
2702 032706r1	7.73	0.825	7.16	1594	9.82	8.63		0.717	130	44.1
2702 030806r1	7.51	0.781	6.99	1534	9.80	8.17		0.699	128	40.3
2702 030806r2	7.25	0.802	7.03	1597	9.54	8.85		0.583	127	42.4
certified value	8.41	0.884	7.91	1757	10.8	10.4	NC	0.817	133	45.3
range	*0.22*	*0.082*	*0.24*	*58*	*REF*	*REF*		*0.011*	*1.1*	*1.8*
percent recovery	**90%**	**98%**	**93%**	**91%**	**90%**	**79%**		**80%**	**95%**	**78%**
percent recovery	**91%**	**99%**	**91%**	**92%**	**92%**	**81%**		**80%**	**96%**	**81%**
percent recovery	**95%**	**93%**	**93%**	**93%**	**90%**	**82%**		**90%**	**97%**	**95%**
percent recovery	**97%**	**95%**	**98%**	**95%**	**89%**	**82%**		**86%**	**98%**	**94%**
percent recovery	**95%**	**95%**	**92%**	**92%**	**91%**	**78%**		**80%**	**92%**	**91%**
percent recovery	**94%**	**93%**	**91%**	**91%**	**88%**	**78%**		**84%**	**91%**	**89%**
percent recovery	**92%**	**91%**	**90%**	**87%**	**94%**	**78%**		**80%**	**90%**	**96%**
percent recovery	**94%**	**92%**	**88%**	**88%**	**85%**	**77%**		**72%**	**90%**	**91%**
percent recovery	**95%**	**94%**	**90%**	**91%**	**86%**	**77%**		**84%**	**90%**	**92%**
percent recovery	**90%**	**89%**	**89%**	**88%**	**97%**	**83%**		**89%**	**97%**	**95%**
percent recovery	**88%**	**91%**	**92%**	**91%**	**93%**	**80%**		**94%**	**99%**	**92%**
percent recovery	**94%**	**92%**	**92%**	**90%**	**92%**	**81%**		**75%**	**90%**	**95%**
percent recovery	**93%**	**93%**	**92%**	**90%**	**90%**	**74%**		**89%**	**99%**	**107%**
percent recovery	**88%**	**87%**	**88%**	**87%**	**88%**	**75%**		**78%**	**93%**	**84%**
percent recovery	**86%**	**88%**	**87%**	**86%**	**89%**	**77%**		**85%**	**95%**	**94%**
percent recovery	**92%**	**93%**	**91%**	**91%**	**91%**	**83%**		**88%**	**98%**	**97%**
percent recovery	**89%**	**88%**	**88%**	**87%**	**91%**	**79%**		**86%**	**96%**	**89%**
percent recovery	**86%**	**91%**	**89%**	**91%**	**88%**	**85%**		**71%**	**95%**	**94%**

Appendix B: Quality Control Metals Data

Sample ID		Al (%)	Ti (%)	Fe (%)	Mn (µg/g)	Mo (µg/g)	U (µg/g)	Re (ng/g)	Cd (µg/g)	Pb (µg/g)	As (µg/g)
Reference Material for BSi											
Chesapeake Bay R-64 r1											
Chesapeake Bay R-64 r2											
Chesapeake Bay R-64 r3											
Chesapeake Bay R-64 r4											
Chesapeake Bay R-64 r5											
Chesapeake Bay R-64 r6											
Chesapeake Bay R-64 r7											
	Published Value										
	range										
	percent recovery										
	percent recovery										
	percent recovery										
	percent recovery										
	percent recovery										
	percent recovery										
	percent recovery										
Still Pond Chesapeake Bay r1											
Still Pond Chesapeake Bay r2											
	Published Value										
	range										
	percent recovery										
	percent recovery										
Replicates											
HC-3	45 or 5 (P)	6.26	0.622	6.10	1881	2.76	2.83	5.24		7.87	10.3
HC-3	45 or 5 (P)	6.20	0.608	6.08	1819	2.72	2.85	4.01		7.94	10.4
	RPD	**1%**	**2%**	**0%**	**3%**	**1%**	**1%**	**27%**		**1%**	**1%**
HC-3	17 or 69 (P)	6.18	0.629	6.14	2307	1.18	2.25	2.33	0.331	13.5	9.45
HC-3	17 or 69 (P)	6.20	0.622	6.19	2305	1.18	2.23	1.86	0.343	13.3	9.49
	RPD	**0%**	**1%**	**1%**	**0%**	**0%**	**1%**	**22%**	**4%**	**1%**	**0%**
HC-3	97 or 141 (P)	6.30	0.662	6.26	1940	7.70	4.00	7.80	0.620	7.36	9.40
HC-3	97 or 141 (P)	6.35	0.670	6.35	2019	7.74	4.00	10.4	0.609	7.38	9.78
	RPD	**1%**	**1%**	**1%**	**4%**	**1%**	**0%**	**29%**	**2%**	**0%**	**4%**
HC-3	135	6.34	0.665	6.49	2064	7.27	3.01	6.77	0.446	7.21	8.93
HC-3	135	6.46	0.673	6.39	2065	7.31	3.07	5.29	0.452	7.24	9.24
	RPD	**2%**	**1%**	**2%**	**0%**	**1%**	**2%**	**25%**	**1%**	**0%**	**3%**
HC-3	169	6.75	0.664	6.75	1797	12.8	5.02	17.7	0.642	7.35	13.3
HC-3	169	6.67	0.640	6.52	1726	12.1	4.82	14.5	0.556	7.01	13.0
	RPD	**1%**	**4%**	**3%**	**4%**	**6%**	**4%**	**20%**	**14%**	**5%**	**2%**
HC-3	207.5	6.60	0.643	6.73	1985	2.54	2.54	3.77	0.412	6.99	8.79
HC-3	207.5	6.63	0.645	6.72	2007	2.46	2.60	4.74	0.428	6.94	9.06
	RPD	**0%**	**0%**	**0%**	**1%**	**3%**	**2%**	**23%**	**4%**	**1%**	**3%**

Appendix B: Quality Control Metals Data

Sample ID		Al (%)	Ti (%)	Fe (%)	Mn (μg/g)	Mo (μg/g)	U (μg/g)	Re (ng/g)	Cd (μg/g)	Pb (μg/g)	As (μg/g)
Replicates, cont.											
HC-5	1 or 81 (P)	6.27	0.438	4.45	1380	1.17	2.10	4.70	0.281	16.6	10.9
HC-5	1 or 81 (P)	6.15	0.436	4.39	1377	1.11	2.06	4.67	0.283	16.5	11.0
	RPD	**2%**	**0%**	**1%**	**0%**	**5%**	**2%**	**1%**	**1%**	**1%**	**1%**
HC-5	47 or 162.5 (P)	6.83	0.464	4.49	692	1.99	2.75	5.06	0.275	18.5	10.2
HC-5	47 or 162.5 (P)	6.93	0.465	4.47	692	2.07	2.83	4.50	0.270	19.5	11.0
	RPD	**1%**	**0%**	**0%**	**0%**	**4%**	**3%**	**12%**	**2%**	**5%**	**8%**
HC-5	73 or 252.5 (P)	6.37	0.432	4.10	587						
HC-5	73 or 252.5 (P)	6.78	0.466	4.44	684						
	RPD	**6%**	**7%**	**8%**	**15%**						
HC-5	87	6.30	0.455	4.62	612	2.69	4.19	11.2	0.398	10.7	10.2
HC-5	87	6.30	0.446	4.51	603	2.73	3.99	10.7	0.386	10.3	9.96
	RPD	**0%**	**2%**	**2%**	**1%**	**1%**	**5%**	**5%**	**3%**	**4%**	**2%**
HC-5	197.5	6.41	0.447	4.35	638	2.24	2.55	4.72	0.301	9.62	8.84
HC-5	197.5	6.51	0.451	4.56	642	2.31	2.51	6.07	0.343	9.51	8.37
	RPD	**2%**	**1%**	**5%**	**1%**	**3%**	**2%**	**25%**	**13%**	**1%**	**5%**
HC-4	52.5	6.58	0.560	5.54	2334	4.22	3.14		0.528	10.6	9.96
HC-4	52.5	6.64	0.564	5.55	2338	4.04	3.26		0.487	10.9	10.1
	RPD	**1%**	**1%**	**0%**	**0%**	**4%**	**4%**		**8%**	**3%**	**1%**
HC-1	17	6.48	0.851	6.75	945	1.12	1.78		0.309	5.49	10.6
HC-1	17	6.56	0.858	6.74	953	0.971	1.85		0.257	5.62	11.5
	RPD	**1%**	**1%**	**0%**	**1%**	**14%**	**4%**		**18%**	**2%**	**8%**
PS-4	1	5.92	0.379	3.56	563	0.994	1.73		0.275	21.7	7.24
PS-4	1	5.68	0.363	3.45	540	0.928	1.72		0.275	21.1	6.82
	RPD	**4%**	**4%**	**3%**	**4%**	**7%**	**1%**		**0%**	**3%**	**6%**
PS-4	57.5	6.38	0.415	3.89	489	1.50	1.91	3.63	0.379	29.4	9.66
PS-4	57.5	6.34	0.410	3.88	481	1.43	1.90	4.92	0.332	29.1	11.3
	RPD	**1%**	**1%**	**0%**	**2%**	**5%**	**1%**	**30%**	**13%**	**1%**	**16%**
PS-4	137.5	6.58	0.425	4.07	487	1.64	2.13		0.385	42.7	14.7
PS-4	137.5	6.59	0.425	4.08	484	1.67	2.09		0.358	41.9	14.8
	RPD	**0%**	**0%**	**0%**	**1%**	**2%**	**2%**		**7%**	**2%**	**1%**
PS-1	1 or 41 (P)	6.35	0.361	3.71	523	1.22	1.82	3.75	0.307	35.5	10.3
PS-1	1 or 41 (P)	6.45	0.367	3.79	538	1.13	1.90	3.98	0.270	36.2	11.2
	RPD	**2%**	**1%**	**2%**	**3%**	**8%**	**4%**	**6%**	**13%**	**2%**	**8%**
PS-1	51	6.51	0.376	3.96	506	1.94	2.08		0.224	58.6	22.5
PS-1	51	6.60	0.383	4.01	512	1.97	2.10		0.226	58.4	21.6
	RPD	**1%**	**2%**	**1%**	**1%**	**2%**	**1%**		**1%**	**0%**	**4%**

Appendix B: Quality Control Metals Data

Sample ID	Al (%)	Ti (%)	Fe (%)	Mn (µg/g)	Mo (µg/g)	U (µg/g)	Re (ng/g)	Cd (µg/g)	Pb (µg/g)	As (µg/g)
Laboratory Control Sample										
LCS062106 r1	0.0279		0.0279	24.4	2.02	2.00	9.16	1.99	2.04	1.93
LCS062006 r2	0.0285		0.0283	24.5	1.99	1.98	48.0	1.95	1.97	2.04
LCS062806 r1	0.0281		0.0285	24.9	1.89	1.95	10.0	1.97	2.00	1.70
LCS062806 r2	0.0286		0.0303	25.7	1.91	1.98	51.5	1.91	2.00	2.17
LCS062706 r1	0.0296		0.0294	25.0	2.04	1.92	10.1	1.91	2.07	24.5
LCS062706 r2	0.0282		0.0288	25.2	2.31	2.40	49.5	2.28	2.36	25.5
LCS060606r1				24.8	2.12	2.03	10.4	1.93	2.37	2.46
LCS060606r2				24.9	1.93	2.00	51.7	1.95	2.04	1.87
LCS060606r3				25.7	1.83	1.99		1.89	1.98	2.26
LCS061406	0.249		0.249	24.5	2.23	2.18	9.47	2.04	2.05	1.76
LCS062006 r1	0.0272		0.0280	24.9	2.01	2.00	48.6	1.94	1.98	1.94
LCS091106	0.0093		0.0092	25.3	2.08	1.92	10.3	1.99	1.86	1.70
LCS083106	0.0102		0.0010	25.8	2.04	1.89	10.3	2.08	1.91	2.15
LCS032306r1	0.0026		0.0025	24.3	1.87	1.87	9.85	1.88	1.89	22.2
LCS032306r2	0.0027		0.0027	23.8	1.92	1.96	48.2	1.87	1.99	1.76
LCS032706r1	0.0028		0.0027	23.4	1.91	2.03	10.2	2.06	24.3	25.1
LCS030806r1			0.0026	23.5	1.92	1.93	12.1	1.98	1.93	1.88
LCS030806r2	0.0028		0.0026	23.9	1.94	2.08	10.7	1.79	1.93	1.78
	102%		**102%**	**97%**	**97%**	**99%**	**92%**	**97%**	**95%**	**95%**
	103%		**103%**	**98%**	**94%**	**100%**	**96%**	**99%**	**100%**	**97%**
	102%		**104%**	**100%**	**93%**	**97%**	**100%**	**98%**	**94%**	**85%**
	104%		**110%**	**103%**	**94%**	**99%**	**103%**	**95%**	**94%**	**109%**
	108%		**107%**	**100%**	**98%**	**96%**	**101%**	**95%**	**102%**	**97%**
	103%		**105%**	**101%**	**115%**	**117%**	**99%**	**114%**	**115%**	**102%**
				99%	**106%**	**102%**	**104%**	**97%**	**119%**	**123%**
				100%	**97%**	**100%**	**103%**	**98%**	**102%**	**94%**
				103%	**92%**	**100%**		**95%**	**99%**	**113%**
	98%		**98%**	**98%**	**103%**	**109%**	**95%**	**102%**	**95%**	**104%**
	99%		**102%**	**99%**	**98%**	**100%**	**97%**	**97%**	**99%**	**103%**
	92%		**92%**	**101%**	**102%**	**96%**	**103%**	**99%**	**92%**	**89%**
	102%		**100%**	**103%**	**101%**	**94%**	**103%**	**104%**	**95%**	**99%**
	105%		**101%**	**97%**	**94%**	**94%**	**99%**	**94%**	**95%**	**89%**
	109%		**106%**	**95%**	**96%**	**98%**	**96%**	**94%**	**100%**	**88%**
	113%		**107%**	**94%**	**96%**	**102%**	**102%**	**103%**	**97%**	**100%**
			105%	**94%**	**96%**	**97%**	**121%**	**99%**	**97%**	**94%**
	113%		**103%**	**96%**	**97%**	**104%**	**107%**	**90%**	**97%**	**89%**

Appendix B: Quality Control Metals Data

Sample ID		Zn (µg/g)	Ni (µg/g)	V (µg/g)	Cr (µg/g)	Cu (µg/g)	Ba (µg/g)	Be (µg/g)	Ca (%)	Mg (%)	P (µg/g)	BSi as SiO_2 (%)
Method Blanks												
Blank 062106 r1		< 0.1	<0.33	<0.22	<0.16	<0.16	<0.11	<0.05	<0.001	<0.001	<2.0	<0.0
Blank 062006 r5		0.109	<0.33	<0.22	<0.16	<0.16	<0.11	<0.05	<0.001	<0.001	<0.1	<0.0
Blank 062806 r1		0.598	0.362	<0.22	<0.16	<0.16	<0.11	<0.05	<0.001	<0.001	<2.0	<0.0
Blank 062806 r2		0.264	<0.33	<0.22	<0.16	<0.16	<0.11	<0.05	<0.001	<0.001	<1.9	<0.0
Blank 062706 r1		0.524	<0.33	<0.22	0.186	<0.16	<0.11	<0.05	<0.001	<0.001	<2.0	<0.005
Blank 062706 r2		0.451	<0.33	<0.22	<0.16	<0.16	<0.11	<0.05	<0.001	<0.001	<2.0	<0.004
Blank 060606r1		< 0.1	<0.33	<0.22	<0.16	<0.16	<0.11	<0.05	<0.001	<0.001	<0.1	
Blank 060606r2		0.304	<0.33	<0.22	<0.16	<0.16	<0.11	<0.05	<0.001	<0.001	<0.1	
Blank 060606r3		< 0.1	<0.33	<0.22	<0.16	<0.16	<0.11	0.0575	<0.001	<0.001		
Blank 061406		< 0.1	<0.33	<0.22	<0.16	<0.16	<0.11	0.0716	<0.001	<0.001		
Blank 062006 r4		< 0.1	<0.33	<0.22	<0.16	<0.16	<0.11	0.0615	<0.001	<0.001		
Blank 091106		0.552	<0.33	<0.22	<0.16	<0.16	<0.11	<0.05	<0.001	<0.001		
Blank 083106		< 0.1	<0.33	<0.22	<0.16	<0.16	<0.11	<0.05	<0.001	<0.001		
Blank 032306r1		< 0.1	<0.33	<0.22	<0.16	<0.16	<0.11	<0.05	<0.001	<0.001		
Blank 032306r2		< 0.1	<0.33	<0.22	<0.16	<0.16	<0.11	<0.05	<0.001	<0.001		
Blank 032706r1		0.360	<0.33	<0.22	<0.16	0.285	<0.11	0.130	<0.001	<0.001		
Blank 030806r1		< 0.1	<0.33	<0.22	<0.16	0.173	<0.11	0.130	<0.001	<0.001		
Blank 030806r2		0.553	<0.33	<0.22	<0.16	<0.16	<0.11	0.0693	<0.001	<0.001		
Matrix Spikes												
HC-3	**Percent recovery**	**100%**	**97%**	**93%**	**97%**	**95%**	**97%**	**103%**			**99%**	
HC-3	**Percent recovery**	**102%**	**98%**	**92%**	**97%**	**94%**	**98%**	**102%**			**98%**	
HC-3	**Percent recovery**	**101%**	**96%**	**92%**	**97%**	**96%**	**96%**	**102%**			**105%**	
HC-3	**Percent recovery**	**96%**	**95%**	**91%**	**96%**	**92%**	**91%**	**99%**				
HC-3	**Percent recovery**	**98%**	**92%**	**94%**	**95%**	**95%**	**101%**	**99%**				
HC-3	**Percent recovery**	**103%**	**96%**	**97%**	**99%**	**97%**	**90%**	**99%**				
HC-5	**Percent recovery**	**99%**	**95%**	**97%**	**98%**	**97%**	**91%**	**99%**			**99%**	
HC-5	**Percent recovery**	**99%**	**95%**	**97%**	**98%**	**97%**	**91%**	**99%**			**96%**	
HC-5	**Percent recovery**	**100%**	**94%**	**98%**	**96%**	**98%**	**92%**	**96%**			**106%**	
HC-5	**Percent recovery**	**101%**	**96%**	**102%**	**101%**	**96%**	**98%**	**99%**				
HC-4	**Percent recovery**	**89%**	**92%**	**94%**	**91%**	**91%**	**97%**	**94%**				
HC-1	**Percent recovery**	**96%**	**95%**	**100%**	**101%**	**101%**	**97%**	**100%**				
PS-4	**Percent recovery**	**92%**	**92%**	**94%**	**96%**	**95%**	**103%**	**89%**	**81%**	**97%**		
PS-4	**Percent recovery**	**92%**	**91%**	**95%**	**97%**	**94%**	**91%**	**90%**	**80%**	**82%**		
PS-4	**Percent recovery**	**93%**	**92%**	**96%**	**95%**	**94%**	**101%**	**91%**	**101%**	**90%**		
PS-1	**Percent recovery**	**92%**	**93%**	**96%**	**97%**	**98%**	**108%**	**91%**	**109%**	**98%**	**98%**	
PS-1	**Percent recovery**	**95%**	**93%**	**95%**	**98%**	**94%**	**95%**	**92%**	**90%**	**89%**		

Appendix B: Quality Control Metals Data

Sample ID	Zn (µg/g)	Ni (µg/g)	V (µg/g)	Cr (µg/g)	Cu (µg/g)	Ba (µg/g)	Be (µg/g)	Ca (%)	Mg (%)	P (µg/g)	BSi as SiO_2 (%)
Standard Reference Material											
Mess3 062706 r1	154	45.8	243	101	31.8	1019	2.41	1.47	1.69		
Mess3 062706 r2	155	47.0	237	102	31.2	1016	2.41	1.47	1.70		
Mess3 062806 r1	153	46.1	239	101	32.1	996	2.45	1.42	1.66		
Mess3 062806 r2	154	46.7	236	102	31.6	994	2.51	1.48	1.71		
Mess3 062106 r1	144	43.3	228	96.1	30.3	943	2.37	1.36	1.64		
Mess3 062006 r2	151	45.0	234	98.7	30.7	956	2.49	1.42	1.69		
Mess3 060606r1	143	44.7	239	98.9	32.5	1000	2.18	1.40	1.63		
Mess3 060606r2	149	45.5	241	101	32.0	1001	2.29	1.40	1.68		
Mess3 060606r3	147	45.7	238	101	32.0	932	2.27	1.39	1.70		
Mess3 061406	144	42.8	232	96.1	31.2	968	2.14	1.42	1.61		
Mess3 062006 r1	152	44.0	234	97.8	31.5	940	2.24	1.47	1.67		
MESS-3 091106	142	43.3	232	96.1	30.0	975	2.31	1.41	1.63		
MESS-3 083106	142	44.3	232	98.6	31.2	964	2.21	1.40	1.60		
Mess3 032306r1	136	40.7	224	95.6	31.5	965	2.06	1.36	1.58		
Mess3 032306r2	141	42.3	229	97.6	30.6	1001	2.11	1.38	1.61		
Mess3 032706r1	144	42.6	233	99.4	30.5	1018	2.26	1.43	1.64		
Mess3 030806r1	138	41.4	226	96.9	30.3	1022	2.04	1.40	1.61		
Mess3 030806r2	144	42.9	231	98.8	31.6	1004	2.21	1.39	1.63		
certified value	159	46.9	243	105	33.9	NC	2.30	1.47	1.6		
range	*8*	*2.2*	*10*	*4*	*1.6*		*0.12*	*0.06*	*REF*		
percent recovery	**97%**	**98%**	**100%**	**96%**	**94%**		**105%**	**100%**	**106%**		
percent recovery	**98%**	**100%**	**98%**	**97%**	**92%**		**105%**	**100%**	**106%**		
percent recovery	**96%**	**98%**	**98%**	**96%**	**95%**		**107%**	**96%**	**104%**		
percent recovery	**97%**	**100%**	**97%**	**98%**	**93%**		**109%**	**101%**	**107%**		
percent recovery	**91%**	**92%**	**94%**	**91%**	**89%**		**103%**	**93%**	**103%**		
percent recovery	**95%**	**96%**	**96%**	**94%**	**91%**		**108%**	**97%**	**106%**		
percent recovery	**90%**	**95%**	**98%**	**94%**	**96%**		**95%**	**95%**	**102%**		
percent recovery	**94%**	**97%**	**99%**	**96%**	**94%**		**100%**	**95%**	**105%**		
percent recovery	**93%**	**97%**	**98%**	**96%**	**94%**		**99%**	**95%**	**106%**		
percent recovery	**90%**	**91%**	**95%**	**91%**	**92%**		**93%**	**97%**	**101%**		
percent recovery	**96%**	**94%**	**96%**	**93%**	**93%**		**97%**	**100%**	**104%**		
percent recovery	**89%**	**92%**	**96%**	**91%**	**88%**		**100%**	**96%**	**102%**		
percent recovery	**89%**	**94%**	**95%**	**94%**	**92%**		**96%**	**95%**	**100%**		
percent recovery	**86%**	**87%**	**92%**	**91%**	**93%**		**90%**	**93%**	**99%**		
percent recovery	**89%**	**90%**	**94%**	**93%**	**90%**		**92%**	**94%**	**101%**		
percent recovery	**91%**	**91%**	**96%**	**95%**	**90%**		**98%**	**97%**	**103%**		
percent recovery	**87%**	**88%**	**93%**	**92%**	**90%**		**89%**	**95%**	**101%**		
percent recovery	**91%**	**91%**	**95%**	**94%**	**93%**		**96%**	**95%**	**102%**		

Appendix B: Quality Control Metals Data

Sample ID	Zn (µg/g)	Ni (µg/g)	V (µg/g)	Cr (µg/g)	Cu (µg/g)	Ba (µg/g)	Be (µg/g)	Ca (%)	Mg (%)	P (µg/g)	BSi as SiO_2 (%)
Standard Reference Material											
2702 062706 r1	460	68.9	347	314	111	389	2.83	0.325	0.912		
2702 062706 r2	469	69.9	351	317	112	385	2.93	0.324	0.927		
2702 062806 r1	460	71.6	347	319	112	386	3.01	0.322	0.934		
2702 062806 r2	479	74.1	349	323	113	385	3.13	0.341	0.974		
2702 062106 r1	465	71.9	359	324	115	386	2.99	0.320	0.945		
2702 062006 r3	459	70.5	344	314	111	365	3.00	0.315	0.944		
2702 060606r1	421	66.8	337	305	109	378	2.44	0.313	0.863		
2702 060606r2	430	67.6	341	309	110	386	2.56	0.309	0.891		
2702 060606r3	446	70.9	349	321	110	362	2.59	0.308	0.926		
2702 061406	434	65.4	340	306	109	374	2.48	0.315	0.876		
2702 062006 r2	458	69.6	347	314	113	342	2.56	0.318	0.892		
2702 091106	434	68.3	342	302	107	369	2.77	0.319	0.889		
2702 083106	443	68.3	348	315	113	372	2.69	0.322	0.881		
2702 032306r1	410	64.3	329	305	108	382	2.48	0.313	0.872		
2702 032306r2	419	64.4	332	303	107	367	2.47	0.310	0.860		
2702 032706r1	432	66.7	342	311	111	394	2.65	0.321	0.912		
2702 030806r1	419	64.5	334	306	108	392	2.42	0.323	0.890		
2702 030806r2	437	68.0	345	314	111	322	2.67	0.300	0.896		
certified value	485	75.4	358	352	118	397	3.0	0.343	0.99		
range	*4.2*	*1.5*	*9.2*	*22*	*REF*	*3.2*	*REF*	*0.024*	*REF*		
percent recovery	**95%**	**91%**	**97%**	**89%**	**94%**	**98%**	**94%**	**95%**	**92%**		
percent recovery	**97%**	**93%**	**98%**	**90%**	**95%**	**97%**	**98%**	**94%**	**94%**		
percent recovery	**95%**	**95%**	**97%**	**91%**	**95%**	**97%**	**100%**	**94%**	**94%**		
percent recovery	**99%**	**98%**	**98%**	**92%**	**96%**	**97%**	**104%**	**100%**	**98%**		
percent recovery	**96%**	**95%**	**100%**	**92%**	**97%**	**97%**	**100%**	**93%**	**95%**		
percent recovery	**95%**	**94%**	**96%**	**89%**	**94%**	**92%**	**100%**	**92%**	**95%**		
percent recovery	**87%**	**89%**	**94%**	**87%**	**93%**	**95%**	**81%**	**91%**	**87%**		
percent recovery	**89%**	**90%**	**95%**	**88%**	**93%**	**97%**	**85%**	**90%**	**90%**		
percent recovery	**92%**	**94%**	**98%**	**91%**	**93%**	**91%**	**86%**	**90%**	**94%**		
percent recovery	**89%**	**87%**	**95%**	**87%**	**92%**	**94%**	**83%**	**92%**	**88%**		
percent recovery	**94%**	**92%**	**97%**	**89%**	**96%**	**86%**	**85%**	**93%**	**90%**		
percent recovery	**89%**	**91%**	**96%**	**86%**	**91%**	**93%**	**92%**	**93%**	**90%**		
percent recovery	**91%**	**91%**	**97%**	**90%**	**96%**	**94%**	**90%**	**94%**	**89%**		
percent recovery	**85%**	**85%**	**92%**	**87%**	**92%**	**96%**	**83%**	**91%**	**88%**		
percent recovery	**86%**	**85%**	**93%**	**86%**	**91%**	**92%**	**82%**	**90%**	**87%**		
percent recovery	**89%**	**88%**	**96%**	**88%**	**94%**	**99%**	**88%**	**94%**	**92%**		
percent recovery	**86%**	**86%**	**93%**	**87%**	**91%**	**99%**	**81%**	**94%**	**90%**		
percent recovery	**90%**	**90%**	**96%**	**89%**	**94%**	**81%**	**89%**	**87%**	**91%**		

Appendix B: Quality Control Metals Data

Sample ID		Zn (µg/g)	Ni (µg/g)	V (µg/g)	Cr (µg/g)	Cu (µg/g)	Ba (µg/g)	Be (µg/g)	Ca (%)	Mg (%)	P (µg/g)	BSi as SiO_2 (%)
Reference Material for BSi												
Chesapeake Bay R-64 r1												6.69
Chesapeake Bay R-64 r2												6.88
Chesapeake Bay R-64 r3												6.83
Chesapeake Bay R-64 r4												6.48
Chesapeake Bay R-64 r5												6.82
Chesapeake Bay R-64 r6												6.99
Chesapeake Bay R-64 r7												6.32
	Published Value											6.49
	range											2.09
	percent recovery											**103%**
	percent recovery											**106%**
	percent recovery											**105%**
	percent recovery											**100%**
	percent recovery											**105%**
	percent recovery											**108%**
	percent recovery											**97%**
Still Pond Chesapeake Bay r1												2.57
Still Pond Chesapeake Bay r2												2.53
	Published Value											2.82
	range											1.17
	percent recovery											**91%**
	percent recovery											**90%**
Replicates												
HC-3	45 or 5 (P)	100	64.1	207	109	89.0	251	1.15	2.65	2.60	828	
HC-3	45 or 5 (P)	98.0	62.8	203	106	87.6	246	1.14	2.36	2.55	867	
	RPD	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**0%**	**12%**	**2%**	**5%**	
HC-3	17 or 69 (P)	121	63.9	204	105	95.3	223	1.13	2.40	2.64	672	
HC-3	17 or 69 (P)	121	64.0	205	106	95.7	222	1.14	2.42	2.63	717	
	RPD	**0%**	**0%**	**0%**	**1%**	**0%**	**0%**	**1%**	**1%**	**0%**	**6%**	
HC-3	97 or 141 (P)	99.8	63.5	205	107	88.6	264	1.08	2.42	2.59	676	
HC-3	97 or 141 (P)	103	64.9	209	110	90.5	267	1.09	2.64	2.61	694	
	RPD	**3%**	**2%**	**2%**	**3%**	**2%**	**1%**	**1%**	**9%**	**1%**	**3%**	
HC-3	135	102	64.9	209	108	94.5	276	1.09	2.49	2.68		
HC-3	135	103	65.4	210	109	95.1	270	1.11	2.40	2.67		
	RPD	**1%**	**1%**	**1%**	**1%**	**1%**	**2%**	**2%**	**4%**	**0%**		
HC-3	169	103	68.8	215	116	97.3	273	1.24	2.52	2.71		
HC-3	169	100	65.8	205	112	92.5	266	1.22	2.38	2.61		
	RPD	**2%**	**4%**	**5%**	**3%**	**5%**	**3%**	**1%**	**6%**	**4%**		
HC-3	207.5	102	69.4	202	111	89.0	261	1.19	2.52	2.79		
HC-3	207.5	103	69.7	204	112	90.2	261	1.18	2.65	2.82		
	RPD	**1%**	**0%**	**1%**	**1%**	**1%**	**0%**	**0%**	**5%**	**1%**		

Sample ID		Zn (µg/g)	Ni (µg/g)	V (µg/g)	Cr (µg/g)	Cu (µg/g)	Ba (µg/g)	Be (µg/g)	Ca (%)	Mg (%)	P (µg/g)	BSi as SiO_2 (%)
Replicates, cont.												
HC-5	1 or 81 (P)	98.6	47.0	139	85.2	46.8	369	1.02	1.42	1.76	617	
HC-5	1 or 81 (P)	97.0	45.7	137	81.8	46.2	359	1.01	1.40	1.75	653	
	RPD	**2%**	**3%**	**1%**	**4%**	**1%**	**3%**	**1%**	**1%**	**1%**	**6%**	
HC-5	47 or 162.5 (P)	108	49.6	143	88.6	47.1	383	1.20	1.36	1.75	626	
HC-5	47 or 162.5 (P)	108	49.3	143	86.5	47.5	381	1.21	1.37	1.76	608	
	RPD	**0%**	**1%**	**0%**	**2%**	**1%**	**1%**	**1%**	**1%**	**1%**	**3%**	
HC-5	73 or 252.5 (P)	84.6	47.6	134	83.8	39.9	335		1.34	1.65	600	
HC-5	73 or 252.5 (P)	91.1	49.5	144	88.0	44.0	368		1.36	1.82	623	
	RPD	**7%**	**4%**	**7%**	**5%**	**10%**	**9%**		**1%**	**10%**	**4%**	
HC-5	87	89.5	47.6	141	86.2	42.6	379	1.11	1.48	1.70		
HC-5	87	89.3	47.3	140	85.6	42.2	378	1.09	1.47	1.69		
	RPD	**0%**	**1%**	**0%**	**1%**	**1%**	**0%**	**2%**	**1%**	**1%**		
HC-5	197.5	89.3	48.1	140	87.2	40.9	356	1.19	1.66	1.79		
HC-5	197.5	88.7	47.6	137	86.5	41.0	370	1.17	1.50	1.79		
	RPD	**1%**	**1%**	**2%**	**1%**	**0%**	**4%**	**2%**	**10%**	**0%**		
HC-4	52.5	99.0	60.6	187	98.5	74.4	297	1.16	2.09	2.39		
HC-4	52.5	97.8	60.0	188	98.6	73.7	300	1.15	1.95	2.38		
	RPD	**1%**	**1%**	**1%**	**0%**	**1%**	**1%**	**1%**	**7%**	**0%**		
HC-1	17	92.3	67.8	259	182	105	171	0.804	4.64	3.03		
HC-1	17	92.6	68.1	260	180	105	172	0.805	4.62	3.05		
	RPD	**0%**	**0%**	**0%**	**1%**	**0%**	**1%**	**0%**	**0%**	**1%**		
PS-4	1	96.2	39.8	107	79.3	37.3	377	0.976	1.49	1.49		
PS-4	1	92.1	38.1	102	74.8	35.6	363	0.952	1.44	1.45		
	RPD	**4%**	**4%**	**4%**	**6%**	**5%**	**4%**	**3%**	**3%**	**3%**		
PS-4	57.5	109	43.3	115	86.4	42.2	414	1.06	1.61	1.51		
PS-4	57.5	108	43.0	114	83.6	42.5	409	1.05	1.59	1.50		
	RPD	**1%**	**1%**	**1%**	**3%**	**1%**	**1%**	**1%**	**1%**	**1%**		
PS-4	137.5	118	46.3	121	85.5	49.0	429	1.18	1.60	1.59		
PS-4	137.5	117	46.1	120	84.7	48.9	427	1.19	1.62	1.57		
	RPD	**1%**	**1%**	**1%**	**1%**	**0%**	**0%**	**1%**	**1%**	**1%**		
PS-1	1 or 41 (P)	102	37.8	107	66.7	48.2	373	1.01	1.89	1.55	714	
PS-1	1 or 41 (P)	104	39.1	108	68.6	48.7	383	1.04	1.83	1.59	711	
	RPD	**1%**	**3%**	**1%**	**3%**	**1%**	**3%**	**3%**	**3%**	**3%**	**0%**	
PS-1	51	118	41.0	111	70.6	62.3	385	1.13	1.69	1.48		
PS-1	51	119	41.7	113	72.2	62.6	385	1.16	1.71	1.51		
	RPD	**1%**	**2%**	**1%**	**2%**	**1%**	**0%**	**3%**	**1%**	**2%**		

Appendix B: Quality Control Metals Data

Sample ID	Zn (µg/g)	Ni (µg/g)	V (µg/g)	Cr (µg/g)	Cu (µg/g)	Ba (µg/g)	Be (µg/g)	Ca (%)	Mg (%)	P (µg/g)	BSi as SiO_2 (%)
Laboratory Control Sample											
LCS062106 r1	24.8	24.9	24.5	25.4	25.5	24.9	2.00	0.028	0.027	473	
LCS062006 r2	26.0	25.5	24.4	25.6	25.4	24.2	2.04	0.029	0.028	490	
LCS062806 r1	26.0	26.0	24.7	26.1	25.8	25.4	2.05	0.029	0.028	490	
LCS062806 r2	26.2	26.4	24.4	26.0	25.6	25.2	2.08	0.031	0.029	474	
LCS062706 r1	26.1	25.7	25.1	26.0	25.5	25.8	25.2	0.030	0.029	473	
LCS062706 r2	26.0	25.7	25.0	26.0	25.3	25.4	25.1	0.030	0.029	509	
LCS060606r1	23.9	25.6	24.8	26.1	25.4	25.0	24.8			506	
LCS060606r2	24.7	25.6	24.9	25.8	25.6	25.0	25.2			475	
LCS060606r3	25.2	26.6	25.2	26.6	25.4	23.9	25.1				
LCS061406	24.4	24.6	24.8	25.4	24.4	24.7	2.01	0.256	0.249		
LCS062006 r1	24.5	25.2	24.5	25.3	24.6	23.6	2.09	0.029	0.028		
LCS091106	42.0	25.4	24.4	24.9	25.1	25.1	24.3				
LCS083106	24.8	25.0	24.7	25.8	25.6	24.9	1.92	0.011	0.010		
LCS032306r1	24.0	25.2	24.4	25.5	25.1	24.5	1.80	0.003	0.003		
LCS032306r2	24.2	25.2	24.7	25.4	25.3	24.8	1.87	0.002	0.002		
LCS032706r1	24.6	25.0	24.6	24.9	25.4	25.1	2.06	0.003	0.002		
LCS030806r1	30.2	25.1	24.5	25.2	25.2	24.7	1.81	0.003	0.003		
LCS030806r2	25.0	25.1	24.8	25.9	25.5	25.4	1.98	0.003	0.002		
	99%	**100%**	**98%**	**102%**	**102%**	**100%**	**100%**	**103%**	**99%**	**93%**	
	104%	**102%**	**97%**	**101%**	**101%**	**97%**	**102%**	**106%**	**102%**	**96%**	
	104%	**104%**	**99%**	**104%**	**103%**	**102%**	**103%**	**107%**	**101%**	**96%**	
	105%	**106%**	**98%**	**104%**	**102%**	**101%**	**104%**	**114%**	**105%**	**93%**	
	104%	**103%**	**101%**	**104%**	**102%**	**103%**	**101%**	**108%**	**104%**	**93%**	
	104%	**103%**	**100%**	**104%**	**101%**	**102%**	**100%**	**107%**	**104%**	**100%**	
	96%	**102%**	**99%**	**104%**	**101%**	**100%**	**99%**			**99%**	
	99%	**102%**	**99%**	**103%**	**102%**	**100%**	**101%**			**93%**	
	101%	**106%**	**101%**	**106%**	**102%**	**96%**	**100%**				
	98%	**98%**	**99%**	**101%**	**98%**	**99%**	**101%**	**101%**	**99%**		
	98%	**101%**	**98%**	**101%**	**98%**	**94%**	**104%**	**104%**	**103%**		
	84%	**102%**	**98%**	**100%**	**100%**	**100%**	**97%**				
	99%	**100%**	**99%**	**103%**	**103%**	**100%**	**96%**	**108%**	**98%**		
	96%	**101%**	**97%**	**102%**	**100%**	**98%**	**90%**	**104%**	**100%**		
	97%	**101%**	**99%**	**102%**	**101%**	**99%**	**93%**	**95%**	**92%**		
	98%	**100%**	**99%**	**100%**	**102%**	**100%**	**103%**	**104%**	**95%**		
	121%	**100%**	**98%**	**101%**	**101%**	**99%**	**91%**	**116%**	**126%**		
	100%	**100%**	**99%**	**104%**	**102%**	**102%**	**99%**	**101%**	**94%**		

Appendix C: Organic Matter Data for Puget Sound and Hood Canal Sediment Cores 2005

Core ID	Core Section (cm)	Mid-Depth (cm)	N (%)	$d^{15}N$ Air	C (%)	$d^{13}C$ PDB	(C/N)a	Fterr	Fmar
HC-3	0-2	1	0.29	6.8	2.62	-23.0	10.5	47%	53%
HC-3	2-4	3	0.28	6.8	2.54	-23.4	10.6	52%	48%
HC-3	4-6	5	0.28	6.4	2.57	-23.3	10.5	51%	49%
HC-3	6-8	7	0.26	6.4	2.41	-23.3	11.0	50%	50%
HC-3	8-10	9	0.26	6.5	2.44	-23.3	11.1	51%	49%
HC-3	10-12	11	0.26	6.3	2.44	-23.3	11.1	50%	50%
HC-3	12-14	13	0.26	6.3	2.46	-23.5	11.2	53%	47%
HC-3	16-18	17	0.25	6.0	2.44	-23.5	11.4	54%	46%
HC-3	18-20	19	0.25	6.2	2.44	-23.5	11.5	54%	46%
HC-3	20-22	21	0.26	6.5	2.51	-23.5	11.4	53%	47%
HC-3	22-24	23	0.26	6.5	2.56	-23.5	11.5	54%	46%
HC-3	24-26	25	0.25	6.6	2.51	-23.5	11.6	53%	47%
HC-3	26-28	27	0.24	6.8	2.41	-23.4	11.6	52%	48%
HC-3	28-30	29	0.24	6.6	2.41	-23.6	11.9	55%	45%
HC-3	30-32	31	0.23	6.7	2.28	-23.2	11.4	49%	51%
HC-3	32-34	33	0.23	6.6	2.22	-23.1	11.3	48%	52%
HC-3	34-36	35	0.23	6.8	2.20	-23.1	11.2	48%	52%
HC-3	36-38	37	0.23	6.4	2.14	-23.0	10.8	47%	53%
HC-3	38-40	39	0.23	6.8	2.15	-23.0	10.8	47%	53%
HC-3	40-42	41	0.23	6.8	2.16	-23.0	10.9	46%	54%
HC-3	42-44	43	0.24	6.5	2.17	-22.8	10.8	43%	57%
HC-3	44-46	45	0.24	6.8	2.21	-22.8	10.7	43%	57%
HC-3	46-48	47	0.23	6.6	2.13	-22.9	10.9	45%	55%
HC-3	48-50	49	0.24	6.8	2.19	-22.8	10.7	44%	56%
HC-3	50-52	51	0.24	6.9	2.16	-22.8	10.7	43%	57%
HC-3	52-54	53	0.24	6.8	2.16	-22.8	10.5	44%	56%
HC-3	54-56	55	0.23	7.1	2.12	-22.8	10.5	44%	56%
HC-3	56-58	57	0.24	7.1	2.27	-22.7	11.2	42%	58%
HC-3	58-60	59	0.24	7.3	2.32	-22.6	11.1	41%	59%
HC-3	60-62	61	0.24	7.2	2.29	-22.6	11.3	40%	60%
HC-3	62-64	63	0.24	7.3	2.32	-22.6	11.3	41%	59%
HC-3	64-66	65	0.24	7.1	2.31	-22.5	11.2	40%	60%
HC-3	66-68	67	0.24	7.4	2.33	-22.5	11.2	39%	61%
HC-3	68-70	69	0.25	6.7	2.30	-22.0	10.6	33%	67%
HC-3	70-72	71	0.26	7.2	2.32	-21.8	10.4	30%	70%
HC-3	72-74	73	0.26	7.1	2.27	-22.0	10.3	33%	67%
HC-3	74-76	75	0.26	6.9	2.24	-22.2	10.2	35%	65%
HC-3	76-78	77	0.25	7.0	2.20	-22.1	10.3	35%	65%
HC-3	78-80	79	0.25	6.9	2.20	-22.1	10.4	35%	65%
HC-3	80-82	81	0.24	6.8	2.20	-22.2	10.5	36%	64%
HC-3	82-84	83	0.25	6.5	2.18	-22.4	10.4	38%	62%
HC-3	84-86	85	0.25	6.7	2.19	-22.4	10.4	39%	61%
HC-3	86-88	87	0.25	6.6	2.20	-22.4	10.4	38%	62%
HC-3	88-90	89	0.25	6.7	2.19	-22.5	10.4	39%	61%
HC-3	90-92	91	0.24	6.9	2.17	-22.4	10.4	38%	62%
HC-3	92-94	93	0.24	6.8	2.17	-22.3	10.3	37%	63%
HC-3	94-96	95	0.25	6.9	2.15	-22.3	10.2	36%	64%

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Core ID	Core Section (cm)	Mid-Depth (cm)	N (%)	$d^{15}N$ Air	C (%)	$d^{13}C$ PDB	(C/N)a	Fterr	Fmar
HC-3	96-98	97	0.24	7.0	2.13	-22.2	10.6	35%	65%
HC-3	98-100	99	0.24	6.7	2.11	-22.2	10.4	36%	64%
HC-3	100-102	101	0.23	6.8	2.08	-22.4	10.4	38%	62%
HC-3	102-104	103	0.22	6.9	1.95	-22.4	10.4	38%	62%
HC-3	104-106	105	0.22	7.2	1.97	-22.6	10.2	41%	59%
HC-3	106-108	107	0.22	6.8	1.95	-22.7	10.3	42%	58%
HC-3	108-110	109	0.23	7.0	2.01	-22.5	10.3	40%	60%
HC-3	110-112	111	0.23	7.2	2.02	-22.6	10.4	42%	58%
HC-3	112-114	113	0.23	6.6	2.01	-22.6	10.2	40%	60%
HC-3	114-116	115	0.23	6.9	2.00	-22.7	10.2	42%	58%
HC-3	116-118	117	0.23	7.0	2.03	-22.7	10.2	43%	57%
HC-3	118-120	119	0.23	7.0	1.99	-22.6	10.2	41%	59%
HC-3	120-122	121	0.22	6.7	2.02	-22.8	10.6	44%	56%
HC-3	122-124	123	0.21	7.5	1.77	-23.1	9.7	48%	52%
HC-3	124-126	125	0.20	7.2	1.75	-22.6	10.1	41%	59%
HC-3	126-128	127	0.20	7.2	1.76	-22.5	10.1	40%	60%
HC-3	128-130	129	0.20	7.0	1.75	-22.6	10.2	41%	59%
HC-3	130-132	131	0.20	7.1	1.74	-22.6	10.1	40%	60%
HC-3	132-134	133	0.20	7.2	1.77	-22.7	10.2	43%	57%
HC-3	134-136	135	0.20	7.2	1.74	-22.6	10.1	41%	59%
HC-3	136-138	137	0.20	7.4	1.67	-23.0	9.9	46%	54%
HC-3	138-140	139	0.19	6.7	1.68	-22.8	10.3	44%	56%
HC-3	140-142	141	0.19	5.8	1.72	-22.4	10.8	39%	61%
HC-3	142-144	143	0.18	5.8	1.71	-22.4	10.8	39%	61%
HC-3	144-146	145	0.19	6.2	1.76	-22.8	10.8	44%	56%
HC-3	146-148	147	0.20	6.1	1.77	-23.2	10.6	49%	51%
HC-3	148-150	149	0.19	6.1	1.78	-23.2	10.8	49%	51%
HC-3	150-152	151	0.20	6.2	1.82	-22.9	10.8	45%	55%
HC-3	152-154	153	0.20	6.5	1.85	-22.7	10.8	42%	58%
HC-3	154-156	155	0.20	6.1	1.92	-22.4	11.0	39%	61%
HC-3	156-158	157	0.20	6.3	1.84	-22.6	10.9	41%	59%
HC-3	160-162	161	0.19	6.3	1.79	-22.7	10.8	42%	58%
HC-3	162-164	163	0.19	6.4	1.77	-22.6	10.7	42%	58%
HC-3	164-166	165	0.18	6.4	1.70	-22.4	10.8	38%	62%
HC-3	166-168	167	0.18	6.6	1.66	-22.6	10.7	41%	59%
HC-3	170-172	171	0.17	6.1	1.60	-22.8	10.8	43%	57%
HC-3	174-176	175	0.18	6.3	1.69	-22.9	11.1	45%	55%
HC-3	176-178	177	0.19	6.2	1.71	-22.8	10.7	43%	57%
HC-3	178-180	179	0.16	6.3	1.47	-22.9	10.7	45%	55%
HC-3	180-182	181	0.17	6.4	1.57	-22.5	10.9	39%	61%
HC-3	182-184	183	0.17	6.6	1.57	-22.6	10.9	40%	60%
HC-3	184-186	185	0.15	6.4	1.39	-23.3	11.0	51%	49%
HC-3	186-188	187	0.15	6.8	1.26	-24.0	10.1	60%	40%
HC-3	188-190	189	0.11	6.8	1.08	-24.1	11.0	62%	38%
HC-3	190-192	191	0.13	6.6	1.27	-23.6	11.3	55%	45%
HC-3	192-194	193	0.20	7.4	1.86	-22.9	11.0	46%	54%
HC-3	194-196	195	0.20	7.5	1.88	-23.0	11.0	46%	54%

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Core ID	Core Section (cm)	Mid-Depth (cm)	N (%)	$d^{15}N$ Air	C (%)	$d^{13}C$ PDB	(C/N)a	Fterr	Fmar
HC-3	196-198	197	0.21	7.4	1.94	-23.0	11.0	46%	54%
HC-3	198-200	199	0.20	7.2	1.99	-23.0	11.3	46%	54%
HC-3	200-205	201	0.20	7.4	1.88	-22.5	11.1	40%	60%
HC-3	205-210	207.5	0.19	7.2	1.84	-22.4	11.0	38%	62%
HC-3	210-215	212.5	0.20	7.6	1.87	-22.8	11.0	44%	56%
HC-5	0-2	1	0.27	6.1	2.48	-23.0	10.9	47%	53%
HC-5	2-4	3	0.27	6.0	2.44	-23.1	10.7	48%	52%
HC-5	4-6	5	0.28	6.1	2.55	-23.2	10.7	49%	51%
HC-5	6-8	7	0.28	6.2	2.51	-23.1	10.6	48%	52%
HC-5	8-10	9	0.28	6.1	2.54	-23.1	10.7	48%	52%
HC-5	10-12	11	0.28		2.52	-23.0	10.7	46%	54%
HC-5	12-14	13	0.27	6.2	2.48	-23.2	10.7	50%	50%
HC-5	14-16	15	0.26	6.0	2.44	-23.3	10.8	50%	50%
HC-5	16-18	17	0.27	6.1	2.47	-23.2	10.8	50%	50%
HC-5	18-20	19	0.27	6.1	2.48	-23.3	10.8	50%	50%
HC-5	20-22	21	0.25	5.9	2.41	-23.2	11.0	49%	51%
HC-5	22-24	23	0.25	5.9	2.41	-23.1	11.2	49%	51%
HC-5	24-26	25	0.26	5.8	2.40	-23.2	10.9	50%	50%
HC-5	26-28	27	0.25	5.8	2.41	-23.2	11.1	49%	51%
HC-5	28-30	29	0.26	5.7	2.52	-23.2	11.4	49%	51%
HC-5	30-32	31	0.25	5.9	2.44	-23.3	11.3	51%	49%
HC-5	32-34	33	0.25	5.8	2.48	-23.4	11.4	52%	48%
HC-5	34-36	35	0.26	5.8	2.53	-23.5	11.4	53%	47%
HC-5	36-38	37	0.25	5.7	2.48	-23.5	11.4	53%	47%
HC-5	38-40	39	0.25	5.9	2.43	-23.5	11.6	54%	46%
HC-5	40-42	41	0.24	5.9	2.38	-23.3	11.5	51%	49%
HC-5	42-44	43	0.23	6.1	2.26	-23.1	11.3	48%	52%
HC-5	44-46	45	0.24	6.2	2.32	-23.1	11.2	48%	52%
HC-5	46-48	47	0.24	6.0	2.30	-23.2	11.2	50%	50%
HC-5	48-50	49	0.24	6.0	2.27	-23.1	11.2	48%	52%
HC-5	50-52	51	0.24	5.9	2.20	-23.2	10.9	49%	51%
HC-5	52-54	53	0.23	5.7	2.22	-23.2	11.1	50%	50%
HC-5	54-56	55	0.23	6.0	2.19	-23.3	11.0	51%	49%
HC-5	56-58	57	0.23	6.0	2.19	-23.2	11.1	50%	50%
HC-5	58-60	59	0.23	6.3	2.13	-23.0	10.9	47%	53%
HC-5	60-62	61	0.22	6.1	2.05	-22.7	10.8	43%	57%
HC-5	62-64	63	0.23	6.2	2.06	-22.8	10.5	44%	56%
HC-5	64-66	65	0.22	6.0	2.05	-22.7	10.8	42%	58%
HC-5	66-68	67	0.23	6.1	2.05	-22.8	10.6	44%	56%
HC-5	68-70	69	0.23	5.6	2.10	-23.2	10.8	49%	51%
HC-5	70-72	71	0.23	5.7	2.10	-23.0	10.8	47%	53%
HC-5	72-74	73	0.22	5.8	2.13	-22.5	11.1	39%	61%
HC-5	74-76	75	0.22	6.1	2.14	-22.1	11.1	34%	66%
HC-5	76-78	77	0.22	6.1	2.07	-21.9	11.0	31%	69%
HC-5	78-80	79	0.23	6.2	2.15	-21.8	10.9	30%	70%
HC-5	80-82	81	0.23	6.4	2.14	-21.7	10.6	28%	72%
HC-5	82-84	83	0.23	6.1	2.12	-21.8	10.8	30%	70%

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Core ID	Core Section (cm)	Mid-Depth (cm)	N (%)	$d^{15}N$ Air	C (%)	$d^{13}C$ PDB	(C/N)a	Fterr	Fmar
HC-5	84-86	85	0.23	6.5	2.14	-22.6	10.8	41%	59%
HC-5	88-90	89	0.23	6.4	2.18	-22.4	10.8	38%	62%
HC-5	90-92	91	0.24	6.4	2.20	-22.4	10.9	38%	62%
HC-5	92-94	93	0.24	6.7	2.21	-22.9	11.0	46%	54%
HC-5	94-96	95	0.23	6.6	2.13	-22.3	10.7	36%	64%
HC-5	96-100	98	0.24	6.5	2.16	-22.3	10.7	37%	63%
HC-5	100-105	102.5	0.24	6.5	2.14	-22.4	10.5	38%	62%
HC-5	105-110	107.5	0.23	6.3	2.13	-22.5	10.6	39%	61%
HC-5	110-115	112.5	0.23	6.4	2.09	-22.6	10.5	41%	59%
HC-5	120-125	122.5	0.23	6.6	2.11	-22.1	10.5	34%	66%
HC-5	125-130	127.5	0.23	6.4	2.06	-22.3	10.4	36%	64%
HC-5	130-135	132.5	0.22	6.3	2.06	-22.2	10.7	35%	65%
HC-5	135-140	137.5	0.23	6.4	2.05	-22.3	10.6	36%	64%
HC-5	140-145	142.5	0.23	6.7	2.09	-22.1	10.5	34%	66%
HC-5	145-150	147.5	0.23	6.5	2.06	-22.2	10.5	35%	65%
HC-5	150-155	152.5	0.23	6.5	2.06	-22.2	10.5	35%	65%
HC-5	155-160	157.5	0.23	6.8	2.05	-22.4	10.4	38%	62%
HC-5	160-165	162.5	0.22	6.6	1.96	-22.2	10.4	35%	65%
HC-5	165-170	167.5	0.23	6.6	2.04	-22.1	10.4	35%	65%
HC-5	170-175	172.5	0.22	6.6	2.01	-22.0	10.5	33%	67%
HC-5	175-180	177.5	0.23	6.7	2.08	-22.1	10.4	34%	66%
HC-5	180-185	182.5	0.24	6.7	2.11	-22.0	10.2	32%	68%
HC-5	185-190	187.5	0.24	6.8	2.12	-22.0	10.3	33%	67%
HC-5	190-195	192.5	0.22	6.5	2.02	-22.3	10.5	37%	63%
HC-5	195-200	197.5	0.22	6.5	2.00	-22.9	10.5	45%	55%
HC-5	200-205	202.5	0.22	6.8	2.06	-22.8	10.7	43%	57%
HC-5	205-210	207.5	0.22	6.3	2.03	-22.3	10.8	37%	63%
HC-5	210-215	212.5	0.23	6.6	2.05	-22.3	10.5	37%	63%
HC-5	215-220	217.5	0.24	6.4	2.10	-22.2	10.3	35%	65%
HC-5	220-225	222.5	0.23	6.5	2.01	-22.1	10.4	34%	66%
HC-5	225-230	227.5	0.23	6.6	2.02	-22.2	10.3	35%	65%
HC-5	230-235	232.5	0.22	6.3	1.99	-22.3	10.6	36%	64%
HC-5	235-240	237.5	0.23	6.4	2.02	-22.5	10.5	40%	60%
HC-5	240-245	242.5	0.23	6.6	2.04	-22.4	10.4	39%	61%
HC-5	245-250	247.5	0.23	6.5	2.05	-22.5	10.2	40%	60%
HC-5	250-255	252.5	0.23	6.7	2.00	-22.3	10.2	36%	64%
HC-5	255-260	257.5	0.22	6.4	1.96	-22.5	10.3	39%	61%
PS-1	0-2	1	0.25	6.5	2.3	-22.3	11	37%	63%
PS-1	2-4	3	0.25	6.4	2.4	-22.3	11	37%	63%
PS-1	4-6	5	0.25	6.3	2.3	-22.2	11	36%	64%
PS-1	6-8	7	0.25	6.1	2.4	-22.4	11	38%	62%
PS-1	8-10	9	0.25	6.5	2.3	-22.2	11	36%	64%
PS-1	10-12	11	0.28	6.2	2.4	-22.3	10	37%	63%
PS-1	12-14	13	0.24	6.4	2.3	-22.5	11	39%	61%
PS-1	14-16	15	0.24	6.0	2.3	-22.3	11	37%	63%
PS-1	16-18	17	0.24	6.1	2.3	-22.4	11	39%	61%
PS-1	18-20	19	0.23	6.4	2.3	-22.8	11	44%	56%

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Core ID	Core Section (cm)	Mid-Depth (cm)	N (%)	$d^{15}N$ Air	C (%)	$d^{13}C$ PDB	(C/N)a	Fterr	Fmar
PS-1	20-22	21	0.23	6.5	2.3	-22.7	11	43%	57%
PS-1	22-24	23	0.23	6.3	2.3	-22.6	11	40%	60%
PS-1	24-26	25	0.23	6.3	2.3	-22.5	11	39%	61%
PS-1	26-28	27	0.23	6.2	2.2	-22.6	12	41%	59%
PS-1	28-30	29	0.23	6.4	2.3	-22.5	11	40%	60%
PS-1	30-32	31	0.23	6.3	2.3	-22.7	12	42%	58%
PS-1	32-34	33	0.22	6.2	2.2	-22.8	12	44%	56%
PS-1	34-36	35	0.22	6.2	2.3	-22.9	12	45%	55%
PS-1	36-38	37	0.23	5.8	2.3	-23.3	12	51%	49%
PS-1	38-40	39	0.22	6.2	2.2	-23.0	12	47%	53%
PS-1	40-42	41	0.22	6.1	2.2	-22.9	12	45%	55%
PS-1	42-44	43	0.22	6.6					
PS-1	44-46	45	0.21	6.1	2.2	-23.0	12	47%	53%
PS-1	46-48	47	0.22	6.1	2.3	-23.0	12	46%	54%
PS-1	48-50	49	0.22	6.2	2.3	-23.1	12	48%	52%
PS-1	50-52	51	0.22	6.3	2.3	-23.0	12	46%	54%
PS-1	52-54	53	0.23	6.3	2.3	-23.1	12	48%	52%
PS-1	54-56	55	0.22	6.0	2.4	-23.3	13	51%	49%
PS-1	56-58	57	0.21	6.2	2.3	-23.5	13	54%	46%
PS-1	58-60	59	0.21	6.4	2.3	-23.1	13	49%	51%
PS-1	60-65	62.5	0.21	6.2	2.2	-23.0	13	47%	53%
PS-1	65-70	67.5	0.21	6.2	2.3	-23.2	13	49%	51%
PS-1	70-75	72.5	0.20	6.2	2.2	-23.1	13	49%	51%
PS-1	75-80	77.5	0.21	6.5	2.2	-23.1	13	48%	52%
PS-1	80-85	82.5	0.21	6.1	2.3	-23.3	13	50%	50%
PS-1	85-90	87.5	0.20	6.4	2.2	-23.2	13	50%	50%
PS-1	90-95	92.5	0.20	6.3	2.2	-23.3	13	51%	49%
PS-1	95-100	97.5	0.20	6.4	2.2	-23.3	13	50%	50%
PS-1	100-105	102.5	0.20	6.2	2.1	-22.9	12	45%	55%
PS-1	105-110	107.5	0.19	6.3	2.0	-22.7	12	42%	58%
PS-1	110-115	112.5	0.20	6.0	2.2	-23.0	13	46%	54%
PS-1	115-120	117.5	0.20	6.0	2.2	-22.9	13	45%	55%
PS-1	120-125	122.5	0.20	5.9	2.2	-22.9	13	45%	55%
PS-1	130-135	132.5	0.20	6.5	2.1	-22.8	12	43%	57%
PS-1	135-140	137.5	0.20	6.9	1.9	-22.1	11	33%	67%
PS-1	140-145	142.5	0.20	7.0	1.8	-21.4	10	24%	76%
PS-1	145-150	147.5	0.21	7.0	2.1	-22.0	12	33%	67%
PS-1	150-155	152.5	0.20	6.8	1.8	-21.5	10	26%	74%
PS-1	155-160	157.5	0.20	6.9	1.8	-21.4	10	24%	76%
PS-1	160-165	162.5	0.21	6.9	1.7	-21.2	10	21%	79%
PS-1	165-170	167.5	0.21	6.9	1.7	-21.2	10	21%	79%
PS-1	175-180	177.5	0.21	7.1	1.7	-21.5	10	25%	75%
PS-1	180-185	182.5	0.20	7.2	1.7	-21.3	10	22%	78%
PS-1	185-190	187.5	0.20	6.8	1.7	-21.2	10	22%	78%
PS-1	190-195	192.5	0.20	6.9	1.8	-21.8	11	29%	71%
PS-1	195-200	197.5	0.20	7.0	1.6	-21.0	10	19%	81%
PS-1	200-205	202.5	0.20	7.2	1.6	-21.1	10	20%	80%

Appendix C: Organic Matter Data for Puget Sound and Hood Canal Sediment Cores 2005

Core ID	Core Section (cm)	Mid-Depth (cm)	N (%)	$d^{15}N$ Air	C (%)	$d^{13}C$ PDB	(C/N)a	Fterr	Fmar
PS-1	205-210	207.5	0.20	7.0	1.6	-21.2	10	21%	79%
PS-1	210-215	212.5	0.20	7.1	1.6	-21.4	10	24%	76%
PS-1	215-220	217.5	0.19	7.1	1.6	-21.2	10	22%	78%
PS-1	220-225	222.5	0.19	7.2	1.6	-21.4	10	25%	75%
PS-1	225-230	227.5	0.19	7.2	1.6	-21.5	10	25%	75%
PS-1	230-235	232.5	0.20	7.2	1.6	-21.6	10	26%	74%
PS-1	235-240	237.5	0.19	7.2	1.6	-21.3	10	23%	77%
PS-1	240-245	242.5	0.19	7.3	1.6	-21.3	10	23%	77%
PS-1	245-250	247.5	0.19	7.1	1.6	-21.4	10	24%	76%
PS-1	250-255	252.5	0.19	7.0	1.6	-21.4	10	24%	76%
PS-1	255-260	257.5	0.19	7.1	1.6	-21.5	10	25%	75%
PS-4	0-2	1	0.27	6.5	2.1	-21.2	9.2	53%	47%
PS-4	2-4	3	0.27	6.4	2.1	-21.1	9.3	52%	48%
PS-4	6-8	7	0.28	6.3	2.2	-20.7	9.0	48%	52%
PS-4	8-10	9	0.27	6.5	2.2	-21.2	9.3	53%	47%
PS-4	10-12	11	0.28	6.2	2.2	-20.8	9.1	50%	50%
PS-4	12-14	13	0.28	6.8	2.2	-20.9	9.4	51%	49%
PS-4	14-16	15	0.28	6.4	2.2	-21.1	9.2	52%	48%
PS-4	16-18	17	0.27	6.4	2.2	-21.3	9.4	53%	47%
PS-4	18-20	19	0.27	6.2	2.1	-21.3	9.3	54%	46%
PS-4	20-22	21	0.26	6.3	2.2	-21.6	9.6	56%	44%
PS-4	22-24	23	0.26	6.3	2.1	-21.4	9.4	54%	46%
PS-4	24-26	25	0.26	6.2	2.1	-21.4	9.4	54%	46%
PS-4	26-28	27	0.26	6.3	2.1	-21.2	9.3	53%	47%
PS-4	28-30	29	0.26	6.2	2.1	-21.5	9.5	56%	44%
PS-4	30-32	31	0.25	6.2	2.1	-21.7	9.6	57%	43%
PS-4	32-34	33	0.25	6.5	2.1	-21.8	9.7	58%	42%
PS-4	34-36	35	0.26	6.2	2.1	-21.7	9.6	57%	43%
PS-4	36-38	37	0.25	6.3	2.1	-22.2	9.8	36%	64%
PS-4	38-40	39	0.24	6.7	2.1	-22.8	10.1	43%	57%
PS-4	40-42	41	0.25	6.5	2.1	-22.6	9.9	40%	60%
PS-4	42-44	43	0.25	6.3	2.1	-22.5	10.0	40%	60%
PS-4	44-46	45	0.25	6.4	2.1	-22.6	10.0	41%	59%
PS-4	46-48	47	0.24	6.7	2.1	-22.7	9.9	43%	57%
PS-4	48-50	49	0.24	6.2	2.0	-22.6	9.9	41%	59%
PS-4	50-55	52.5	0.24	6.4	2.0	-22.7	10.0	43%	57%
PS-4	55-60	57.5	0.24	6.3	2.1	-22.8	10.1	44%	56%
PS-4	60-65	62.5	0.24	6.2	2.1	-23.0	10.2	46%	54%
PS-4	65-70	67.5	0.24	6.5	2.1	-22.9	10.0	46%	54%
PS-4	70-75	72.5	0.24	6.3	2.1	-23.2	10.2	49%	51%
PS-4	75-80	77.5	0.24	6.3	2.1	-23.1	10.5	48%	52%
PS-4	80-85	82.5	0.24	6.2	2.1	-23.0	10.4	47%	53%
PS-4	85-90	87.5	0.24	6.2	2.1	-23.2	10.6	49%	51%
PS-4	90-95	92.5	0.24	6.2	2.1	-23.0	10.4	47%	53%
PS-4	95-100	97.5	0.23	6.1	2.1	-23.3	10.7	50%	50%
PS-4	100-105	102.5	0.24	6.3	2.1	-23.2	10.4	50%	50%
PS-4	105-110	107.5	0.22	6.2	2.0	-23.2	10.6	50%	50%

Appendix C: Organic Matter Data for Puget Sound and Hood Canal Sediment Cores 2005

Core ID	Core Section (cm)	Mid-Depth (cm)	N (%)	$d^{15}N$ Air	C (%)	$d^{13}C$ PDB	(C/N)a	Fterr	Fmar
PS-4	110-115	112.5	0.22	6.0	2.0	-23.6	10.6	55%	45%
PS-4	115-120	117.5	0.22	6.1	2.0	-23.4	10.6	53%	47%
PS-4	120-125	122.5	0.22	6.0	2.0	-23.6	10.4	54%	46%
PS-4	125-130	127.5	0.22	6.2	1.9	-23.5	10.3	54%	46%
PS-4	130-135	132.5	0.20	5.2	1.9	-23.5	11.1	54%	46%
PS-4	135-140	137.5	0.21	5.9	1.9	-23.7	10.8	56%	44%
PS-4	140-145	142.5	0.20	5.4	1.9	-23.7	11.2	56%	44%
PS-4	145-150	147.5	0.20	5.6	1.9	-23.5	11.2	54%	46%
PS-4	150-155	152.5	0.21	6.3	2.2	-22.5	11.8	39%	61%
PS-4	155-160	157.5	0.22	6.4	2.2	-22.4	11.5	38%	62%
PS-4	160-165	162.5	0.22	6.1	2.2	-22.4	11.8	38%	62%
PS-4	165-170	167.5	0.21	5.6	2.2	-22.5	12.1	39%	61%
PS-4	170-175	172.5	0.21	5.7	2.1	-22.5	11.7	39%	61%
PS-4	175-180	177.5	0.21	5.8	2.0	-22.3	11.6	37%	63%
PS-4	180-185	182.5	0.20	5.8	1.9	-22.6	11.0	42%	58%
PS-4	185-190	187.5	0.20	6.0	1.8	-22.6	10.9	41%	59%
PS-4	190-195	192.5	0.20	5.8	1.9	-22.7	10.8	42%	58%
PS-4	195-200	197.5	0.19	5.6	1.8	-22.8	10.8	44%	56%
PS-4	200-205	202.5	0.20	5.9	1.8	-22.6	10.7	42%	58%
PS-4	205-210	207.5	0.19	5.8	1.7	-22.6	10.7	41%	59%
PS-4	210-215	212.5	0.19	5.9	1.7	-22.6	10.2	40%	60%
PS-4	215-220	217.5	0.19	5.7	1.7	-22.5	10.0	40%	60%

Appendix C: Organic Matter Data for Puget Sound and Hood Canal Sediment Cores 2005

Core ID	Core Section (cm)	Mid-Depth (cm)	Sig8 (mg/g)	Lamb8	S/V	C/V	(Ad/Al) v	(Ad/Al)s	3,5Bd/V	P/(V+S)	PON/P	C/F	LPVI
HC-3	4-6	5	0.50	1.95	0.24	0.07	0.41	0.28	0.04	0.17	0.28	1.34	8.0
HC-3	10-12	11	0.55	2.24	0.21	0.06	0.38	0.27	0.04	0.15	0.29	1.17	6.4
HC-3	12-14	13	0.48	1.97	0.23	0.07	0.39	0.28	0.04	0.16	0.28	1.34	7.6
HC-3	16-18	17	0.54	2.20	0.20	0.06	0.38	0.28	0.04	0.15	0.29	1.19	5.8
HC-3	18-20	19	0.55	2.27	0.21	0.07	0.40	0.27	0.04	0.15	0.29	1.19	6.6
HC-3	24-26	25	0.62	2.47	0.18	0.06	0.41	0.27	0.03	0.13	0.29	1.17	5.1
HC-3	26-28	27	0.55	2.27	0.20	0.08	0.38	0.26	0.04	0.15	0.30	0.98	6.8
HC-3	28-30	29	0.73	3.02	0.14	0.10	0.35	0.26	0.04	0.13	0.29	0.38	5.5
HC-3	32-34	33	0.51	2.28	0.18	0.06	0.38	0.28	0.04	0.14	0.29	1.21	5.1
HC-3	36-38	37	0.35	1.65	0.27	0.08	0.36	0.27	0.05	0.18	0.31	1.89	10.7
HC-3	40-42	41	0.42	1.94	0.21	0.07	0.32	0.26	0.04	0.16	0.32	1.53	6.6
HC-3	44-46	45	0.35	1.58	0.29	0.09	0.35	0.26	0.05	0.19	0.30	2.02	12.2
HC-3	50-52	51	0.34	1.55	0.30	0.09	0.38	0.27	0.05	0.20	0.31	2.20	12.8
HC-3	54-56	55	0.33	1.54	0.30	0.09	0.34	0.27	0.05	0.20	0.30	2.47	12.8
HC-3	56-58	57	0.31	1.36	0.31	0.09	0.38	0.25	0.04	0.22	0.34	2.38	13.2
HC-3	60-62	61	0.31	1.35	0.31	0.09	0.36	0.29	0.04	0.22	0.36	2.33	13.5
HC-3	68-70	69	0.33	1.42	0.32	0.09	0.37	0.26	0.04	0.21	0.35	2.55	13.6
HC-3	72-74	73	0.31	1.38	0.29	0.09	0.38	0.26	0.04	0.21	0.36	2.44	11.8
HC-3	74-76	75	0.33	1.46	0.31	0.09	0.39	0.27	0.04	0.21	0.32	2.19	13.1
HC-3	80-82	81	0.29	1.31	0.30	0.09	0.39	0.27	0.04	0.24	0.34	2.44	13.0
HC-3	84-86	85	0.31	1.42	0.36	0.09	0.38	0.24	0.04	0.18	0.31	2.34	17.0
HC-3	88-90	89	0.28	1.30	0.31	0.10	0.39	0.25	0.05	0.20	0.33	2.53	14.3
HC-3	92-94	93	0.27	1.24	0.32	0.09	0.40	0.26	0.05	0.22	0.32	2.90	14.2
HC-3	96-98	97	0.26	1.23	0.29	0.09	0.39	0.27	0.04	0.21	0.33	2.85	12.2
HC-3	98-100	99	0.32	1.53	0.30	0.09	0.36	0.27	0.06	0.24	0.40	2.50	13.1
HC-3	102-104	103	0.28	1.46	0.32	0.09	0.36	0.24	0.06	0.24	0.41	2.84	14.2
HC-3	106-108	107	0.30	1.53	0.31	0.09	0.37	0.26	0.06	0.23	0.40	2.58	13.9
HC-3	116-118	117	0.29	1.44	0.30	0.10	0.36	0.27	0.05	0.22	0.38	2.62	13.6
HC-3	122-124	123	0.27	1.55	0.36	0.10	0.38	0.28	0.06	0.22	0.37	2.28	17.8
HC-3	124-126	125	0.31	1.77	0.36	0.12	0.39	0.31	0.07	0.15	0.14	2.28	20.5
HC-3	130-132	131	0.26	1.50	0.31	0.09	0.37	0.28	0.06	0.23	0.38	2.53	13.0
HC-3	140-142	141	0.25	1.46	0.31	0.09	0.38	0.27	0.06	0.21	0.38	2.40	12.9
HC-3	148-150	149	0.25	1.40	0.28	0.09	0.40	0.28	0.06	0.22	0.38	2.26	11.2
HC-3	154-156	155	0.29	1.53	0.27	0.09	0.36	0.28	0.05	0.20	0.39	2.66	11.0
HC-3	160-162	161	0.33	1.85	0.37	0.11	0.39	0.25	0.07	0.15	0.12	2.47	19.9
HC-3	164-166	165	0.20	1.18	0.34	0.11	0.43	0.34	0.08	0.15	0.15	2.37	18.4
HC-3	180-182	181	0.27	1.73	0.36	0.15	0.39	0.29	0.08	0.16	0.15	2.40	26.4
HC-3	188-190	189	0.22	2.08	0.34	0.10	0.38	0.26	0.06	0.13	0.13	2.31	16.7
HC-3	192-194	193	0.25	1.36	0.32	0.13	0.38	0.30	0.08	0.37	0.46	2.56	18.3
HC-3	205-210	207.5	0.30	1.65	0.33	0.11	0.40	0.28	0.06	0.14	0.13	2.45	17.2
HC-5	0-2	1	0.64	2.60	0.24	0.08	0.39	0.27	0.04	0.13	0.13	1.49	8.6
HC-5	4-6	5	0.71	2.79	0.26	0.08	0.37	0.28	0.05	0.13	0.13	1.47	9.9
HC-5	10-12	11	0.64	2.56	0.24	0.08	0.39	0.29	0.04	0.13	0.13	1.42	9.1
HC-5	12-14	13	0.65	2.60	0.23	0.08	0.37	0.27	0.04	0.12	0.14	1.40	8.4
HC-5	18-20	19	0.70	2.81	0.22	0.07	0.39	0.26	0.04	0.11	0.15	1.32	7.3
HC-5	20-22	21	0.70	2.92	0.21	0.07	0.36	0.28	0.04	0.11	0.15	1.48	6.7
HC-5	22-24	23	0.73	3.01	0.21	0.08	0.37	0.29	0.04	0.11	0.15	1.25	6.9

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HC-5	26-28	27	0.72	2.98	0.20	0.08	0.42	0.26	0.04	0.10	0.15	1.14	6.9
HC-5	32-34	33	0.78	3.16	0.18	0.08	0.42	0.27	0.03	0.09	0.15	0.94	5.6
HC-5	38-40	39	0.80	3.28	0.17	0.07	0.41	0.29	0.03	0.10	0.15	1.02	5.3
HC-5	40-42	41	0.77	3.22	0.17	0.07	0.42	0.27	0.03	0.10	0.15	1.12	5.2
HC-5	42-44	43	0.73	3.21	0.19	0.08	0.38	0.28	0.04	0.10	0.17	1.04	6.4
HC-5	48-50	49	0.65	2.88	0.19	0.08	0.38	0.27	0.04	0.10	0.16	1.40	6.4
HC-5	54-56	55	0.57	2.61	0.24	0.10	0.40	0.24	0.04	0.14	0.26	1.44	9.9
HC-5	58-60	59	0.61	2.85	0.25	0.10	0.36	0.21	0.04	0.13	0.22	1.49	10.2
HC-5	64-66	65	0.49	2.38	0.26	0.10	0.42	0.27	0.05	0.14	0.25	1.75	11.3
HC-5	66-68	67	0.46	2.23	0.27	0.11	0.47	0.30	0.05	0.14	0.27	1.74	12.3
HC-5	68-70	69	0.54	2.59		0.11	0.36	0.27	0.05	0.13	0.23	1.60	
HC-5	72-74	73	0.46	2.15	0.26	0.11	0.45	0.33	0.05	0.14	0.26	1.81	12.8
HC-5	82-84	83	0.44	2.08	0.29	0.13	0.48	0.27	0.05	0.16	0.26	1.96	16.7
HC-5	90-92	91	0.48	2.19	0.28	0.11	0.37	0.24	0.05	0.16	0.23	1.96	13.9
HC-5	94-96	95	0.46	2.17	0.27	0.11	0.42	0.29	0.04	0.15	0.27	2.14	13.5
HC-5	100-105	102.5	0.44	2.07	0.28	0.12	0.38	0.24	0.04	0.16	0.22	2.34	14.3
HC-5	110-115	112.5	0.43	2.06	0.31	0.13	0.37	0.25	0.05	0.17	0.24	2.19	18.7
HC-5	120-125	122.5	0.41	1.92	0.29	0.12	0.38	0.27	0.05	0.17	0.22	2.12	15.3
HC-5	140-145	142.5	0.48	2.28	0.30	0.11	0.36	0.23	0.04	0.15	0.23	2.02	14.5
HC-5	150-155	152.5	0.43	2.08	0.29	0.11	0.35	0.24	0.05	0.15	0.23	2.07	13.7
HC-5	165-170	167.5	0.46	2.25	0.27	0.11	0.43	0.27	0.05	0.16	0.24	1.95	13.0
HC-5	180-185	182.5	0.45	2.12	0.30	0.13	0.42	0.29	0.05	0.17	0.27	2.19	16.6
HC-5	190-195	192.5	0.43	2.14	0.27	0.11	0.43	0.29	0.05	0.16	0.26	2.16	13.4
HC-5	195-200	197.5	0.47	2.36	0.27	0.13	0.43	0.28	0.05	0.17	0.26	1.88	14.9
HC-5	205-210	207.5	0.42	2.05	0.30	0.13	0.44	0.29	0.06	0.17	0.24	2.37	17.6
HC-5	225-230	227.5	0.39	1.92	0.30	0.14	0.44	0.31	0.06	0.17	0.26	2.25	18.6
HC-5	235-240	237.5	0.40	1.96	0.30	0.14	0.42	0.27	0.06	0.19	0.25	2.35	18.9
HC-5	255-260	257.5	0.39	2.02	0.29	0.13	0.40	0.27	0.05	0.18	0.27	2.37	16.5
PS-1	0-2	1	0.50	2.16	0.18	0.07	0.36	0.27	0.04	0.15	0.24	1.34	5.3
PS-1	4-6	5	0.53	2.26	0.18	0.06	0.39	0.27	0.04	0.15	0.22	1.28	5.2
PS-1	8-10	9	0.55	2.37	0.17	0.06	0.34	0.25	0.03	0.15	0.23	1.20	4.6
PS-1	14-16	15	0.57	2.45	0.17	0.06	0.36	0.28	0.03	0.14	0.24	1.15	4.7
PS-1	16-18	17	0.61	2.58	0.18	0.06	0.38	0.24	0.03	0.15	0.25	1.25	4.9
PS-1	18-20	19	0.58	2.55	0.17	0.06	0.36	0.27	0.03	0.14	0.25	1.21	4.7
PS-1	22-24	23	0.59	2.58	0.17	0.06	0.36	0.26	0.04	0.14	0.25	1.25	4.5
PS-1	24-26	25	0.60	2.65	0.18	0.06	0.38	0.24	0.03	0.14	0.25	1.16	4.9
PS-1	28-30	29	0.59	2.58	0.16	0.05	0.37	0.26	0.03	0.14	0.24	1.24	4.2
PS-1	32-34	33	0.61	2.76	0.15	0.06	0.33	0.27	0.03	0.13	0.26	1.09	4.0
PS-1	36-38	37	0.67	2.84	0.15	0.05	0.36	0.25	0.03	0.12	0.26	1.11	3.8
PS-1	40-42	41	0.67	2.98	0.14	0.05	0.37	0.26	0.03	0.12	0.24	1.22	3.4
PS-1	50-52	51	0.68	2.94	0.12	0.04	0.32	0.24	0.02	0.11	0.28	1.02	2.7
PS-1	54-56	55	0.79	3.32	0.11	0.04	0.34	0.23	0.02	0.10	0.29	0.97	2.5
PS-1	56-58	57	0.82	3.54	0.11	0.04	0.33	0.25	0.02	0.10	0.28	0.90	2.6
PS-1	58-60	59	0.82	3.52	0.11	0.04	0.32	0.24	0.02	0.10	0.29	0.94	2.4
PS-1	60-65	62.5	0.79	3.52	0.12	0.05	0.35	0.26	0.02	0.11	0.31	0.90	2.9
PS-1	65-70	67.5	0.73	3.21	0.12	0.05	0.35	0.25	0.02	0.11	0.29	0.96	3.0
PS-1	70-75	72.5	0.74	3.32	0.11	0.04	0.34	0.24	0.02	0.11	0.28	0.98	2.6

Appendix C: Organic Matter Data for Puget Sound and Hood Canal Sediment Cores 2005

Core ID	Core Section (cm)	Mid-Depth (cm)	Sig8 (mg/g)	Lamb8	S/V	C/V	(Ad/Al) v	(Ad/Al)s	3,5Bd/V	P/(V+S)	PON/P	C/F	LPVI
PS-1	80-85	82.5	0.72	3.15	0.11	0.04	0.31	0.24	0.02	0.11	0.31	1.08	2.7
PS-1	85-90	87.5	0.68	3.08	0.11	0.04	0.31	0.24	0.03	0.14	0.40	1.01	2.7
PS-1	95-100	97.5	0.59	2.63	0.14	0.05	0.32	0.25	0.03	0.12	0.30	1.29	3.4
PS-1	100-105	102.5	0.53	2.47	0.15	0.05	0.32	0.23	0.03	0.14	0.31	1.44	3.8
PS-1	105-110	107.5	0.47	2.32	0.16	0.06	0.32	0.24	0.03	0.14	0.32	1.37	4.3
PS-1	115-120	117.5	0.41	1.86	0.20	0.07	0.32	0.26	0.04	0.17	0.32	1.67	6.4
PS-1	130-135	132.5	0.43	2.10	0.19	0.07	0.28	0.24	0.04	0.15	0.31	1.88	5.8
PS-1	135-140	137.5	0.33	1.76	0.27	0.09	0.35	0.24	0.05	0.19	0.31	2.34	11.1
PS-1	140-145	142.5	0.28	1.58	0.30	0.10	0.34	0.23	0.05	0.20	0.31	2.75	13.3
PS-1	155-160	157.5	0.27	1.52	0.30	0.12	0.36	0.24	0.05	0.22	0.31	2.82	15.7
PS-1	165-170	167.5	0.25	1.49	0.32	0.13	0.37	0.26	0.05	0.23	0.31	3.11	17.9
PS-1	185-190	187.5	0.26	1.52	0.30	0.12	0.35	0.25	0.05	0.23	0.31	3.05	15.3
PS-1	205-210	207.5	0.23	1.43	0.34	0.13	0.36	0.23	0.06	0.24	0.30	2.99	20.1
PS-1	220-225	222.5	0.22	1.38	0.33	0.13	0.37	0.24	0.05	0.24	0.31	3.31	18.8
PS-1	230-235	232.5	0.24	1.46	0.36	0.13	0.39	0.25	0.06	0.20	0.22	3.03	21.7
PS-1	255-260	257.5	0.25	1.58	0.36	0.12	0.38	0.25	0.06	0.18	0.20	2.69	20.3
PS-4	0-2	1	0.50	2.37	0.24	0.09	0.36	0.25	0.04	0.15	0.19	1.62	9.1
PS-4	6-8	7	0.49	2.24	0.23	0.08	0.36	0.25	0.04	0.16	0.18	1.63	8.2
PS-4	12-14	13	0.50	2.28	0.24	0.09	0.36	0.25	0.04	0.16	0.19	1.61	9.2
PS-4	16-18	17	0.57	2.61	0.23	0.08	0.34	0.24	0.04	0.15	0.18	1.58	8.2
PS-4	20-22	21	0.54	2.49	0.23	0.08	0.34	0.24	0.04	0.15	0.18	1.59	8.1
PS-4	24-26	25	0.54	2.57	0.22	0.08	0.33	0.25	0.04	0.14	0.18	1.75	7.6
PS-4	26-28	27	0.53	2.49	0.23	0.08	0.36	0.24	0.04	0.15	0.19	1.62	8.6
PS-4	30-32	31	0.56	2.66	0.23	0.08	0.35	0.25	0.04	0.14	0.19	1.64	8.4
PS-4	36-38	37	0.54	2.55	0.21	0.07	0.41	0.30	0.04	0.14	0.19	1.56	7.0
PS-4	40-42	41	0.55	2.60	0.22	0.09	0.33	0.28	0.04	0.14	0.19	1.57	8.1
PS-4	44-46	45	0.55	2.60	0.21	0.08	0.34	0.24	0.04	0.14	0.20	1.53	7.2
PS-4	50-55	52.5	0.56	2.73	0.21	0.08	0.33	0.25	0.04	0.14	0.19	1.52	7.0
PS-4	65-70	67.5	0.62	2.98	0.20	0.07	0.35	0.25	0.03	0.13	0.21	1.54	6.3
PS-4	75-80	77.5	0.61	2.88	0.19	0.07	0.38	0.25	0.03	0.12	0.20	1.51	5.9
PS-4	95-100	97.5	0.74	3.45	0.18	0.07	0.34	0.26	0.03	0.11	0.19	1.25	5.3
PS-4	110-115	112.5	0.74	3.69	0.15	0.06	0.35	0.23	0.03	0.10	0.18	1.30	4.1
PS-4	125-130	127.5	0.72	3.80	0.15	0.06	0.33	0.24	0.03	0.10	0.20	1.25	4.2
PS-4	130-135	132.5	0.72	3.80	0.19	0.09	0.37	0.27	0.03	0.20	0.46	1.14	6.5
PS-4	135-140	137.5	0.62	3.27	0.18	0.09	0.36	0.26	0.03	0.20	0.45	0.95	6.6
PS-4	145-150	147.5	0.60	3.18	0.18	0.08	0.38	0.26	0.03	0.11	0.19	1.20	5.6
PS-4	150-155	152.5	0.61	2.83	0.17	0.07	0.35	0.24	0.03	0.11	0.20	1.16	5.1
PS-4	155-160	157.5	0.60	2.80	0.17	0.07	0.35	0.23	0.03	0.11	0.20	1.32	5.1
PS-4	160-165	162.5	0.60	2.73	0.18	0.08	0.37	0.25	0.03	0.12	0.20	1.38	5.9
PS-4	165-170	167.5	0.58	2.61	0.18	0.08	0.36	0.25	0.03	0.11	0.19	1.21	5.5
PS-4	175-180	177.5	0.51	2.53	0.20	0.09	0.32	0.24	0.04	0.12	0.20	1.65	7.2
PS-4	180-185	182.5	0.42	2.24	0.24	0.10	0.35	0.26	0.05	0.14	0.20	2.00	10.4
PS-4	200-205	202.5	0.43	2.42	0.25	0.10	0.33	0.25	0.04	0.14	0.19	1.92	11.1
PS-4	215-220	217.5	0.38	2.28	0.27	0.11	0.33	0.27	0.05	0.14	0.19	2.01	12.7

Appendix D: Pollen Data

Core: PS-1 **Puget Sound 2005 Sediment Core**

Mid Depth (cm)	3	11	29	41	53	67.5	77.5	97.5	107.5	147.5	167.5	187.5	227.5	257.5
Abies	0.8	1.1	0	0.4	0	0.6	0.9	1.2	1.2	0.9	0.9	0.7	2.9	1.8
Picea	0	0.8	0.7	0.4	0.8	0.6	0.6	0.7	1.4	0.6	0.6	0.7	1.2	0.9
Pinus	5.1	3.8	2.0	5.8	0.6	4.1	4.5	5.0	8.7	0.9	5.4	3.3	5.3	7.1
Pseudotsuga/Larix	1.6	1.6	1.0	4.3	1.1	2.6	1.5	3.2	4.3	1.6	3.9	3.0	5.0	6.2
Tsuga	2.2	4.1	0.7	4.7	1.4	4.7	6.3	5.7	11.6	3.7	6.3	3.3	7.9	6.5
PINACEAE	1.3	1.4	3.3	1.9	0.8	2.3	1.2	1.7	2.1	0.9	1.5	1.9	2.0	2.7
T-C-T	18.5	17.1	23.6	20.6	20.7	17.3	29.3	26.3	25.1	46.3	44.7	48.7	38.3	35.4
Total conifers	**30**	**30**	**31**	**38**	**25**	**32**	**44**	**44**	**54**	**55**	**63**	**62**	**63**	**60**
Alnus	**55**	**53**	**52**	**48**	**49**	**40**	**32**	**32**	**22**	**25**	**15**	**22**	**18**	**24**
Betula	0.5	1.4	1.0	0.4	1.7	0.9	0.3	0.2	0.5	0.3	0.6	0.4	0.9	0.9
CHENOPODIACEAE	0.3	0	0	0	1.1	0.9	0.6	1.0	0.7	0.9	0.3	0.4	0.9	0
Artemisia	0.3	1.4	0.3	0.4	1.1	0.3	0.9	0.5	0.7	0.3	0.3	1.1	1.2	1.2
Aster type	0	0	0.3	0	0	0.3	0.3	0	0.2	0	0	0	0	0
Tamaxacum type	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0
Quercus	0	0	0	0	0	0	0	0.2	0	0	0	0.4	0	0
LABIATAE	0	0	0.3	0	0	0	0	0	0.2	0	0	0	0	0
LEGUMINOSAE	0	0	0	0	0	0	0	0	0.0	0	0	0	0	0
Salix	0	0	0	0	0.8	0.6	0.3	0.2	0.2	0.3	0.3	0.4	0	0.3
GRAMINEAE	1.9	3.0	3.3	1.6	1.7	2.6	3.3	1.2	2.8	0.6	0.6	3.0	1.5	0.6
CYPERACEAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3
ERICACEAE	0	0	0	0	0	0	0	0.2	0	0.3	0	0	0	0
Tricolpate pollen	0.3	1.1	0.7	0.4	2.2	2.1	1.5	1.2	0.9	1.2	0.6	1.5	0.6	0.3
Tricolporate pollen	0.3	0	0.3	0.4	0.6	0	0.3	0.2	0	0.6	0.3	0.4	0	0.3
?Moss spores	0.5	0	0.7	0	1.4	0	0	0.5	0	0.6	0	0.7	0.6	0
?Sphagnum	0.3	0	0	0	0.3	0	0	0	0	0	0	0	0.3	0.3
Selaginella	0	0.3	0	0	0	0	0	0	0	0.6	0	0	0	0
POLYPODIACEAE	4.3	4.3	3.3	3.5	4.4	6.5	5.1	4.5	5.2	4.3	7.6	3.0	6.4	4.4
Dryopteris type	1.1	1.6	0.7	1.2	0.6	2.6	2.4	3.0	1.4	0.6	0.9	0.4	0.9	0.6
Trilete spores	1.9	1.1	3.0	1.9	5.8	4.1	4.5	7.2	6.4	4.0	5.1	2.2	1.8	2.1
Unknowns	0.5	0.3	0.3	0.4	1.4	1.2	0.3	1.2	0.5	1.6	1.2	0.7	0.9	1.2
Indeterminates	3.5	2.2	2.7	3.9	3.0	5.9	3.6	2.5	3.8	3.1	3.3	2.2	4.1	3.2
Fungal spores	0.3	1.6	2.3	1.9	2.8	2.6	0.9	4.5	1.4	3.1	0.9	0.7	1.5	1.5
Algae	1.3	2.2	2.0	4.3	1.7	2.9	2.1	2.7	1.7	1.6	0	0	1.8	3.5
Marine Algae	1.1	1.9	0.7	2.3	1.7	2.6	1.2	2.7	3.8	1.9	7.9	1.1	5.8	6.2
Dinoflagellate	0	0	0.3	0	0	0	0.3	0.5	0.5	0.3	0.3	0	1.5	2.9
Foraminifers	0.3	0	0.7	0.4	0.6	0.3	0.3	1.0	0	0.3	0.3	0.4	0.3	0.3
Total tally	523	584	409	349	466	481	432	611	603	465	468	332	530	504

Pollen counts are total pollen and spores
Fungi, algae, and foraminifers are numbers per 100 pollen/spores.

Appendix D: Pollen Data

Core: PS-2 **Puget Sound 2005 Sediment Core**

Mid Depth (cm)	3	23	43	53	63	73	87.5	107.5	117.5	137.5	167.5	187.5	197.5	237.5
Abies	0.2	0	1.0	1.4	3.0	0.7	0.2	1.1	1.0	0.7	0.6	1.0	1.9	1.7
Picea	0.9	1.2	0.5	0	0.7	1.4	0.9	0.8	1.2	1.9	1.7	2.1	2.7	0.6
Pinus	4.2	4.0	5.1	3.7	8.4	7.3	4.2	7.3	6.4	5.1	4.5	3.3	4.8	6.8
Pseudotsuga/Larix	2.6	4.0	3.6	2.3	3.7	3.8	1.7	2.5	3.2	2.2	2.8	3.1	2.9	5.1
Tsuga	4.0	2.8	5.4	5.3	7.9	4.7	5.7	5.6	5.1	4.1	7.8	4.9	6.0	6.2
PINACEAE	2.1	1.5	2.1	0.9	2.0	1.9	1.4	1.7	1.5	2.4	3.1	1.8	1.2	1.7
T-C-T	22.8	19.5	15.6	15.9	16.9	16.0	27.6	24.0	20.6	25.1	27.5	25.7	30.2	38.8
Total conifers	**37**	**33**	**33**	**30**	**43**	**36**	**42**	**43**	**39**	**42**	**48**	**42**	**50**	**61**
Alnus	**46**	**51**	**52**	**55**	**45**	**47**	**44**	**42**	**45**	**39**	**35**	**34**	**27**	**23**
Betula	0.9	1.5	0.5	0.9	0.7	0.7	0	0.6	0.2	1.0	0	1.3	0.5	0
CHENOPODIACEAE	0.2	0	0	0.5	0.5	0.7	0.2	0.3	0.5	0.2	0.6	0.8	0.7	0
Artemisia	1.2	0	0	1.6	0.5	0.5	0.7	0.3	0.5	0	0.8	0	0	0.6
Aster type	0.2	0	0.3	0	0	0.5	0	0	0	0	0.6	0.3	0.2	0
Tamaxacum type	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0
Quercus	0.2	0.3	0	0	0	0	0	0	0	0	0.3	0	0	0
POLYGONACEAE	0	0	0.5	0	0	0	0	0	0	0.2	0	0	0	0
Salix	0.2	0.6	0.5	0	0	0.5	0.2	0	0	0	0	0	0.5	0
GRAMINEAE	2.1	1.9	2.1	2.5	2.2	2.6	1.7	2.5	1.7	4.8	3.1	2.3	3.4	1.1
ERICACEAE	0	0.3	0	0.2	0	0	0	0	0	0	0	0	0	0
Tricolpate pollen	0.9	1.2	0.5	0.7	1.0	0.5	0.2	0.8	0.7	0.7	1.4	1.0	1.2	1.7
Tricolporate pollen	0.2	0.9	0	0	0	0.9	0.2	0	0	0	0.3	1.3	1.0	0.3
?Moss spores	0.7	0	0	0	0	0	0	0.6	0	0	0	0.3	0.2	0
?Sphagnum	0.2	0	0	0	0	0	0	1.7	0.5	0.5	0	0	1.2	0.3
POLYPODIACEAE	4.2	2.8	2.6	2.8	3.2	3.3	3.1	2.2	3.9	6.3	3.6	5.1	5.1	6.2
Dryopteris type	1.2	1.5	1.5	2.1	1.0	1.2	1.7	1.1	1.2	1.0	2.2	2.1	1.2	1.1
Trilete spores	1.6	1.2	2.3	1.8	1.2	2.4	1.4	2.0	3.2	3.4	2.0	4.6	4.3	2.5
Unknowns	0.7	0.3	0.8	0.7	0.2	0.7	0.2	0	0.5	0.2	0.3	0.5	0.5	0
Indeterminates	1.6	3.1	2.8	1.8	1.5	2.6	4.2	2.8	2.9	1.4	2.2	3.9	3.6	2.5
Fungal spores	0.5	0.9	1.8	1.6	0.5	1.4	0.9	0.6	1.0	1.4	2.8	1.0	1.0	2.5
Algae	1.9	0.3	1.8	0.9	0.7	3.1	1.9	0.6	2.5	1.4	0.8	0.8	1.9	1.4
Marine Algae	0.9	0.6	0	1.4	0.7	0.2	0.7	0.8	1.5	1.0	0.8	1.3	1.4	2.8
Dinoflagellate	0.2	0	0	0.0	0.2	0.7	0.2	0.0	0.2	0.2	0	0.3	0.2	0.3
Foraminifers	0.2	0.3	0.3	0.2	0.5	0.2	0.2	0.6	0.2	0.2	1.4	0.3	0.2	0.3
Total tally	544	419	480	533	475	547	536	427	516	502	433	486	521	435

Pollen counts are total pollen and spores
Fungi, algae, and foraminifers are numbers per 100 pollen/spores.

Appendix D: Pollen Data

Core: PS-3 **Puget Sound 2005 Sediment Core**

Depth (cm)	3	5	13	15	23	25	33	35	43	46	57.5	67.5	77.5
Abies	0.6	1.0	1.6	0.7	1.3	1.7	1.6	0.8	1.8	0.9	0.6	1.3	1.7
?Picea	0.2	0.2	0.8	0	0.4	0	0.2	0.5	0.6	0	0.0	0.2	0.2
Pinus	5.2	5.2	5.8	7.3	6.7	4.6	5.1	11.1	5.7	2.8	9.6	5.3	3.8
Pseudotsuga	2.7	1.2	2.1	2.1	3.8	1.7	0.8	1.6	2.2	0.8	2.4	1.6	0.9
Tsuga	6.7	6.0	8.2	6.6	11.3	5.8	7.1	8.4	7.5	4.7	9.6	8.0	10.2
PINACEAE	2.5	2.8	2.7	2.1	3.4	1.7	2.6	4.1	3.1	1.3	3.6	1.3	2.6
T-C-T	14.3	14.1	8.9	18.5	8.8	16.2	16.3	13.0	13.4	17.6	7.8	14.0	15.5
Total conifers	**32**	**31**	**30**	**37**	**36**	**32**	**34**	**39**	**34**	**28**	**34**	**32**	**35**
Alnus	**53**	**52**	**57**	**53**	**53**	**52**	**51**	**45**	**51**	**55**	**44**	**47**	**48**
Betula	0.6	0.6	0.4	0.7	0	0.6	0	0.5	0.6	0	1.2	0.3	0.9
CHENOPODIACEAE	0	0	0	0	0	0.2	1.6	0.8	0.4	0.2	0.6	1.3	0.2
Ambrosia	0	0	0	0	0.2	0.2	0.2	0	0	0.2	0	0.2	0.2
Artemisia	0.4	0.4	0.8	0.3	0	1.2	1.4	0	0	0.9	0	1.0	0.9
Aster type	0.2	0.4	0.2	0	0.4	0	0.2	0.3	0	0.6	0	0.7	0.7
Quercus	0	0	0	0	0	0	0	0.3	0	0	0	0	0.2
POPLYGONACEAE	0	0.2	0	0.3	0	0	0	0	0	0	0	0	0
LABIATAE	0	0	0	0	0	0	0	0	0	0	1.2	0	0.3
ROSACEAE	0	0.2	0	0	0.2	0	0	0	0	0	0.6	0	0
LEGUMINOSAE	0	0	0	0	0	0	0	0	0	0	0	0	0
Salix	0.4	0.6	0.8	0	0.6	0.4	0.2	0.8	0.2	0	0.6	0.3	0
UMBELLIFERAE	0	0	0	0	0.2	0	0	0	0	0	0	0	0.3
GRAMINEAE	3.5	3.2	1.0	1.4	0.8	2.7	1.0	0.5	1.0	3.2	0	1.6	1.7
CYPERACEAE	0	0	0.4	0	0.2	0.2	0	0	0	0.6	0.6	0	0
Typha/Sparganium	0	0	0	0	0.2	0	0	0	0	0	0.6	0	0
ERICACEAE	0.2	0.4	0	0	0	0	0	0	0	0	0	0.2	0
?Acer	0	0	0	0	0	0	0	0	0	0	0	0	0
?Plantago	0.2	0	0.2	0	0	0	0	0	0	0	0	0	0
?Ranunculus	0.0	0	0	0	0	0	0	0	0	0	0	0	0.3
Tricolpate pollen	0.4	0.2	0	0	0.2	0.8	0.2	0	0.4	0.4	0	0.5	0.2
Tricolporate pollen	0.2	0.2	0.6	0	0.2	0.2	0	0	0.2	0	0.6	0.2	0.3
Retitricolpate pollen	0	0	0	0	0	0	0	0	0	0	0	0	0
Retitrcolporate pollen	0	0	0	0	0	0	0	0	0	0	0	0	0
Monosulcate pollen	0	0	0	0	0.2	0.2	0.2	0	0	0	0	0	0
?Moss spores	0.4	0.4	0.2	0	0	0	0.8	0	0.2	0	0	0.7	0
?Sphagnum	0	0	0	0	0	0	0	0	0	0	0	0.3	0
Lycopodium	0	0.2	0	0	0.2	0	0	0.5	0	0.2	1.2	0.3	0.2
Selaginella	0	0	0	0	0.2	0.2	0.2	0	0.2	0.4	0	1.6	1.4
POLYPODIACEAE	3.3	3.0	2.9	1.7	1.7	2.7	4.7	3.2	5.7	3.0	3.0	4.6	3.6
Dryopteris type	0.8	1.6	1.0	0.7	1.7	1.5	0.8	1.1	1.2	1.5	0	2.6	0.9
Trilete spores	1.2	1.6	0.6	0.3	1.1	2.1	1.2	0.3	1.8	1.5	1.2	2.0	1.4
?Osmunda	0	0	0	0	0	0	0	0	0	0	0	0	0
Unknowns	0.2	0.2	0.2	0.3	0.4	0.2	0.2	1.6	0.2	0.6	2.4	0.2	0.3
Indeterminates	3.5	4.2	3.3	3.5	2.3	3.3	2.2	5.1	2.8	3.8	9.0	2.6	2.8

Appendix D: Pollen Data

Core: PS-3 **Puget Sound 2005 Sediment Core**

Depth (cm)	3	5	13	15	23	25	33	35	43	46	57.5	67.5	77.5
Fungal spores	1.0	0.2	0.4	0.3	0.8	2.3	1.0	1.6	0.8	2.6	1.2	1.5	0.9
Algae	2.7	3.4	1.4	5.2	3.4	4.6	3.3	3.0	2.6	4.1	4.2	3.6	1.7
Botryococcus	0	0	0	0	0	0	0	0	0	0	0	0	0
Pediastrum	0	0	0	0	0	0	0	0	0	0	0	0	0
Marine Algae	2.1	1.8	1.9	0.7	2.5	1.0	2.0	2.2	1.0	3.0	4.2	0.8	2.2
Dinoflagellate	0.4	0	0	0	0.6	0.2	0	0.3	0.4	0.6	0	0	0.3
Foraminifers	0.2	0.8	0.4	1.0	1.1	1.2	1.0	1.4	0.8	1.1	1.2	0.5	0.3
Total tally	731	663	609	352	578	661	642	451	678	720	212	781	774

Pollen counts are total pollen and spores
Fungi, algae, and foraminifers are numbers per 100 pollen/spores.

Appendix D: Pollen Data

Core: PS-3 **Puget Sound 2005 Sediment Core**

Depth (cm)	87.5	97.5	107.5	117.5	127.5	137.5	152.5	157.5	167.5	177.5	187.5	197.5
Abies	1.3	1.2	1.8	2.6	1.0	3.4	2.5	2.6	3.9	2.8	2.4	3.5
?Picea	0	0	1.3	1.9	0	3.1	1.2	1.1	0.8	2.3	0	3.7
Pinus	5.7	7.2	5.8	8.8	10.0	8.4	11.9	7.4	13.0	7.8	7.6	9.1
Pseudotsuga	1.3	1.0	1.6	2.1	1.7	4.5	2.6	2.4	3.6	1.4	3.1	3.7
Tsuga	8.2	9.9	7.1	12.8	8.5	15.9	13.0	12.4	13.6	11.3	9.4	11.7
PINACEAE	4.7	4.3	4.4	3.8	4.0	5.3	2.8	2.6	3.9	4.1	7.3	2.6
T-C-T	10.4	17.4	22.6	19.1	17.0	27.4	24.4	41.7	25.8	30.0	30.5	26.4
Total conifers	**32**	**41**	**45**	**51**	**42**	**68**	**58**	**70**	**65**	**60**	**60**	**61**
Alnus	**48**	**34**	**26**	**30**	**39**	**18**	**26**	**20**	**21**	**22**	**25**	**24**
Betula	0.6	0.2	0.4	1.1	0.2	0.5	0.5	0.2	0.6	0.7	0.2	0.2
CHENOPODIACEAE	0.6	1.2	0.5	0	0.2	0.7	0.0	0.2	0.2	0.9	1.1	0.5
Ambrosia	0.3	0	0.2	0	0	0	0.0	0	0	0	0	0
Artemisia	0	0.2	0.4	0.4	0.2	0.2	0.5	0	0	0.5	0.9	0.5
Aster type	0.3	0.2	0.7	0.8	0.2	0.2	0.2	0.4	0	0	0.2	0.3
Quercus	0	0.5	0.4	0.2	0.2	0.5	0	0	0	0.2	0.2	0
POPLYGONACEAE	0	0	0	0	0	0	0.2	0	0.2	0	0	0
LABIATAE	0.3	0.5	0	0	0	0	0.2	0	0	1.4	0	0
ROSACEAE	0	0	0	0	0	0	0	0	0.2	0	0	0
LEGUMINOSAE	0	0	0	0	0	0	0	0	0	0	0	0
Salix	0.9	1.0	0.9	0.2	0.5	0.3	0.2	0.4	0.2	0.2	0	0.2
UMBELLIFERAE	0	0	0.2	0	0	0.3	0	0	0	0	0	0.2
GRAMINEAE	1.3	1.7	1.3	1.3	1.0	1.5	0.7	0.9	0.8	1.2	1.6	1.7
CYPERACEAE	0	0	0.2	0	0.2	0.2	0.4	0	0.2	0	0	0.2
Typha/Sparganium	0	0	0.2	0	0	0	0	0	0	0	0	0
ERICACEAE	0	0	0	0	0	0	0.4	0	0.2	0	0	0.2
?Acer	0	0	0	0	0	0	0.2	0	0	0	0	0
?Plantago	0	0	0	0	0	0	0	0	0	0	0	0
?Ranunculus	0	0	0	0	0	0	0	0	0	0	0	0
Tricolpate pollen	0.3	1.2	0.4	0.9	0.7	0.2	0.4	0.2	0.4	0.5	0.2	0
Tricolporate pollen	0.3	0	0.2	0.2	0	0	0	0	0.2	0.2	0.2	0
Retitricolpate pollen	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0
Retitrcolporate pollen	0	0	0	0	0	0	0	0	0.2	0.2	0	0
Monosulcate pollen	0.3	0	0	0	0	0	0.2	0	0	0	0	0
?Moss spores	0	1.0	6.8	1.5	1.5	0	0.2	0	0.4	0.4	0	0.3
?Sphagnum	0	0	0	0	0	0	0	0	0	0	0	0.2
Lycopodium	1.9	1.9	0.2	0	1.2	0.2	0	0	0.2	0	0	0.2
Selaginella	0.9	2.9	1.8	0.8	1.0	0.9	0	0.2	0.2	0	0	0.2
POLYPODIACEAE	3.5	3.1	4.2	3.4	2.7	2.6	4.9	2.8	3.7	5.9	1.8	4.2
Dryopteris type	1.9	1.0	1.1	1.7	0.5	0.9	0.9	0.9	0.8	1.6	0.9	2.3
Trilete spores	0.6	2.4	3.6	2.6	2.7	1.7	1.1	0.9	1.8	0.7	0.9	1.4
?Osmunda	0.3	0	0	0	0	0.2	0	0	0	0	0	0
Unknowns	1.3	0.7	0.7	0	0.7	0	0.5	0.4	0.6	0.0	1.1	0.7
Indeterminates	4.4	5.1	5.1	3.6	4.7	2.6	3.9	2.4	3.7	3.9	4.9	2.3

Appendix D: Pollen Data

Core: PS-3 **Puget Sound 2005 Sediment Core**

Depth (cm)	87.5	97.5	107.5	117.5	127.5	137.5	152.5	157.5	167.5	177.5	187.5	197.5
Fungal spores	0.6	1.2	2.2	0.9	1.5	1.2	0.9	0.9	2.2	1.8	1.1	1.6
Algae	2.2	1.7	1.8	2.1	3.5	3.4	3.7	7.4	7.3	3.5	4.2	3.8
Botryococcus	0.6	0	0	0.2	0	0	0	0	0	0	0	0
Pediastrum	0.3	0	0	0	0	0	0	0	0	0	0	0
Marine Algae	1.9	5.3	3.5	4.1	5.5	7.0	6.0	3.5	3.2	8.7	20.3	15.6
Dinoflagellate	0.0	1.0	0	0.9	0.5	1.0	0.2	0.7	0.2	0.7	4.9	4.5
Foraminifers	0.6	1.2	0.7	1.7	2.2	1.4	1.1	1.3	2.0	1.1	2.4	2.4
Total tally	365	531	752	754	514	865	807	652	754	838	772	948

Appendix D: Pollen Data

Core: HC-3 **Hood Canal 2005 Sediment Core**

Depth (cm)	3	21	43	53	63	75	83	95	103	115	123	143	163	183
Abies	0.3	0.6	0.6	0.8	2.2	0.9	1.3	2.1	0.8	1.2	0.4	0.5	1.4	1.0
Picea	1.0	0.0	0.0	1.3	1.4	1.6	2.2	1.8	1.8	0.6	0.7	1.6	0.9	1.4
Pinus	8.6	2.9	8.7	7.4	11.7	3.8	9.3	7.1	7.9	7.2	2.6	9.0	8.2	6.1
Pseudotsuga/Larix	2.6	4.1	5.8	3.0	8.1	7.2	9.3	9.5	7.9	5.6	6.3	8.3	6.3	6.8
Tsuga	6.3	2.9	9.3	8.4	12.3	8.8	12.1	13.0	13.8	5.3	2.6	7.6	11.1	5.7
PINACEAE	4.3	2.9	2.9	2.8	4.7	2.2	6.7	3.8	3.6	2.8	0.4	2.8	4.0	2.4
T-C-T	15.1	20.3	20.9	36.3	11.7	30.8	10.4	34.0	18.4	45.8	41.3	25.8	23.3	38.5
Total conifers	**38**	**34**	**48**	**60**	**52**	**55**	**51**	**71**	**54**	**69**	**54**	**56**	**55**	**62**
Alnus	**41**	**49**	**22**	**21**	**26**	**21**	**27**	**13**	**26**	**15**	**27**	**27**	**22**	**15**
Betula	0.3	0	0	0.8	0.3	0.6	0.6	0	0.3	0	0	0.2	0.3	0.3
CHENOPODIACEAE	0.3	1.2	1.2	0.8	1.1	0.6	1.5	0.3	1.5	0.6	1.1	1.4	0	2.0
Artemisia	0.3	0	0	0.5	0.3	0.3	0.6	0.3	0.3	0.3	0	0.2	0	0
Aster type	1.0	0.6	0	0.3	0	0	0	0	0	0.3	0	0	0	0
Tamaxacum type	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0
Quercus	0	0.6	0.6	0	0	0	0	0	0	0	0	0	0	0
LABIATAE	0	0	0	0	0	0	0	0	0	0	0.4	0	0	0
LEGUMINOSAE	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0
Salix	0	0.6	0.6	0.3	0.3	0.3	0.6	0.3	0	0	3.3	0.2	0.3	0.7
GRAMINEAE	1.3	1.7	0.6	1.5	1.7	1.3	0.2	1.2	0.8	0.3	0.4	0.5	1.1	1.0
CYPERACEAE	0.3	0	0	0.3	0	0	0	0	0	0	0	0	0	0
ERICACEAE	0.3	0.6	0.6	0	0	0	0	0	0	0	0	0	0	0
Tricolpate pollen	0.3	2.3	2.3	0.3	0.6	0.9	0.9	0.3	1.5	0.3	1.8	0.9	0.6	0.3
Tricolporate pollen	0	0	0	0.5	0.6	0	0.9	0.3	0.5	0	1.5	0.2	0	0
?Moss spores	0	0	0	0	0	0	0.2	0	1.0	0	0.7	0.5	0	1.0
?Sphagnum	0	0	0	0	0	0	0	0.6	0	0.3	0	0.5	0	0
Selaginella	0	0	0	0	0	0	1.3	0	0.5	0	0	0	0.3	0
POLYPODIACEAE	4.3	2.9	7.6	4.8	8.1	7.9	6.5	4.7	6.4	5.3	5.2	6.2	9.9	8.1
Dryopteris type	2.3	0.6	5.2	1.8	1.7	1.9	1.7	2.1	1.3	1.2	1.5	0.7	2.3	1.4
Trilete spores	4.6	1.7	7.0	2.0	4.2	2.8	3.2	1.2	2.8	2.8	0.7	2.5	3.1	3.7
Unknowns	1.6	1.2	0.6	0.8	0.6	0.6	0.6	0.3	0.5	0.3	0.4	0.9	0.9	0.7
Indeterminates	3.3	3.5	3.5	4.8	2.2	6.0	1.9	4.4	2.6	4.7	1.8	2.5	3.7	3.7
Fungal spores	0.7	2.3	2.3	2.5	3.4	2.5	3.9	1.5	4.3	1.6	4.1	3.9	6.0	6.8
Algae	0.7	1.2	2.3	2.0	2.2	2.5	0.4	1.2	2.3	3.7	3.0	4.8	1.1	3.4
Marine Algae	3.0	2.9	4.1	5.3	10.6	10.4	9.7	8.0	7.9	5.6	1.8	5.3	6.3	4.7
Dinoflagellate	0	0	0	0	0.3	0.6	0	0.3	0	0.3	0	0	0.6	0
Foraminifers	0	0	0	0	0	0.6	0.4	1.2	0.3	0	0	0.5	0.3	0
Total tally	460	243	272	558	609	535	751	505	615	436	388	714	596	435

Pollen counts are total pollen and spores
Fungi, algae, and foraminifers are numbers per 100 pollen/spores.

Appendix D: Pollen Data

Core: HC-4 **Hood Canal 2005 Sediment Core**

Depth (cm)	3	5	9	17	19	27	29	37	39	47	49
Abies	0.7	2.5	1.0	0.8	1.1	1.2	1.6	0.2	1.3	2.4	3.5
Picea	0	0.2	1.0	0.6	0.2	0	0	0.2	0.5	0.7	1.1
Pinus	3.7	8.3	9.1	7.7	6.6	8.4	9.8	9.1	9.8	7.5	10.4
Pseudotsuga/Larix	1.2	2.7	6.2	4.1	2.2	3.0	3.2	3.3	2.8	3.8	6.2
Tsuga	5.3	8.4	10.4	9.2	7.9	8.6	9.5	10.5	9.8	14.0	19.0
PINACEAE	2.3	2.5	2.9	2.4	2.9	2.8	2.0	3.3	3.5	2.4	5.4
T-C-T	24	18	18	21	16	23	23	19	24	24	17
Total conifers	**38**	**43**	**48**	**46**	**37**	**47**	**49**	**46**	**52**	**54**	**63**
Alnus	**43**	**43**	**35**	**38**	**41**	**35**	**33**	**32**	**25**	**18**	**20**
Betula	0.2	0.2	0.3	0.2	0.4	0	0.7	0.2	0.3	0	0.2
CHENOPODIACEAE	1.1	0.3	0.3	0.4	0.4	0.5	0.2	0.8	0.8	0.9	0.6
Ambrosia	0	0	0	0	0	0.2	0	0	0	0	0
Artemisia	0.2	0.5	1.0	0	0.7	0	0	1.0	0.5	0.2	0.7
Aster type	0.7	0.2	0	0	0.9	0	0	0.2	0	0.2	0
Tamaxacum type	0.2	0	0	0	0.2	0	0	0	0	0	0
Quercus	0	0	0	0	0	0	0	0	0	0	0
POPLYGONACEAE	0	0	0	0	0	0	0	0	0	0	0
LABIATAE	0	0.2	0	0	0	0	0	0	0	0	0
ROSACEAE	0.4	0	0	0	0	0	0	0	0	0.2	0
LEGUMINOSAE	0	0	0	0	0	0.2	0	0	0	0.0	0
Salix	0.4	0.2	0	0.6	0.7	0.3	0	0.6	0	0.2	0
Tilia	0	0	0	0	0	0	0	0	0	0	0
UMBELLIFERAE	0	0	0	0	0	0	0	0	0	0	0
GRAMINEAE	2.1	0.3	0.6	0.9	2.2	0.8	0.2	1.0	1.5	1.8	0.6
CYPERACEAE	0.2	0	0	0.2	0	0	0	0.2	0	0	0
Typha/Sparganium	0	0.7	0	0	0	0	0	0	0	0	0
ERICACEAE	0	0	0	0	0.2	0.2	0	0	0	0	0
?Acer	0.2	0	0	0	0	0	0	0	0	0	0
?Plantago	0.2	0	0	0	0	0	0	0	0	0	0
?Ranunculus	0	0	0	0	0	0	0	0	0	0.2	0
Tricolpate pollen	0.4	0.5	0.6	0.2	0	0.8	0.2	0.4	0.5	0.2	0
Tricolporate pollen	0.2	0.5	0	0.2	0	0.2	0	0.4	0	0	0
Retitricolpate pollen	0	0	0	0	0	0	0.2	0	0	0	0
Retitrcolporate pollen	0	0.2	0	0	0.2	0	0	0	0	0	0
Monosulcate pollen	0	0	0	0	0	0.2	0	0	0	0	0
?Moss spores	0.2	0.2	0	0	0	0.2	0	0.4	0	0.4	0.2
?Sphagnum	0.2	0	0	0	0	0.2	0	0.2	0	0	0
Lycopodium	0	0	0	0.2	0	0	0	0	0	0	0
Selaginella	0	0	0	0.2	0	1.0	0	0	0	0	0
POLYPODIACEAE	5.0	4.6	6.2	5.8	8.1	4.0	6.8	6.2	6.5	8.0	6.0
Dryopteris type	2.8	3.0	2.6	3.0	2.4	2.5	2.0	2.3	3.3	1.3	1.5
Trilete spores	1.8	1.3	1.6	2.6	2.0	4.1	3.0	5.2	6.0	9.3	4.5
?Osmunda	0	0	0	0	0	0	0	0	0	0	0

Appendix D: Pollen Data

Core: HC-4 **Hood Canal 2005 Sediment Core**

Depth (cm)	3	5	9	17	19	27	29	37	39	47	49
Unknowns	0.5	0	1.0	0.2	0.2	0.5	0.2	0.6	0	0	0.2
Indeterminates	3.0	1.7	2.6	2.1	3.3	3.0	3.6	2.9	4.0	4.2	3.4
Fungal spores	5.3	2.7	2.6	3.2	2.0	3.0	3.0	2.9	2.0	3.1	2.6
Algae	2.1	2.9	1.9	3.8	7.9	5.8	4.8	3.9	1.5	3.5	1.3
Botryococcus	0	0	0	0	0	0	0	0	0	0	0
Pediastrum	0	0	0	0	0	0	0	0	0	0	0
Marine Algae	5.2	2.4	3.6	3.2	3.5	4.5	2.0	2.7	2.0	2.4	2.1
Dinoflagellate	0.2	0.5	0.3	0.2	0.4	0.5	0.5	0.2	0	0.2	0.4
Foraminifers	0.4	0.8	1.0	0.6	0.2	0.3	0.2	0	0	0.2	0.2
Total tally	805	977	452	745	658	799	658	676	579	675.0	763

Pollen counts are total pollen and spores
Fungi, algae, and foraminifers are numbers per 100 pollen/spores.

Appendix D: Pollen Data

Core: HC-4 **Hood Canal 2005 Sediment Core**

Depth (cm)	57.5	57.5	77.5	87.5	97.5	107.5	117.5	127.5	137.5	147.5
Abies	2.1	2.3	3.6	3.4	1.5	1.5	1.3	3.4	0.7	1.8
Picea	0.3	0.2	0.4	2.5	0.7	0.7	0.6	4.7	1.1	1.8
Pinus	8.0	10.7	7.4	6.3	12.4	5.6	8.7	6.8	8.8	7.9
Pseudotsuga/Larix	3.2	4.2	5.4	8.0	7.3	9.7	0.1	8.1	7.7	10.0
Tsuga	14.7	19.5	15.2	16.5	11.7	14.1	14.3	13.6	7.3	11.8
PINACEAE	2.4	3.2	2.4	3.0	4.0	6.3	1.6	5.9	4.0	3.2
T-C-T	33	18	27	33	17	27	33	21	34	34
Total conifers	**64**	**58**	**62**	**73**	**55**	**65**	**60**	**63**	**63**	**71**
Alnus	**18**	**17**	**22**	**14**	**26**	**19**	**20**	**19**	**15**	**15**
Betula	0.1	0	1.3	0	0.4	0	0.6	0	0	0.7
CHENOPODIACEAE	0.8	0.8	1.4	0.4	0.4	0.4	1.8	0.8	0.7	1.1
Ambrosia	0	0	0	0	0	0	0	0	0	0
Artemisia	0	0.4	0.4	0	0.4	0.4	0.4	0	0	0.4
Aster type	0	0	0	0	0	0	0.3	0	0.4	0
Tamaxacum type	0	0	0	0	0	0	0	0	0	0
Quercus	0	0	0	0	0	0	0	0	0	0
POPLYGONACEAE	0	0	0	0	0	0	0	0	0	0.4
LABIATAE	0	0.2	0	0	0	0	0	0	0	0
ROSACEAE	0.1	0	0	0	0	0	0	0	0	0
LEGUMINOSAE	0.0	0	0	0	0	0	0	0	0	0
Salix	0.3	0	0	0.4	0.4	0.4	0.3	0	0.7	0
Tilia	0	0	0.2	0	0	0	0	0	0	0
UMBELLIFERAE	0.1	0	0	0	0	0	0	0	0.4	0
GRAMINEAE	1.0	0.8	0.2	2.1	2.6	0.7	1.3	0.8	1.1	1.1
CYPERACEAE	0	0	0	0	0	0	0	0.4	0	0
Typha/Sparganium	0	0	0.2	0	0.4	0	0	0	0	0
ERICACEAE	0	0	0	0	0.4	0	0.1	0	0	0
?Acer	0	0	0	0	0	0	0	0	0	0
?Plantago	0	0.2	0	0	0	0	0	0	0	0
?Ranunculus	0	0.2	0	0	0.4	0	0	0	0	0
Tricolpate pollen	0.2	0.2	0.2	0.4	0.4	0	0.4	0	0.4	0.7
Tricolporate pollen	0.2	0	0.2	1.3	0	0	0.3	0	0.4	0
Retitricolpate pollen	0	0	0	0	0.4	0	0	0	0	0
Retitrcolporate pollen	0	0	0	0	0	0.4	0	0	0	0
Monosulcate pollen	0	0	0	0	0	0	0	0	0	0
?Moss spores	0.8	0	0	0	0	0.7	0.4	0	0.7	0
?Sphagnum	0.1	0	0	0	0	0.4	0	0	0	0
Lycopodium	0	0	0	0	0	0	0.1	0	0	0
Selaginella	0.3	0	0	0	0	0	0	0	0	0
POLYPODIACEAE	5.6	8.6	6.7	2.1	5.1	6.3	6.1	5.9	6.2	5.4
Dryopteris type	3.0	2.7	2.0	0.8	2.6	1.9	3.6	1.7	0.7	1.8
Trilete spores	3.1	6.3	2.2	1.3	1.1	1.1	1.6	2.1	6.2	2.9
?Osmunda	0	0.2	0	0	0	0	0	0	0	0

Appendix D: Pollen Data

Core: HC-4 **Hood Canal 2005 Sediment Core**

Depth (cm)	57.5	57.5	77.5	87.5	97.5	107.5	117.5	127.5	137.5	147.5
Unknowns	0.2	0.2	0	1.3	0.4	0.4	0.4	0	0.4	0
Indeterminates	2.6	4.4	1.4	3.8	4.4	3.3	2.5	6.4	2.6	0
Fungal spores	5.6	2.9	2.0	1.3	0.7	1.9	8.4	2.5	2.9	2.2
Algae	1.7	2.5	2.9	2.5	2.6	4.5	8.3	1.7	4.4	3.2
Botryococcus	0	0	0	0	0	0	0	0	0	0
Pediastrum	0	0	0	0	0	0	0	0	0	0
Marine Algae	6.6	10.1	5.8	8.0	2.6	11.2	10.4	4.7	5.1	3.9
Dinoflagellate	0.2	0.2	0.2	0.4	1.5	0.4	0.3	0.8	1.1	0
Foraminifers	0.8	0.8	0.2	0	0	0	0.4	0	0.4	0.7
Total tally	1143	736	817	327	396	399	1024	386	367	419

Appendix D: Pollen Data

Core: HC-4 **Hood Canal 2005 Sediment Core**

Depth (cm)	157.5	167.5	177.5	187.5	197.5	207.5	217.5	227.5	237.5	247.5
Abies	1.6	2.2	2.7	2.4	2.4	1.3	1.5	0.6	2.7	0.8
Picea	1.6	2.6	0.9	0.5	2.4	1.0	1.8	1.4	0.8	1.1
Pinus	5.4	4.9	13.6	7.2	8.7	5.6	6.6	5.8	6.8	10.6
Pseudotsuga/Larix	9.6	7.1	0.4	5.3	8.7	9.2	9.0	6.1	0.5	10.3
Tsuga	13.5	13.1	15.9	9.8	13.0	12.5	10.2	13.1	13.1	10.6
PINACEAE	2.6	2.2	3.9	2.9	4.7	2.0	3.6	2.8	3.0	5.9
T-C-T	39	43	30	39	39	43	35	42	40	31
Total conifers	**73**	**75**	**67**	**67**	**79**	**75**	**67**	**71**	**67**	**70**
Alnus	**10**	**13**	**21**	**15**	**7.1**	**12**	**13**	**15**	**16**	**12**
Betula	0.3	0.4	0.3	0.3	0.4	0	0.6	0	0.4	0.3
CHENOPODIACEAE	0.3	0	0.7	0.8	1.2	1.0	0.9	1.1	0.7	0.6
Ambrosia	0	0	0	0	0	0	0	0	0.1	0
Artemisia	0.3	0.7	0.5	0.5	0.4	0.3	0.3	0.3	0.3	0
Aster type	0	0.4	0.1	0	0	0	0	0	0.3	0
Tamaxacum type	0	0	0	0	0	0	0	0	0	0
Quercus	0	0	0	0	0	0	0	0.3	0.3	0.3
POPLYGONACEAE	0	0	0	0	0	0	0	0	0	0.3
LABIATAE	0	0	0	0.3	0	0	0	0	0	0
ROSACEAE	0	0	0	0.3	0	0	0	0	0	0
LEGUMINOSAE	0	0	0	0	0	0	0	0	0	0
Salix	0	0	0.1	0.8	0	0	0	0	0.4	0
Tilia	0	0	0	0.3	0	0	0	0	0	0
UMBELLIFERAE	0	0	0	0	0	0	0	0	0	0
GRAMINEAE	0.6	0.7	0.7	0.5	1.6	1.3	0.9	0.3	0.3	0.3
CYPERACEAE	0	0	0	0	0	0	0	0	0.1	0
Typha/Sparganium	0	0	0	0	0	0	0	0	0.0	0
ERICACEAE	0	0	0.1	0	0	0.3	0	0	0	0
?Acer	0	0	0	0	0	0	0	0	0	0
?Plantago	0	0	0	0	0	0	0	0.3	0	0
?Ranunculus	0	0	0	0.3	0	0	0	0	0	0
Tricolpate pollen	0.6	0.4	0.1	0.0	0.8	0.3	0	0.8	0.7	1.1
Tricolporate pollen	0	0	0.3	0.3	0	0	0	0.3	0.4	0.3
Retitricolpate pollen	0	0	0	0	0	0	0	0	0	0
Retitrcolporate pollen	0	0	0	0	0	0	0	0	0	0
Monosulcate pollen	0	0	0	0	0	0	0	0	0.1	0.3
?Moss spores	0	0	0	1.9	0.4	0	0	0	0.3	0.8
?Sphagnum	0	0	0	0.3	0	0.3	0.3	0	0	0
Lycopodium	0	0	0	0	0	0	0	0	0	0
Selaginella	0	0	0	0	0	0	0	0	0	0
POLYPODIACEAE	5.4	2.2	4.5	4.0	3.9	3.6	6.3	3.6	6.1	2.8
Dryopteris type	2.2	0.7	1.9	2.1	1.2	0.7	1.2	2.2	2.2	1.1
Trilete spores	3.5	1.1	1.2	1.6	0.8	1.7	2.4	0.8	1.1	3.4
?Osmunda	0	0	0	0	0	0	0	0	0	0

Appendix D: Pollen Data

Core: HC-4 **Hood Canal 2005 Sediment Core**

Depth (cm)	157.5	167.5	177.5	187.5	197.5	207.5	217.5	227.5	237.5	247.5
Unknowns	0	1.9	0.4	0	0.4	0.7	0.6	0.8	1.0	2.2
Indeterminates	3.8	3.0	1.5	3.7	3.1	2.6	6.0	2.5	2.0	4.5
Fungal spores	1.0	0.4	5.3	5.9	3.5	2.6	2.1	1.4	7.1	3.4
Algae	2.6	4.1	3.5	7.2	2.0	2.3	3.6	1.7	4.2	3.1
Botryococcus	0	0	0	0	0	0	0	0	0	0
Pediastrum	0	0	0	0	0.4	0	0	0	0	0
Marine Algae	6.7	14.2	8.9	6.6	5.9	8.3	6.3	11.4	15.1	15.1
Dinoflagellate	0	0.7	0.4	1.3	1.6	1.3	0	1.4	0.4	0.8
Foraminifers	0.3	0.4	0.5	1.1	1.2	0.7	0	0.3	1.1	0.6
Total tally	420	374	1072	571	362	451	468	516	1137	522

Appendix D: Pollen Data

Core: HC-5 **Hood Canal 2005 Sediment Core**

Depth (cm)	3	13	23	33	43	53	63	73	83	95	107.5	117.5	127.5
Abies	0.9	1.3	0.3	2.1	1.8	2.6	2.9	2.2	1.7	2.2	2.2	0.9	1.9
Picea	2.3	2.3	0	0.5	3.3	2.3	3.5	1.7	2.6	3.4	3.1	1.2	1.0
Pinus Undiff.	8.9	4.9	4.5	8.9	7.6	3.7	7.0	7.1	6.1	9.0	12.6	9.0	8.4
Pseudotsuga	3.1	2.3	3.5	2.8	4.3	2.6	5.4	3.7	6.4	4.8	6.0	4.7	3.2
Tsuga	5.4	6.5	8.7	8.9	7.1	10.3	8.0	11.0	15.7	17.7	17.3	10.9	10.4
PINACEAE	3.1	1.3	1.9	2.6	2.3	2.8	3.8	3.2	2.0	3.4	5.3	3.4	3.2
T-C-T	15.4	15.6	28.7	17.0	17.7	18.8	24.5	30.0	22.7	21.9	22.0	25.8	33.3
Total conifers	**39**	**34**	**48**	**43**	**44**	**43**	**55**	**59**	**57**	**62**	**69**	**56**	**61**
Alnus	**40**	**46**	**39**	**40**	**36**	**31**	**23**	**21**	**21**	**19**	**13**	**23**	**22**
Betula	0.3	0.3	0	0.5	0.5	0.6	0.3	0.5	0.9	0.3	0.3	0.3	0.6
Corylus	0	0	0	0	0	0	0	0.0	0.3	0	0	0	0
CHENOPODIACEAE	0.3	0.3	0.6	0	1.0	0.9	0.3	0.2	0.6	0.3	0.9	0	1.0
Ambrosia	0	0	0	0	0	0	0	0	0	0	0	0	0
Artemisia	0.9	1.3	0.3	0.5	0.8	0.6	1.6	0.2	1.5	1.1	0.6	0.6	0.3
Aster-type	0	0	0	0.7	0	0.3	0	0.2	0.3	0	0	0	0.6
CARYOPHYLLACEAE	0	0	0	0	0	0	0	0	0	0	0	0	0
LAMIACEAE	0	0	0	0	0	0	0	0	0	0	0	0.3	0
Quercus	0	0	0	0	0.3	0	0	0	0	0.6	0	0	0
POLYGONACEAE	0	0.3	0	0	0	0.3	0	0	0	0	0	0	0
ROSACEAE	0	0.3	0	0	0	0	0.3	0	0.3	0	0	0	0
Salix	0.3	0	0.6	0	0	0	0	0.2	0.0	0.3	0	0.3	0
ULMACEAE	0	0	0	0	0	0	0	0	0	0	0	0.6	0
UMBELLIFERAE	0	0	0	0	0	0	0	0	0	0	0	0	0
POACEAE	1.7	1.6	1.9	2.3	2.3	1.4	0.3	2.0	0.9	0.8	1.6	0.6	0.3
Typha	0.3	0.5	0	0	0	0	0	0	0	0	0	0	0
CYPERACEAE	0	0	0	0	0.3	0	0.3	0	0.3	0	0	0	0.3
Monosulcate	0	0.3	0	0	0	0	0	0	0	0	0	0	0
Tricolpate	1.1	1.3	0.6	0.9	0.5	0.9	0.6	0.5	0.3	0.8	0.9	0.9	0.6
Tricolporate	0.3	0.3	0.3	0	0.0	0	0	0	0	0	0.6	0.3	0
Reti-tricolpate	0	0	0.3	0	0.5	0	0	0.2	0.6	0	0	0.3	0.3
Reti-tricolporate	0	0	0	0	0.3	0	0	0	0	0	0	0	0
Unknowns	0	0.3	0	0.2	0	0	0.3	0.7	0	0	0.6	0.6	0
Indeterminate	2.0	0.8	1.3	1.6	2.5	3.1	2.5	3.2	3.5	4.8	2.5	3.7	3.6
POLYPODIACEAE	9.4	9.4	2.9	7.0	7.1	5.1	6.1	4.9	6.1	5.9	6.3	4.3	6.8
Dryopteris-type	2.3	2.1	1.3	1.9	0.8	0.6	1.9	1.2	0.9	1.4	2.5	2.8	0.6
Trilete	2.3	1.0	2.6	2.1	3.5	12.3	7.3	6.1	5.8	2.2	1.9	5.0	1.0
Fungal spores	1.4	2.9	2.3	2.1	2.8	3.1	5.7	2.7	8.4	3.7	4.4	3.1	8.7
Algae	2.3	0.5	7.1	2.1	1.3	3.7	4.1	5.4	4.9	3.4	0.3	3.7	7.8
Marine Algae	2.0	1.3	0.6	1.9	0.3	0.3	1.6	1.5	1.7	2.8	3.5	2.5	1.6
Dinoflagellate	0	0	0.3	0.7	0	1.1	0	1.5	0	0.3	0	0.6	0.3
Foraminifers	0	0.3	0	0.7	0.3	0.6	1.3	1.0	0.9	0.6	1.3	1.2	0.6
Total Tally	497	475	393	572	553	500	478	577	506	499	450	457	504

Pollen counts are total pollen and spores

Fungi, algae, and foraminifers are numbers per 100 pollen/spores.

Appendix D: Pollen Data

Core: HC-5 **Hood Canal 2005 Sediment Core**

Depth (cm)	137.5	147.5	157.5	167.5	177.5	187.5	197.5	207.5	217.5	237.5	247.5	257.5
Abies	2.3	3.9	1.5	4.5	2.5	2.4	1.3	2.1	2.2	2.4	1.6	1.2
Picea	4.4	2.0	3.8	2.6	4.1	1.9	3.6	1.6	1.1	3.4	2.5	2.8
Pinus Undiff.	11.6	13.5	7.6	7.4	6.8	10.0	7.4	8.2	9.7	6.6	7.1	7.8
Pseudotsuga	5.9	8.1	4.7	6.7	5.2	7.0	6.1	4.5	5.9	5.3	5.9	8.7
Tsuga	21.6	22.8	13.2	13.0	14.2	13.8	9.4	9.8	13.2	13.7	14.6	13.1
PINACEAE	3.9	4.9	4.1	5.2	3.0	4.1	2.6	2.6	1.6	2.6	2.2	2.8
T-C-T	9.3	16.2	26.0	29.4	27.0	28.2	31.4	26.1	28.0	26.6	28.0	29.6
Total conifers	**59**	**71**	**61**	**69**	**63**	**67**	**62**	**55**	**62**	**61**	**62**	**66**
Alnus	**20**	**14**	**19**	**19**	**18**	**19**	**15**	**20**	**23**	**19**	**20**	**16**
Betula	0.3	0.2	0.3	0.0	0.3	0.3	1.0	0.8	0.8	0.3	0.3	0.3
Corylus	0	0	0	0	0	0.3	0	0	0.3	0	0	0.3
CHENOPODIACEAE	0.8	0.5	1.8	0.4	0.8	0	1.3	0	0.8	0.3	0.3	0.6
Ambrosia	0	0	0	0	0.3	0	0.3	0	0	0	0	0
Artemisia	1.5	0.2	1.2	0	0.8	0.5	0.6	1.1	0.3	1.8	0	0
Aster-type	0	0.5	0.6	0.7	0	0	0.3	0	0	0	0.3	0
CARYOPHYLLACEAE	0	0	0	0.0	0	0	0	0	0	0	0	0
LAMIACEAE	0	0	0	0	0	0	0	0	0	0	0	0
Quercus	0	0	0	0	0	0	0.3	0	0	0.3	0	0.3
POLYGONACEAE	0	0	0	0	0	0	0	0	0	0	0	0.3
ROSACEAE	0.3	0	0	0	0.3	0	0.3	0	0.3	0	0	0
Salix	0.3	0	0	0	0.5	0.8	0.3	0.8	0.3	1.3	0.6	0.6
ULMACEAE	0	0	0	0	0	0	0	0	0	0	0	0
UMBELLIFERAE	0	0	0	0	0.3	0	0	0	0	0.3	0	0
POACEAE	1.3	1.0	0.6	0.7	0.3	0.3	0.6	1.1	0.5	0.8	0.6	1.2
Typha	0	0	0	0.4	0	0	0	0	0	0	0	0
CYPERACEAE	0	0	0	0	0	0	0	0	0	0	0	0
Monosulcate	0.3	0	0	0	0.3	0	0	1.1	0	0	0.3	0
Tricolpate	0.5	0.5	0.6	0.7	0.5	0.3	0.3	0	0.5	0.3	0.6	0.9
Tricolporate	0.3	0	0	0	0	0	0	0	0	0.3	0	0
Reti-tricolpate	0	0	0	0	0	0	0	0	0.3	0	0	0
Reti-tricolporate	0	0	0	0	0	0.3	0	0	0	0	0	0
Unknowns	0.3	0	0.3	0	0.5	0	0.3	1.1	0.3	0.3	0.3	0
Indeterminate	3.1	2.9	4.7	3.0	3.0	3.0	3.9	4.0	2.2	2.6	2.5	2.8
POLYPODIACEAE	7.7	6.1	7.0	4.8	8.2	4.6	9.4	9.5	5.6	6.1	7.8	6.9
Dryopteris-type	2.3	1.2	0.9	1.1	1.1	1.1	1.9	1.6	0.5	2.4	2.2	0.9
Trilete	1.8	1.0	2.3	0.7	1.6	2.2	2.6	4.2	2.4	3.2	2.5	3.1
Fungal spores	2.1	2.7	4.4	3.0	6.3	3.5	6.1	2.9	5.4	4.2	5.0	8.1
Algae	0.8	1.7	4.7	3.3	3.3	3.8	4.5	1.6	7.0	1.8	1.6	5.6
Marine Algae	1.8	10.8	5.8	3.3	3.0	4.9	4.5	3.4	3.2	4.2	3.7	3.4
Dinoflagellate	0.3	0.7	0.9	1.1	0.3	1.1	0	0.3	0	0.8	0.9	0.3
Foraminifers	1.3	0	2.0	0.7	1.6	0.3	1.3	0.3	0.8	0.5	0.3	0.6
Total Tally	684	610	541	444	530	540	483	506	540	533	470	495

Appendix E Diatom Data for Hood Canal and Puget Sound 2005 Sediment Cores

Core ID	**HC-5**	**HC-5**	**HC-5**	**HC-5**	**HC-5**	**HC-5**	**HC-5**	**HC-1**	**HC-1**	**HC-1**	**HC-1**
Core Segment (cm)	0-2	10-12	20-22	30-32	40-42	130-135	220-225	0-2	40-42	120-125	180-185
Mid-Depth (cm)	1	11	21	31	41	132.5	222.5	1	41	122.5	182.5
Total Diatom Species Counts	416	443	430	447	417	420	441	442	431	426	428
c:p	2.7	3.0	2.4	2.6	3.4	2.8	2.7	2.4	2.8	1.4	1.6
centric % ab	73.3	74.7	70.2	72.0	77.2	73.8	72.8	70.8	73.3	58.5	60.5
pennate %ab	26.7	25.3	29.8	28.0	22.8	26.2	27.2	29.2	26.7	41.5	38.6
planktonic	80.9	78.8	77.7	78.7	81.0	77.4	75.7	77.6	76.3	62.0	64.3
benthic	19.1	21.2	22.3	21.3	19.0	22.6	24.3	22.4	23.7	38.0	34.8
Planktonic/ Benthic Ratio	4.2	3.7	3.5	3.7	4.3	3.4	3.1	3.5	3.2	1.6	1.9
C:Bacs	4.7	4.9	4.3	4.2	6.0	4.6	4.2	3.7	3.7	2.0	2.1
c:araphid	6.6	7.4	5.2	6.7	7.9	7.4	7.5	7.1	10.5	4.7	6.3
araphid/ bacs	0.7	0.7	0.8	0.6	0.8	0.6	0.6	0.5	0.4	0.4	0.3
c+araph/ bacs	5.4	5.6	5.1	4.8	6.7	5.2	4.7	4.2	4.1	2.4	2.4
T. nit:P.sul	4.6	1.9	2.3	3.3	2.2	1.7	1.6	11.4	5.2	5.0	3.4
Shannon's H'	3.8	3.7	3.5	3.6	3.8	3.5	3.9	3.9	4.0	4.2	4.0
Total Species Counted	96	97	89	88	93	85	102	108	98	119	101
Total Genera Counted	30	33	28	27	29	33	35	34	36	42	39
Total Species Bacs	37	35	36	40	35	31	42	46	40	52	46
Total Species Centrics	51	49	44	41	49	45	51	50	46	49	44
Total Species Frags	8	13	9	7	9	9	9	12	12	18	11
						Percent Abundance					
Thalassionema nitzschiodes	8.90	6.55	10.7	8.05	6.5	5.71	6.1	5.7	2.6	3.5	4.7
Skeletonema costatum	14.2	15.8	18.8	12.8	11.0	20.7	9.3	13.6	11.1	13.4	12.9
Skeletonema costatum + Detonula spp	17.1	23.9	19.8	14.1	15.1	25.5	12.0	13.1	11.1	12.7	12.9
Rhizosolenia	4.10	2.93	3.49	5.82	2.20	0.00	0.70	4.10	5.30	0.20	0.00
Paralia sulcata	1.92	3.39	4.65	2.46	2.90	3.33	3.90	0.50	0.50	0.70	1.40
Cyclotellas	0.96	1.58	1.40	2.46	0.70	0.48	1.60	2.70	6.70	2.10	7.50
Thalassiosira	14.7	13.3	15.1	21.5	24.5	14.3	18.6	19.5	16.7	13.4	10.0
Pseudonitzschia	0.71	0.90	1.40	1.12	0.20	1.19	0.70	1.60	0.90	0.70	0.50
Cocconeis Achnanthes	6.02	4.06	6.28	6.71	4.10	3.10	6.30	4.50	4.90	7.30	8.40
Naviculales	4.80	5.60	5.60	6.00	5.80	5.20	8.60	9.70	7.90	10.6	11.0
Chaetoceros	22.4	16.3	15.8	19.9	22.1	24.0	28.3	17.2	20.2	16.7	20.8
Total % Listed	**95.8**	**94.4**	**103**	**101**	**95.1**	**104**	**96.1**	**92.2**	**87.9**	**81.3**	**90.1**
Million valves/ cc sed	**182**	**240**	**206**	**264**	**294**	**299**	**299**	**89.0**	**114**	**105**	**96.3**

Appendix E Diatom Data for Hood Canal and Puget Sound 2005 Sediment Cores

Core ID	**PS-1**	**PS-1**	**PS-1**	**PS-1**	**PS-1**	**PS-1**	**PS-4**	**PS-4**	**PS-4**	**PS-4**	**PS-4**	**PS-4**
Core Segment (cm)	0-2	26-28	50-52	80-85	135-140	240-245	0-2	28-30	75-80	125-130	180-185	215-220
Mid-Depth (cm)	1	27	51	82.5	137.5	242.5	1	29	77.5	127.5	182.5	217.5
Total Diatom Species Counts	437	438	443	431	436	421	432	436	436	413	402	432
c:p	4.1	3.8	4.7	3.0	2.8	2.7	4.3	3.4	3.0	4.9	3.7	2.8
centric % ab	80.3	79.0	82.4	74.7	73.4	73.2	81.0	77.3	75.0	83.1	78.9	73.8
pennate %ab	19.7	21.0	17.6	25.3	26.6	26.8	19.0	22.7	25.0	16.9	21.1	26.2
planktonic	84.1	77.9	81.5	76.1	74.5	74.4	82.9	81.4	75.5	84.0	79.8	74.3
benthic	15.9	22.1	18.5	23.9	25.5	25.6	17.1	18.6	24.5	16.0	20.2	25.7
Planktonic/ Benthic Ratio	5.3	3.5	4.4	3.2	2.9	2.9	4.9	4.4	3.1	5.2	3.9	2.9
C:Bacs	5.8	5.9	6.4	5.0	4.2	4.3	6.6	6.4	4.8	6.7	4.8	4.0
c:araphid	14.0	10.5	17.4	7.2	8.0	7.5	12.1	7.3	8.0	18.1	16.7	9.7
araphid/ bacs	0.4	0.6	0.4	0.7	0.5	0.6	0.6	0.9	0.6	0.4	0.3	0.4
c+araph/ bacs	6.2	6.4	6.8	5.7	4.7	4.8	7.2	7.2	5.4	7.1	5.1	4.4
T. nit:P.sul	1.2	0.7	0.6	1.2	1.2	1.1	1.2	1.8	0.9	1.1	1.1	1.0
Shannon's H'	3.7	3.6	3.4	3.7	3.8	3.6	3.5	3.7	3.8	3.4	3.6	3.8
Total Species Counted	93	89	87	94	95	89	82	82	105	80	85	105
Total Genera Counted	31	33	32	33	37	35	33	29	35	28	35	39
Total Species Bacs	30	36	33	36	42	36	29	23	41	31	35	49
Total Species Centrics	57	42	46	45	46	43	43	45	52	43	45	44
Total Species Frags	6	11	8	13	7	10	10	14	12	6	5	12
							Percent Abundance					
Thalassionema nitzschiodes	2.5	4.1	2.5	5.3	5.5	6.2	2.8	5.3	4.4	3.1	3.7	3.9
Skeletonema costatum	17.8	18.5	26	15.5	7.6	6.9	16.4	13.3	19	24.9	16.7	16.7
Skeletonema costatum + Detonula spp	14.4	19.6	26.9	16.9	8.94	6.89	17.1	14.7	19.0	25.2	16.7	16.9
Rhizosolenia	4.80	1.40	2.00	3.50	0.00	0.50	6.00	7.60	2.80	2.20	0.20	0.00
Paralia sulcata	2.10	5.90	4.30	4.40	4.60	5.50	2.30	3.00	5.00	2.70	3.50	3.90
Cyclotellas	0.90	0.90	0.50	0.20	1.40	1.40	0.20	0.50	1.40	0.70	0.50	0.20
Thalassiosira	14.0	20.1	21.2	22.0	17.4	12.4	19.2	25.7	23.2	25.9	26.1	26.6
Pseudonitzschia	3.40	0.70	0.90	0.50	0.20	0.50	1.40	1.80	1.10	0.50	0.70	0.50
Cocconeis Achnanthes	4.30	4.80	4.30	4.60	3.90	7.10	2.10	5.70	4.80	4.80	5.70	6.90
Naviculales	4.10	6.40	6.30	7.70	9.90	7.80	6.50	2.80	8.00	6.10	8.00	7.90
Chaetoceros	27.0	24.7	19.0	20.0	30.5	40.1	20.8	18.1	16.7	13.3	17.4	16.4
Total % Listed	**95.3**	**107**	**114**	**101**	**89.9**	**95.3**	**94.8**	**98.5**	**105.4**	**109.4**	**99.2**	**99.9**
Million valves/ cc sed	**122**	**153**	**214**	**277**	**262**	**205**	**160**	**140**	**155**	**402**	**304**	**495**

Appendix F: Foraminifera Data for Hood Canal and Puget Sound 2005 Sediment Cores													
Abundances record the actual number of specimens recovered from the sample.													
Core ID	**Core Seg. (cm)**	**Mid-Depth (cm)**	**Est. Year**	*Ammontium planissimum*	*Alveolophragmium columbiensis*	*Buccella frigida*	*Eggerella advena*	*Nonionella stella*	*Reophax scorpius*	*Spiroplectammina biformis*	*Trocchammina charlottensis*	**Total Benthic foraminifers**	Diversity
PS-1	0-2	1	2004									**0**	0
PS-1	4-6	5	2002				1					**1**	1
PS-1	10-12	11	1998									**0**	0
PS-1	26-28	27	1985							1	1	**2**	2
PS-1	32-34	33	1981									**0**	0
PS-1	38-40	39	1976									**0**	0
PS-1	44-46	45	1971									**0**	0
PS-1	50-52	51	1965									**0**	0
PS-1	60-65	62.5	1956							1		**1**	1
PS-1	70-75	72.5	1948									**0**	0
PS-1	80-85	82.5	1939								1	**1**	1
PS-1	90-95	92.5	1929	1						3		**4**	2
PS-1	100-105	102.5	1920									**0**	0
PS-1	110-115	112.5	1910									**0**	0
PS-1	120-125	122.5	1901		1							**1**	1
PS-1	130-135	132.5	1891									**0**	0
PS-1	145-150	147.5	1876								2	**2**	1
PS-1	150-155	152.5	1871				3					**3**	1
PS-1	160-165	162.5	1862						1			**1**	1
PS-1	170-175	172.5	1853								1	**1**	1
PS-1	180-185	182.5	1844	1						1		**2**	2
PS-1	190-195	192.5	1836									**0**	0
PS-1	200-205	202.5	1827							1		**1**	1
PS-1	210-215	212.5	1817				1					**1**	1
PS-1	220-225	222.5	1808	1	4	1	1	6				**13**	5
PS-1	230-235	232.5	1798				1				1	**2**	2
PS-1	240-245	242.5	1788				1				1	**2**	2
PS-1	250-255	252.5	1779			1						**1**	1

Appendix F: Foraminifera Data for Hood Canal and Puget Sound 2005 Sediment Cores																				
Abundances record the actual number of specimens recovered from the sample.																				
Core ID	**Core Segment (cm)**	**Mid-Depth (cm)**	**Est. Year**	*Ammotium planissima.*	*Alveolophragmium columbiensis*	*Buccella frigida*	*Eggerella advena*	*Elphidiella hannai*	*Elphidium frigidum*	*Elphidium magellanicum*	*Elphidium clavatum/subarctica*	*Fursenkoina seminuda*	*Nodosaria spp.*	*Nonionella stella*	*Oolina spp.*	*Quinqueloculina akneriana*	*Reophax scoripus*	*Trochammina kellettae*	**Total Benthic foraminifers**	Diversity
PS-2	0-2	1	2005		2				4	7	2								**15**	4
PS-2	8-10	9	2002																**0**	0
PS-2	20-22	21	1998																**0**	0
PS-2	30-32	31	1994																**0**	0
PS-2	40-42	41	1991																**0**	0
PS-2	50-52	51	1988																**0**	0
PS-2	60-62	61	1984																**0**	0
PS-2	70-72	71	1980				2												**2**	1
PS-2	80-85	82.5	1975				1												**1**	1
PS-2	90-95	92.5	1971		1												1		**2**	2
PS-2	100-105	102.5	1967		1	2	1												**4**	3
PS-2	110-115	112.5	1963				2											1	**3**	2
PS-2	120-125	122.5	1959					1			1								**2**	2
PS-2	130-135	132.5	1955																**0**	0
PS-2	140-145	142.5	1951																**0**	0
PS-2	150-155	152.5	1947																**0**	0
PS-2	160-165	162.5	1942																**0**	0
PS-2	170-175	172.5	1938																**0**	0
PS-2	180-185	182.5	1933																**0**	0
PS-2	190-195	192.5	1929																**0**	0
PS-2	200-205	202.5	1924																**0**	0
PS-2	210-215	212.5	1920			1					1								**2**	2
PS-2	225-230	227.5	1913																**0**	0
PS-2	230-235	232.5	1910		1	4	2				2	1	1	3	1	1			**16**	9
PS-2	240-245	242.5	1906	2	2	2			1		2			1		1			**11**	7

Appendix F: Foraminifera Data for Hood Canal and Puget Sound 2005 Sediment Cores

Abundances record the actual number of specimens recovered from the sample.

Core ID	**Core Segment (cm)**	**Mid-Depth (cm)**	**Est. Year**	*Ammotium plantissima*	*Alveolophragmium columbiensis*	*Buccella frigida*	*Buliminella elegantissima*	*Dyocibicides perforatus*	*Eggerella advena*	*Elphidium clavatum*	*Elphidium frigidum*	*Elphidium subarctica*	*Elphidiella hannai*	*Lagena spp.*	*Lagenammina atlantica*	*Nonionella basispinata*	*Nonionella stella*	*Praeglobobulimina affinis*	*Spiroplectammina biformis*	*Trochammina charlottensis*	*Trochammina kellettae*	**Total Benthic foraminifers**	Diversity
PS-3	0-2	1	2005				1			12	1		1							1		**16**	5
PS-3	10-12	11	2000						2	1												**3**	2
PS-3	20-22	21	1996																1	1	1	**3**	3
PS-3	30-32	31	1991																			**0**	0
PS-3	40-42	41	1985	1					2											4		**7**	3
PS-3	50-55	52.5	1979						2											2		**4**	2
PS-3	60-65	62.5	1973																			**0**	0
PS-3	70-75	72.5	1966	1					4										1	3		**9**	4
PS-3	80-85	82.5	1961	2	4				3										2	3	1	**15**	6
PS-3	90-95	92.5	1954	1					9										1	7		**18**	4
PS-3	100-105	102.5	1948		2				2											1		**5**	3
PS-3	110-115	112.5	1941						6										1	4		**11**	3
PS-3	120-125	122.5	1935	1					4										3	5		**13**	4
PS-3	130-135	132.5	1928						6	1									1	16		**24**	4
PS-3	140-145	142.5	1922						10										4	6	2	**22**	4
PS-3	150-155	152.5	1916						8										2	5	2	**17**	4
PS-3	160-165	162.5	1910						5										5	6	2	**18**	4
PS-3	170-175	172.5	1904						2						1		2		1			**6**	4
PS-3	180-185	182.5	1898																	2		**2**	1
PS-3	190-195	192.5	1892			2							2				1	2				**7**	4
PS-3	200-205	202.5	1886			5		1			2	5	1			1	1			2		**18**	8
PS-3	200-205	202.5	1886	1		1	1		5	3				1	1					3	3	**19**	9

Appendix F: Foraminifera Data for Hood Canal and Puget Sound 2005 Sediment Cores

Abundances record the actual number of specimens recovered from the sample.

Core ID	**Core Segment (cm)**	**Mid-Depth (cm)**	**Est. Year**	*Alveolophragmium columbiensis*	*Buccella frigida*	*Eggerella advena*	*Elphidium subarctica*	*Elphidiella hannai*	*Fursenkoina seminuda*	*Lagena elongata*	*Nonionella basispinata*	*Nonionella stella*	*Praeglobobulimina affinis*	*Quinqueloculina akneriana*	*Spiroplectammina biformis*	*Trochammina kellettae*	*Trochammina charlottensis*	**Total Benthic foraminifers**	Diversity
PS-4	0-2	1	2005			1		1							1			**3**	3
PS-4	8-10	9	2002															**0**	0
PS-4	18-20	19	1997															**0**	0
PS-4	28-30	29	1993															**0**	0
PS-4	38-40	39	1988															**0**	0
PS-4	48-50	49	1983															**0**	0
PS-4	55-60	57.5	1979															**0**	0
PS-4	65-70	67.5	1974	1								1						**2**	2
PS-4	75-80	77.5	1969															**0**	0
PS-4	85-90	87.5	1964			1									1			**2**	2
PS-4	95-100	97.5	1959	1		2									2			**5**	3
PS-4	110-115	112.5	1952	5		3									3			**11**	3
PS-4	120-125	122.5	1947		2													**2**	1
PS-4	130-135	132.5	1942															**0**	0
PS-4	140-145	142.5	1937															**0**	0
PS-4	150-155	152.5	1931															**0**	0
PS-4	160-165	162.5	1926															**0**	0
PS-4	170-175	172.5	1921															**0**	0
PS-4	180-185	182.5	1915					2				2						**4**	2
PS-4	190-195	192.5	1910															**0**	0
PS-4	200-205	202.5	1904		2								2					**4**	2
PS-4	210-215	212.5	1899	1	5	1	1		1	1	1		1	1	1	3	1	**18**	12

Appendix F: Foraminifera Data for Hood Canal and Puget Sound 2005 Sediment Cores

Abundances record the actual number of specimens recovered from the sample.

Core ID	**Core Segment (cm)**	**Mid-Depth (cm)**	**Est. Year**	*Ammontium planissimum*	*Alveolophragmium columbiensis*	*Buccella frigida*	*Buliminella elegantissima*	*Eggerella advena*	*Elphidium clavatum*	*Lagenammina atlantica*	*Recurvoides turbinatus*	*Reophax scorpius*	*Spiroplectammina biformis*	*Trochammina inflata*	*Trochammina charlottensis*	*Trochammina kelletae*	*Trochammina pacifica*	**Total Benthic foraminifers**	Diversity
HC-1	0-2	1	2004					2										**2**	1
HC-1	10-12	11	1995					5			1		2		1			**9**	4
HC-1	20-22	21	1985					7										**7**	1
HC-1	30-32	31	1974					8			1							**9**	2
HC-1	40-42	41	1963					5					2					**7**	2
HC-1	50-55	52.5	1951					7			1						1	**9**	3
HC-1	60-65	62.5	1939				3	9					1					**13**	3
HC-1	70-75	72.5	1928					10										**10**	1
HC-1	80-85	82.5	1916					11				1			2		1	**15**	4
HC-1	90-95	92.5	1904					1							7			**8**	2
HC-1	100-105	102.5	1892					8			2							**10**	2
HC-1	110-115	112.5	1879					2			1		1		1			**5**	4
HC-1	120-125	122.5	1867	1				4			3				3			**11**	4
HC-1	130-135	132.5	1855					6			1		4	1	2			**14**	5
HC-1	140-145	142.5	1843		1			10		1	1		2		1			**16**	6
HC-1	150-155	152.5	1831					12						2				**14**	2
HC-1	160-165	162.5	1819					2			1		1		1			**5**	4
HC-1	170-175	172.5	1807					1							1			**2**	2
HC-1	180-185	182.5	1794			2		9			1				1			**13**	4
HC-1	190-195	192.5	1781			1	13		1		1		2		1	2		**21**	7
HC-1	200-205	202.5	1769			5	33	1							3			**42**	4
HC-2	0-2	1	2003					1										**1**	1
HC-2	10-12	11	1996															**0**	0
HC-2	20-22	21	1996															**0**	0
HC-2	30-32	31	1996															**0**	0
HC-2	40-42	41	1992					1										**1**	1
HC-2	50-52	51	1971															**0**	0
HC-2	60-62	61	1949					1										**1**	1
HC-2	70-72	71	1926					1							1			**2**	2
HC-2	80-82	81	1904															**0**	0
HC-2	90-92	91	1880					6										**6**	1
HC-2	100-102	101	1856															**0**	0
HC-2	110-112	111	1832					1										**1**	1
HC-2	120-122	121	1809															**0**	0
HC-2	130-132	131	1784															**0**	0
HC-2	140-142	141	1759															**0**	0
HC-2	150-152	151	1735					1			2							**1**	1
HC-2	160-162	161	1710								2				2			**4**	2
HC-2	170-172	171	1681					2			1							**4**	2
HC-2	180-182	181	1655					7										**8**	2
HC-2	190-192	191	1629															**0**	0
HC-2	200-202	201	1604					2										**2**	1
HC-2	210-215	212.5	1574					1										**1**	1
HC-2	220-225	222.5	1549															**0**	0

Appendix F: Foraminifera Data for Hood Canal and Puget Sound 2005 Sediment Cores

Abundances record the actual number of specimens recovered from the sample.

Core ID	Core Seg. (cm)	Mid-Depth (cm)	Est. Year	*Alveolophragmium columbiens*	*Bolivina pacifica*	*Buccella frigida*	*Globocassidulina globosa*	*Cibicides fletcheri*	*Eggerella advena*	*Elphidium clavatum*	*Elphidiella hannai*	*Elphidium subarctica*	*Fursenkoina seminuda*	*Praeglobobulimina affinis*	*Quinqueloculina akneriana*	*Reophax scorpius*	*Recurvoides turbinatus*	*Spiroplectammina biformis*	*Stainfortha fusiformis*	*Trochammina nana*	*Trochammina pacifica*	*Trochammina kellettae*	*Trochammina charlottensis*	*Uvigerina peregrina*	**Total Benthic foraminifers**	Diversity
HC-3	18-20	19	1977							1							1								**2**	2
HC-3	30-32	31	1957	1					1				1												**3**	3
HC-3	40-42	41	1944		1				1																**2**	2
HC-3	50-52	51	1929																						**0**	0
HC-3	60-62	61	1909																						**0**	0
HC-3	70-72	71	1889																						**0**	0
HC-3	80-82	81	1869																						**0**	0
HC-3	90-92	91	1849			2		1						1										5	**9**	4
HC-3	100-102	101	1828					2																2	**4**	2
HC-3	110-112	111	1806					1																3	**4**	2
HC-3	120-122	121	1783					2																	**2**	1
HC-3	130-132	131	1760	1		2		1																7	**11**	4
HC-3	140-142	141	1738	4				1																11	**16**	3
HC-3	150-152	151	1714	1				4																4	**9**	3
HC-3	160-162	161	1690																						**0**	0
HC-3	170-172	171	1666																						**0**	0
HC-3	180-182	181	1642																			1			**1**	1
HC-3	190-192	191	1642					1																	**1**	1
HC-3	200-205	202.5	1594				2								1								1		**4**	3
HC-3	210-215	212.5	1568				1		1						1										**3**	3
HC-5	0-2	1	2004			3			4										2						**9**	3
HC-5	10-12	11	1993						4											1					**5**	2
HC-5	20-22	21	1981						6							1	2	2							**11**	4
HC-5	30-32	31	1968						25							1	21			1					**48**	4
HC-5	40-42	41	1955						10							6	12			1					**29**	4
HC-5	50-52	51	1942						6							13	8	1							**28**	4
HC-5	60-62	61	1928						2							9	6								**17**	3
HC-5	70-72	71	1914													1	6								**7**	2
HC-5	80-82	81	1900													3	3								**6**	2
HC-5	90-92	91	1886													1	3								**4**	2
HC-5	100-105	102.5	1869						1								23								**24**	2
HC-5	110-115	112.5	1854						6								7								**13**	2
HC-5	120-125	122.5	1839						2								4			1					**7**	3
HC-5	130-135	132.5	1825						1							6	8								**15**	3
HC-5	140-145	142.5	1811						2							5	4				2				**13**	4
HC-5	150-155	152.5	1797						1							4	4								**9**	3
HC-5	160-165	162.5	1784																		1				**1**	1
HC-5	170-175	172.5	1770						2							1									**3**	2
HC-5	180-185	182.5	1754						7							1	19				1				**28**	4
HC-5	190-195	192.5	1738						3							3	17								**23**	3
HC-5	200-205	202.5	1723						7							3	4	1							**15**	4
HC-5	210-215	212.5	1707						3			1		2			3				1			1	**11**	6
HC-5	220-225	222.5	1688						1							1								2	**4**	3
HC-5	230-235	232.5	1671						6		1						3	3						3	**16**	5
HC-5	240-245	242.5	1655						2							1	2								**5**	3
HC-5	250-255	252.5	1639																					2	**2**	1

Appendix F: Foraminifera Data for Hood Canal and Puget Sound 2005 Sediment Cores

Abundances record the actual number of specimens recovered from the sample.

Core ID	**Core Seg. (cm)**	**Mid-Depth (cm)**	**Est. Year**	*Alveolophragmium columbiensis*	*Astrononion incilis*	*Bolivina pacifica*	*Buccella frigida*	*Buliminella elegantissima*	*Globocassidulina globosa*	*Cibicides fletcheri*	*Eggerella advena*	*Elphidium clavatum*	*Elphidium frigidum*	*Epistominella exiqua*	*Miliolinella oblonga*	*Nonionella stella*	*Praeglobobulimina affinis*	*Quinqueloculina akneriana*	*Reophax scorpius*	*Recurvoides turbinatus*	*Rosalina columbiensis*	*Stainforthia feylingi*	*Stainforthia fusiformis*	*Spiroplectammina biformis*	*Trifarina angulosa*	*Uvigerina hispida*	*Uvigerina peregrina*	*Uvigerina peregrina dirupta*	**Total Benthic foraminifers**	Diversity
HC-4	0-2	1	2004																	3			4				1		**8**	3
HC-4	10-12	11	1987																										**0**	0
HC-4	20-22	21	1967								7									2									**9**	2
HC-4	30-32	31	1945								18								1	61									**80**	3
HC-4	40-42	41	1923								1									5									**6**	2
HC-4	50-55	52.5	1896								4									2									**6**	2
HC-4	60-65	62.5	1871																										**0**	0
HC-4	70-75	72.5	1847																										**0**	0
HC-4	80-85	82.5	1824																										**0**	0
HC-4	90-95	92.5	1799														3										2		**5**	2
HC-4	100-105	102.5	1773				1					10								1									**12**	3
HC-4	110-115	112.5	1746			1	1					1															2		**5**	4
HC-4	120-125	122.5	1721				2				2						1	1		2			4						**12**	6
HC-4	130-135	132.5	1693								1									1			1				2		**5**	4
HC-4	140-145	142.5	1665			3					2		1			1	2	1		8		8	2				5	2	**35**	11
HC-4	150-155	152.5	1638			1	2		1		6	1					3	3		7		7	9		1	1	6		**48**	13
HC-4	160-165	162.5	1612														2	1		1				1			1	6	**12**	6
HC-4	170-175	172.5	1587			1	1				2						4	4	1	10		6	4				4		**37**	10
HC-4	180-185	182.5	1564		1	1			1	1	2		1					2		4	1	17	9				2		**42**	12
HC-4	190-195	192.5	1540			1				1	5						1	11		3		60					13		**95**	8
HC-4	200-205	202.5	1513	1		1				1	15						1			11		11						14	**55**	8
HC-4	210-215	212.5	1486			1	1		1	1	8	2						1		6		8					10		**39**	10
HC-4	220-225	222.5	1459			1	2	1	1	1	10			1				6		7		25	8					7	**70**	12
HC-4	230-235	232.5	1431			1	1				2							1		6		4					13		**28**	7
HC-4	240-245	242.5	1404								4	1								1		6					1		**13**	5
HC-4	250-255	252.5	1377							1	5				2							1						2	**11**	5