An Environmental and Historical Overview of the Puget Sound Ecosystem

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Introduction: The Physical and Biological Setting

The Puget Sound ecosystem corresponds to the southern (U.S.) portion of the Strait of Georgia (aka Georgia Basin)–Puget Sound ecosystem (fig. 1). Collectively, these areas are sometimes referred to as the Salish Sea ecosystem, which straddles the United States and Canada border, and includes approximately 18,000 km^2 of water and 110,000 km^2 of land area (excluding the upper Fraser River watershed but including 419 islands) and some 7,500 km of marine shoreline, including islands (fig. 1; SeaDoc Society, 2009). The Salish Sea ecosystem is a fjord with flooded glacial valleys and is classified as a large estuary, or system of estuaries, fed by highly seasonal freshwater from the surrounding basins. The largest input of freshwater comes from the Fraser River, which drains a large part of British Columbia, Canada. Other important sources of fresh water are the Campbell, Powell, Cedar, Duwamish/Green, Elwha, Nisqually, Nooksack, Puyallup, Skagit, Skokomish, Snohomish, and Stillaguamish Rivers. This paper focuses on the Puget Sound portion of the ecosystem, despite its obvious connection to the larger system, because political boundaries tend to govern the way information is collected and summarized. Where possible, information about the Salish Sea ecosystem is included.

Much of the Salish Sea ecosystem has been shaped by similar geologic forces, including plate tectonics, volcanism, and glaciation. The topography and bathymetry of the ecosystem was most recently transformed during the Wisconsin Glacial Episode. This Episode included three major continental glaciations, starting about 70,000 years ago, separated by relatively warm interglacial periods, such as we are experiencing today. The last of these glaciations began about 30,000 years ago, reached its greatest advance 21,000 years ago near the southern edge of Puget Sound marine waters, and ended about 10,000 years ago. At the height of the most recent glaciation, sometime between 16,500 and 15,000 years ago, mammals such as humans migrated to North America from Siberia across the Bering Land Bridge (Goebel and others, 2008).

Soils of the ecosystem are derived from a complex mix of glacial and volcanic (lahar) deposits at lower elevations and in many of the major river valleys, to volcanic and marine rock at higher elevations. The character of the marine nearshore area is a function of the complex shape and geology of the coastline and the glacial deposits that have been redistributed by waves, tides and rivers (Shipman, 2008). In general, southern Puget Sound is shallower with finer grained sediments than areas to the north. Water depth in Puget Sound increases rapidly with distance from the shore. The mean water depth is 62 m, with a maximum of 370 m (Burns, 1985), and it takes approximately 5 months to completely exchange Puget Sound water with Pacific Ocean water. The weather and climate of the Puget Sound ecosystem are dominated by two main elements: winds typically blowing from west to east across the Pacific Ocean bring mild, moisture-laden air to the region throughout much of the year; mountain ranges deflect low-level air coming from the ocean, and during winter block colder air from the interior U.S. (Mass, 2008). The resulting general pattern of wet, mild winters and dry, cool summers is superimposed on complex regional topography, which ranges in elevation from 4,270 m to sea level. The western slopes of the Olympic and Cascade Mountains (fig. 1) receive enormous quantities of rain and snow during the winter. Other areas, such as the northeastern tip of the Olympic peninsula and the San Juan Island archipelago, remain relatively dry because they lie in the rainshadow of the Olympic Mountains. The maritime climate supplies water to more than ten thousand rivers and streams.

Characteristics of the watersheds that make up the Puget Sound ecosystem vary dramatically across the region. Sharp topographic relief creates highly variable local-scale climate, and in combination with diverse soil types, results in a wide variety of environmental conditions. This range in conditions supports high levels of biodiversity and other important biological phenomena. The terrestrial landscape is dominated by some of the most productive coniferous forest communities in the world, where many of the conifer species reach their maximum growth potential for height and diameter (Franklin and Dyrness, 1988). Douglas-fir forest communities dominate the lowlands of Puget Sound by virtue of their tolerance to well-drained, glacially derived soils, while hemlock and true fir (genus Abies) communities dominate wetter areas in the foothills and more mountainous regions (Franklin and Dyrness, 1988). Interspersed among the forests, particularly at lower elevations, are other notable features, such as prairie, madrone forest, oak woodland, and wetland and bog

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Figure 1. The Salish Sea Ecosystem showing marine waters in the Straits of Georgia and Juan de Fuca, and Puget Sound, and the surrounding watersheds. (Adapted from Stefan Freelan; accessed November 2009, at http://myweb.facstaff.wwu.edu/~stefan/SalishSea.htm).

ecosystems. While acknowledging that many taxonomic groups have not been well studied, the Center for Biological Diversity (2005) recognized about 7,000 species of organisms that occur in the Puget Sound Basin, including 4,248 animals, 1,504 plants, 851 fungi, and 392 algae, and ranks the Puget Sound Basin as a "hot spot" for biodiversity nationally. The World Wildlife Fund includes the Puget Sound Basin (along with Northeast Pacific Coast) as one of 200 priority ecoregions for protecting biodiversity worldwide (Ricketts and others, 1999). Lombard (2006) suggests that the Puget Sound Basin also is unique by virtue of both high salmon species richness and high natural salmon productivity, making this one of the most productive salmon areas along the Pacific Coast. This productivity is not limited to salmon. Washington State supports the second largest oyster production in the nation and the most important clam fishery (geoduck) on the west coast of North America (Puget Sound Action Team, 2007).

The Growing Human Influence

Shortly after sailing into the southern portion of the inland waters of the Pacific Northwest in 1792, George Vancouver claimed the area for Great Britain and named it after his Lieutenant, Peter Puget. Most if not all inhabitants of the Puget Sound region were Native Americans commonly referred to as Coast Salish people, who took their principal identity from permanent villages where they lived during the rainy winter months (Drucker, 1963; 1965). Villages along the coast and in major river valleys were supported by the region's abundant natural resources, primarily salmon, smelt, eulachon, herring (roe), and shellfish. Western Red Cedar was used as a building material for longhouses and canoes and as a source of material for clothing (Boas, 1992). Up until 4 to 6 thousand years ago, Native Americans were likely hunter-fisher-gatherers; however, by the time Vancouver visited the region, most coastal Native Americans lived in permanent villages and relied on specific high-productivity resource areas. The transition from hunter-gatherer to more sedentary lifestyles was related to a number of factors: exploitation of the region's abundant food resources, particularly salmon, which were increasing with the expansion of estuaries as sea level stabilized following the last glaciation (Mitchell, 1983); improved technology for fishing, hunting, and food storage; and increasing social complexity and organization (Deur, 1999).

Explorers and sea otter and beaver trappers arrived in Washington via ship or the Oregon Trail during the early 19th century. The first European settlement was established in 1846 at New Market, or Tumwater (near Olympia, fig. 1), as it currently known. In 1853, the Washington Territory was formed from part of the Oregon Territory. Logging started as early as the 1850s and quickly became a focal point of economic activity for the growing population. Forests were first harvested by axe and horse teams along marine shorelines, which also helped to open ports and facilitate shipping trade up and down the Pacific Coast (Chasan, 1981). Henry Yesler started the first steam-powered sawmill in the region, which was quickly followed by Pope and Talbot's mill at Port Gamble. By the 1870s, fueled by the California Gold Rush, San Francisco became a major market of Puget Sound Basin timber. In the 1890s, about a decade after the arrival of the transcontinental railroad, Washington State was one of the top five producers of timber in the United States, had increased salmon landings by 2,000 percent over catches two decades earlier, and was attracting adventuresome entrepreneurs from around the country (Center for the Study of the Pacific Northwest, 2009). In short, the industrial revolution that brought railroads to Washington ushered in the mechanized era of natural resource extraction on par with the scale of the region's natural resource bounty. However, the effects of the industrial revolution were not consistent across the Pacific Northwest. Oregon, which was founded by farmers, had a different land-use philosophy. This theme was touched on by Ivan Doig (1982): "Even what I have been calling the Pacific Northwest is a multiple. A basic division begins at the Columbian River; south of it, in Oregon, they have been the sounder citizens, we in Washington the sharper strivers. Transport fifty from each state as a colony on Mars and by nightfall the Oregonians will put up a school and a city hall, the Washingtonians will establish a bank and a union."

A Changing Landscape

Washington achieved statehood in 1889 and its constitution reflects the Progressive Era's heightened concern over the powers of central government (Lombard, 2006), and the belief in private property ownership in combination with untapped natural resources as the economic engine of the region (Conte, 1982). To disperse central government powers, the constitution provided substantial authority to local governments (counties, cities, and towns) to make and enforce regulations that do not conflict with general law, a legacy that continues to this day. For example, there are 2 countries, 100 cities, 12 counties, 12 conservation districts, 12 local health authorities, 3 regional councils, 22 Indian Tribes, 14 state agencies, 9 federal agencies, and 22 port districts that have some jurisdiction in Puget Sound environmental issues. As stated by Lombard (2006): "Power sharing reduces opportunities for abuse and pushes decision makers closer to the level of citizens most affected, but it also results in the fragmentation of authority of over key issues for ecosystems …". Less than 1 year after the State Constitution was adopted in 1889, the legislature authorized the sale of land between the high and low tides (Washington Department of Natural

Resources, 2000) in an act entitled "Tide and Shoreland; Appraisement and Disposal of " (Conte, 1982). By 1971, when the legislature prohibited such sales, only 40 percent of the tidelands in the Puget Sound Basin area remained in state ownership (Bish, 1982). Sale of tidelands was consistent with other Progressive Era and pro-growth agendas since most of the local commerce and industry were centered on marine harbors that provided access to deep-water shipping lanes. Although the issue was contentious at the time, ultimately selling of these tidal lands was viewed as a necessary precursor to timely port development (Conte, 1982).

The era of unmitigated ecosystem provisioning (exploitation) would come to a familiar conclusion. The peak of the salmon pack occurred in the decade from 1910 to 1919, while lumber production in the 12 counties surrounding Puget Sound declined from about 6 million board feet in 1926 to about 2 million by 1951 (Chasen, 1981). Throughout the 1920s, shellfish production declined, a fact that oysterman blamed on water pollution associated with the wood pulp industry. The economy would gradually become increasingly diversified and less dependent on natural resource extraction, particularly after the Second World War. By the mid-20th century, people of the region were coming to value Puget Sound and surrounding forests "as amenities, as objects of contemplation, and settings for avocational activities" (Chasen, 1981).

An Ecosystem in Decline

The Puget Sound Basin, like many coastal ecosystems worldwide, is in serious decline (U.S. Commission on Ocean Policy, 2004; Ruckelshaus and McClure, 2007; Heinz Center, 2008). Human population growth in the Puget Sound region has increased from about 1.29 million people in 1950 to about 4.22 million in 2005, and is expected to reach 5.36 million by 2025 (Puget Sound Regional Council, 2010; fig. 2). Much of the ecological capital (large salmon runs, mature forests, coastal wetlands, clean water) that supported extractive industries in the late 19th century has been exploited and degraded. Over the last 100 years, more than 60 percent of the State's old-growth forest has been harvested, and much of the remaining old-growth remnants are limited to relatively high elevation public land (Washington Department of Natural Resources, 1998). Approximately 23 percent of Puget Sound Basin forestland has been converted to human-dominated uses, including agriculture and urban lands (Washington Department of Natural Resources, 1998). Tidal marsh and other river estuarine ecosystem types declined by 80 percent in the last 150 years through a process of diking and draining. Much of this loss occurred prior to statehood (Bortleson and others, 1980) as early farmers took advantage of flat and fertile, relatively treeless ground near river estuaries and flood plains. Currently, about a third of the Puget Sound shoreline has been modified by the construction of seawalls, docks, and other structures (Berry, 2000). Some of this shoreline modification and the pattern of coastal land use resulted from development of major ports in the late 1800s along with connecting rail lines, especially those running along the central eastern Puget Sound shoreline. However, Puget Sound is experiencing a relatively new (beginning around 1970) round of shoreline modifications related to residential (re)development. In the process of upgrading small vacation cabins and summer homes to larger, more expensive structures, many landowners are adding seawalls to protect their investments against threat of shoreline erosion (Small and Carman, 2005). Rivers and streams have been modified by dams and water withdrawals. Nearly one-fourth of the watersheds in Puget Sound basin are over-appropriated, that is, there is not enough water to supply granted water rights and also support fish and water quality (Washington Department of Natural Resources, 2000). In 12 of 19 basins in the Puget Sound ecosystem for which data were available, a limiting factors analysis (Smith, 2005) rated water availability as poor, where a poor rating was associated with one or more of the following problems: 303(d) listing for low flow, known salmon mortality due to low flow or other studies documenting low flow problems, and prohibition to additional water allocation due to over appropriation. Point sources of water pollution have been effectively controlled even as their legacy remains, for example, the state identified 115 sites in 2008 representing more than 3,900 acres of contaminated sediments in Puget Sound (Washington Department of Ecology, 2008). Approximately 50 percent of this contamination results from readily indentified point sources including pulp, paper, and chemical production; and petroleum refining, transport, and storage. Water quality is increasingly threatened by nonpoint sources of contamination such as urban runoff from an extensive transportation network, and by new classes of chemicals such as endocrine disrupters and fire retardants that pervade our homes and businesses. The Center for Biological Diversity (2005) identified nearly 1,000 imperiled species in the region. A more recent assessment (Brown and Gaydos, 2007) noted that the number of marine related species of concern in the Salish Sea ecosystem had increased from 60 species in 2002 to 64 species in 2006. Although many species in these assessments use areas outside of the Puget Sound Basin, some iconic species or subpopulations, including Puget Sound Chinook Salmon, Steelhead Salmon, and the Southern (Puget Sound) Resident Killer Whale, are among those imperiled mostly by human related activities in the region.

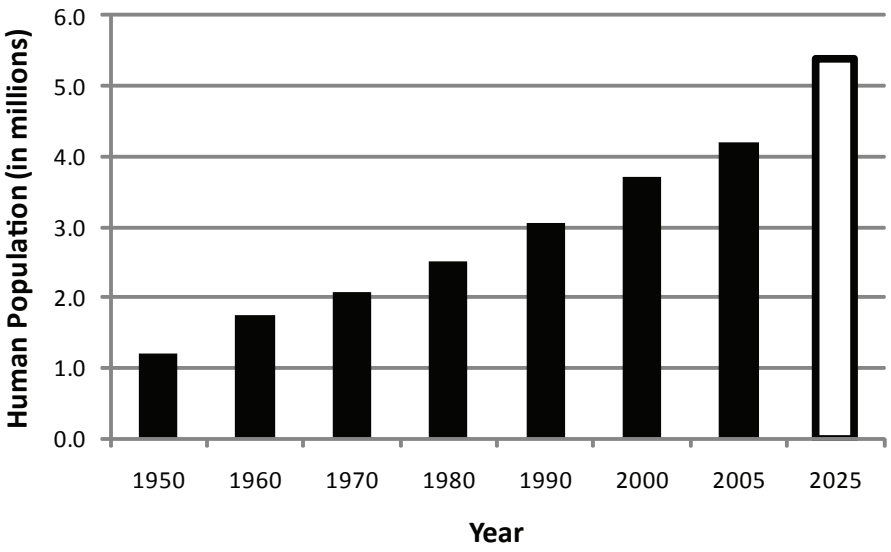

Figure 2. Human population estimates from 1950 to 2005 and projections to 2025 for the Puget Sound area of Washington State (Puget Sound Regional Council, 2010).

New Efforts to Protect Puget Sound

Many aspects of environmental issues today can be traced to land-use policy decisions made early in the history of the State, which makes the challenge of protecting and restoring the ecosystem that much more difficult. Nonetheless, Washington State and other entities are responding to the challenges of protecting and restoring the Sound in the face of increasingly important threats such as human population growth and climate change. Two new programs, the Puget Sound Nearshore Restoration Project (a joint effort sponsored by the Washington Department of Fish and Wildlife and U.S. Army Corps of Engineers) and the Puget Sound Partnership (a new state agency) are particularly promising. While details about these organizations are beyond the scope of this overview paper, both science-based programs recognize the need for a systems view of the issues (Millennium Ecosystem Assessment, 2005), the role humans play in the ecosystem, and the importance of addressing ecosystem process, structure, and function as part of the problem identification and solution.

In order to save Puget Sound, the same forces that shaped its early history, that is, the reliance on natural resource extraction, and the dispersed governance structure, must now realign. Benefits provided by a functioning ecosystem should be (re)defined in terms of ecosystem services that provide for both extractive industries (and the jobs they create) and other less visible but no less important benefits such as clean water, flood control, carbon sequestration, recreation, and fish and wildlife habitat. We must give clearer voice to the value of aesthetic, cultural, and spiritual ecosystem services, since they are difficult to quantify in traditional economic terms. Local government officials, who have been granted substantial power by the state, must recognize our inherent dependence on the ecosystem. Leaders must create a vision of the future that both supports functioning ecosystems and, in turn, is supported by the citizens they serve.

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