

Characterizing the Backshore Vegetation of Puget Sound

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Abstract

Puget Sound beaches are an important component in supporting natural processes and food webs. Backshores are an ecotone beyond the reaches of the regular tides that are stable enough to support vegetation but are periodically disturbed by extreme high tides, usually in conjunction with extreme storm events.

This study showed that the flora associated with South and Central Puget Sound backshores appear to separate into six predominant plant species, as well as nine species that are unique to coastal shorelines but are not found consistently on Puget Sound backshores. The study also answered some questions about the plants' broader role in the ecology of the ecotone and its significance in overall Puget Sound restoration efforts. I also proposed a definition for the backshore that takes into account elevation, vegetation, stability, and soils composition.

Other key findings included the role of plants in stabilizing sediments; the range of sediment size in which the plants may be found; the strong potential for revegetation efforts in the backshore; and the ecological services provided by backshore vegetation as well as the anthropogenic impacts to the ecotone.

The most potentially significant finding was the presence of buried wood in association with backshore vegetation, and the various possibilities for how the wood may provide support to the plants, which can then help maintain and recolonize disturbed backshores, thereby supporting multiple upland and marine food webs.

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Dedication

I dedicate my thesis to my son, Benjamin Wallace Guttman Beck,
in hopes that his generation has the courage to truly defend and
preserve Puget Sound—for its inherent natural wonders and beauty,
and so that it can flourish for the benefit of
future generations of all organisms.

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-- Erica Guttman

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SECTION 1: INTRODUCTION

Background

Puget Sound boasts over 3,000 km of beautiful, diverse shorelines that are home to a wide variety of organisms—including humans. Ecological systems along these shorelines are complex and dynamic, changing gradually or abruptly in response to numerous exogenous variables, including wind, tidal currents, and human disturbances. The landscape of Puget Sound is the result of a series of significant glaciations. The long, narrow valleys that define today's shoreline were carved out by the ice retreat during the Pleistocene Epoch, about 13,000 years ago, and stabilized to the present level between 5,000 and 6,000 years ago, when there was an uplifting of the earth's crust under the Puget Lowland (Downing 1983; Shipman 2008).

A defining feature of Puget Sound beaches is the presence of the coastal bluffs or sea cliffs formed as a result of wave-induced erosion of the deposits left by these glaciations. These bluffs provide the sediments that feed the beaches and are critical to nearshore sediment-transport processes (Downing 1983; Shipman 2008).

Historically, large sections of the Puget Sound shoreline were heavily forested with enormous conifers and associated understory trees and shrubs (Kruckeberg 1991). With the arrival of European settlers in the early 1800s, an era of natural resource exploitation began, and all the largest trees along rivers and marine shorelines had been harvested by the late 1800s (Kruckeberg 1991; Tonnes 2008).

Today, a seemingly still-pristine Puget Sound faces a crisis, with many marine species listed as threatened or endangered, and with contaminated water and sediments in several basins. Many factors have led to the decline, including heavy development in the Puget Sound basin that has disrupted the natural hydrological processes; increased stormwater runoff and associated thermal and non-point-source pollution; and upland and marine riparian habitat loss (Puget Sound Action Team, 2007; Hart Crowser, Inc., Department of Ecology, et al. 2007). Widespread efforts are now underway to restore the Sound's health, with a focus on threatened and endangered species.

As part of this work, scientists and policy makers are taking a broader ecosystems approach to understanding the complexities of the Puget Sound nearshore, the physical area that extends from the far edge of the photic zone to the adjacent uplands, including the top of any associated bluffs. As the interface between the uplands and freshwater and the marine environment of greater Puget Sound, the nearshore is critically important in exchanging energy, materials—including wood and sediments—and nutrients to support multiple complex processes and food webs (Goetz et al. 2004). The Puget Sound Nearshore Partnership (PSNP) is identifying ecosystem problems, evaluating solutions, and collaborating to restore and preserve some Puget Sound habitats. As part of its work, PSNP has identified high-priority research goals and selected and studied “Valued Ecosystem Components,” which are intended to represent a cross-section of species and physical structures in the nearshore (Leschine & Petersen 2007; Gelfenbaum et al. 2006). This recent work

notes the influence of Puget Sound beaches, including the backshore component, in supporting natural processes and many valued organisms (Leschine & Petersen 2007; Gelfenbaum et al. 2006; Johannessen & MacLennan 2007).

The listing of Puget Sound salmonids under the Endangered Species Act has prompted increased attention to be focused on the natural processes that shape Puget Sound, including sediment transport and materials exchange from the uplands to the intertidal zone, as well as interruptions to those processes by anthropogenic forces. Particular interest has been paid to the functions of beaches, especially the role of beaches in supporting organisms that occupy important niches in the foodweb, such as amphipods and forage fish (see Penttila 1995; Zelo et al. 2000; Sobicinski 2003; Johannessen & MacLennan 2007; Tonnes 2008), and on beaches' role in sediment supply and accretion.

Several planning and policy documents designed to protect and restore Puget Sound, such as Shoreline Master Plan updates and Critical Areas Ordinances, cite protecting and restoring backshores and associated vegetation as an important goal in overall Puget Sound restoration efforts. Although there is general recognition of the importance of the area above the upper intertidal zone, research in this zone has primarily centered on its relevance to habitat for forage fish, as well as geomorphological processes. Very little research has been directed specifically at the broader ecology of this zone, with recent work by Sobocinski (2003) and Tonnes (2008) offering notable exceptions.

Sobocinski et al. (2003) confirm this point: “The supratidal zone (also referred to as supralittoral) is a unique ecotone, the ecology of which has been little studied. Because it is the most terrestrial portion of the intertidal zone, it often has escaped notice of marine ecologists and terrestrial specialists.”

The flora associated with the Puget Sound backshore ecotone has received scant research attention and is usually referred to in the most general terms, as an aside to more central research questions about fauna or geomorphology. Most information on backshore plant communities comes from studies of outer-coastal and dune environments, which are generally different systems than the more protected Puget Sound backshores. Downing (1983) asserts that true dune systems are rare in Puget Sound, as they derive from wind-delivered sediments rather than wave- and current-delivered sediments. Dune systems are also subject to classic vegetation zonation (McLachlan & Brown 2006). Even with the growing body of literature about plants of outer-coastal communities globally, our understanding of those vegetative communities remains quite fragmented (Ievinsh 2006).

The primary purpose of my study was to characterize the backshore vegetation assemblages of bluff-backed beaches and accretional shoreforms in parts of South and Central Puget Sound, and to shed light on broader questions about the ecology of this ecotone and its significance in overall Puget Sound restoration efforts.

SECTION 2: UNDERSTANDING THE BACKSHORE

2.1 Definition

The backshore is an area above mean higher high water (MHHW), well beyond the upper intertidal zone, in the supratidal zone. The supratidal zone is concerned strictly with elevation and may or may not include elements that would be associated with a backshore, under my definition, described below.

Brennan (2007) defines backshores as relatively narrow berms beginning on the seaward side of bluff-backed beaches. His definition does not associate backshores with various accretional barrier-beach shoreforms, as defined by Shipman (2008), including various types of spits, cusped forelands, semi-enclosed lagoons, barrier estuaries, and open coastal inlets—though these shoreforms may harbor vegetative communities similar to bluff-backed beaches.

Downing (1983) points out that a limited supply of sand makes permanent backshores relatively rare features in Puget Sound: they are found on only 32 percent of the shoreline. His definition notes that backshores remain dry except during severe storms.

Based on my observation over the course of my study, the backshore might be defined more precisely than standard definitions that do not necessarily distinguish it from the supratidal zone. If we consider the backshore as an ecological feature rather than just an elevational feature, we can find guidance from definitions of wetlands, which take into account the complexity of hydrology, soils, and vegetation. For the

purposes of this thesis, my working definition of “backshore” includes these four components:

- (1) **Elevation:** The backshore occupies the area from approximately just above MHHW to the terminus of the storm berm, which might be the upland edge of a bluff-backed beach or the beginning of a salt marsh, lagoon, or estuary on the landward side of a depositional feature such as a barrier beach.
- (2) **Soils:** Backshore soils are fast draining and lacking or low in organic matter, silt, and clay (Hugh Shipman, personal communication, 2009).
- (3) **Vegetation:** The backshore contains an assemblage of plants particularly associated with the substrates, salt influence, and hydrology of this zone.
- (4) **Stability/instability:** The backshore must be in a supratidal area that is high enough to allow an accumulation of substrate and provide opportunities for vegetation to colonize over time, yet still low enough that there are regular but infrequent disturbances from major high-tide/storm events that limit soil development. Not all supratidal zones will be stable enough to support a backshore, nor will all backshores necessarily re-accrete sediments and regenerate vegetation following disturbances.

The template for Puget Sound backshores is created by the geomorphology and reinforced by the biology of the system. The backshore is defined by up to three bordering systems: (1) the beach, in which wave energy limits the seaward extent of the backshore; (2) the salt marsh, in which hydric soils separate backshore from salt marsh species (although a few species cross over at the transition zones of these two systems); and (3) the upland edge, in which soils with more organic matter, silt and clay support a broader array of plant species that can outcompete the backshore species.

Thus, throughout this thesis “backshore” will mean an area in the supratidal zone that has an assemblage of colonizing plants, and “supratidal,” will refer to the elevation on the beach, which may or may not be considered a backshore under my definition (see Figs. 1-A and 1-B).

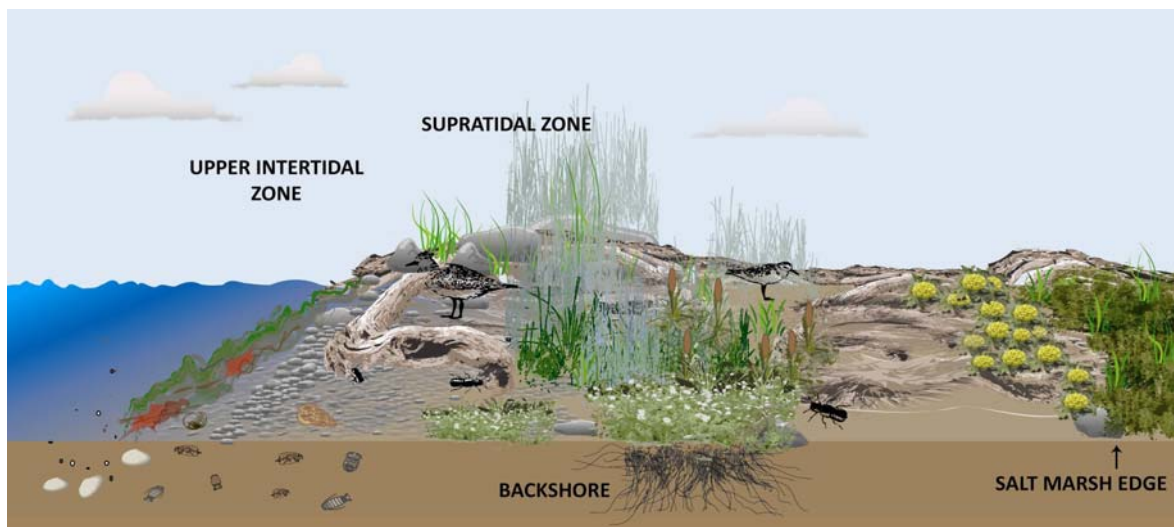


Figure 1-A. Schematic of the upper intertidal and supratidal zones, including backshore with a salt marsh on the landward side. Note that the backshore begins within the supratidal zone and has ecological features such as colonizing plants and animals. *Illustration courtesy of Jameson Honeycutt.*

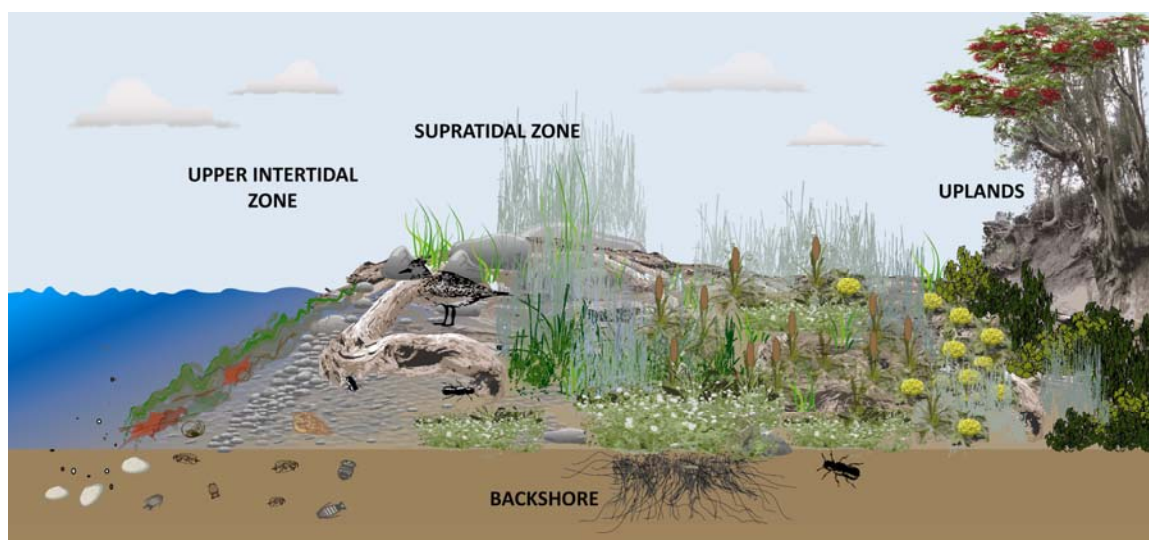


Figure 1-B. Backshore backed by bluff. Note that intertidal zone and supratidal zone refer to elevation, while backshore refers to ecological features. *Illustration courtesy of Jameson Honeycutt.*

2.2 Processes

The backshore is a unique ecotone between the uplands and the marine environment.

As a transition zone, it is influenced by the marine riparian zone and/or the salt marsh zone on its landward side, as well as certain features on its marine side, including salt spray, splash, and occasional disturbances from very high tides—especially when these coincide with storm events.

The general geological processes that shape backshores involve the gradual accumulation of beach-derived sediments to create a wide berm above the reach of the regular tides. In some locations, additional sediment accretion is due to small, sand-sized particles transported by the wind. The substrates of the backshore are generally composed of various-sized rocks, gravels, and sand particles, with limited or no clay, silt, or organic components (Hugh Shipman, personal communication, 2009). The backshore sediments are periodically disturbed and redistributed by the waves and currents that affect this zone during extreme high tides or extreme storm events, or these two events occurring simultaneously.

Like other parts of the Puget Sound nearshore, the backshore exchanges energy, materials, and nutrients with the uplands. It is the repository for large drift logs that are delivered to the marine environment by landslides, and which provide a measure of stability to plants, animals and sediments until they are disturbed by storms and carried away or repositioned. Leaves, insects, and other material from overhanging terrestrial plants fall onto the backshore, forming the basis for multiple terrestrial and aquatic food webs. The backshore receives important inputs of

seaweeds and marine-based detritus, which are consumed by terrestrial and semi-terrestrial invertebrates, which are in turn consumed by many species of birds—transferring much of that energy to the uplands (Downing 1983; Polis & Hurd, 1996; Brennan 2007; Dugan et al. 2008).

Backshore berms are built and sustained through a combination of forces, including: winter storms and high spring tides; drift logs that support substrate accumulation; and backshore vegetation that traps windblown sand (Downing 1983; Kozloff 1993; Zelo et al. 2000; Johannessen & MacLennan 2007).

When left in its natural state, the backshore zone can absorb wave energy in its sediments, plants, and drift logs (Downing 1983; Johannessen & MacLennan 2007; Tonnes 2008). However, because it is the highest and driest part of the beach, the backshore zone is heavily used for both recreation and construction of roads and residential houses (Downing 1983; Gabriel and Terich 2005; Tonnes 2008).

Natural processes and the flora and fauna dependent on the supratidal zone are adversely affected by hard armoring, which can eliminate the backshore as well as cut off sediment supply to maintain the necessary substrates. Hard armoring is often placed below MHHW, effectively replacing the supratidal zone with a vertical seawall backed by fill. This reduces opportunities for exchanges of sediments and organisms. Armoring causes a coarsening of sediment grain size and depletes sediment down-drift. It also disrupts or eliminates the habitat for the flora and fauna that occupy the supratidal zone, which can have far-reaching consequences to a variety of food webs (Zelo et al. 2000; Sobocinski 2003; Johannessen & MacLennan 2007). Armoring also

leads to a lower overall beach profile because the reflected energy scours sediments. In addition to disrupting the delivery of sediments to downdrift beaches, hard armoring can increase sediment removal by increasing the intensity of longshore drift currents (Gabriel & Terich 2005).

Sobocinski (2003) found clear correlations between armoring and decreased taxa richness and abundance in both supratidal insect and infaunal invertebrate assemblages, particularly talitrid amphipods dependent on the supratidal zone. Sobocinski's study found that armoring disrupted the delivery of wrack, a critical component of the food web, and decreased the deposition of other organic debris.

The impacts of disrupting these food webs are shown in the work of Dugan et al. (2008), who found loss of habitat evident throughout the year on armored versus natural beaches. Armoring completely removed the supratidal zone (referred to as “dry upper beaches” by the authors) and narrowed the width of the upper intertidal zone (called “mid-beach zones”). Armored beaches had lower abundance, biomass, and size of upper intertidal macroinvertebrates, and a significantly lower abundance of—and species richness for—shorebirds, gulls, and seabirds.

Tonnes (2008) investigated the role of driftwood accumulation in supporting the backshore and marine riparian ecosystem. He found that populations of talitrid amphipods were significantly denser in association with driftwood deposits in the supratidal zone, and further that the largest drift logs—greater than one meter in diameter—were more likely than smaller logs to provide stability to support more terrestrial vegetation. These larger logs had been deposited prior to industrial logging

in the 1850s, and thus, future recruitment of large logs is likely to be limited—altering these long-time processes and the habitats they create in coming centuries.

2.3 Fauna

With the exception of a few mammals, songbirds, and shorebirds, most of the animals one is likely to encounter on the backshore are small, and it is these organisms that support larger food webs. Insects, isopods, and amphipods take refuge under logs, objects or plants on the beach or by burrowing into the sand (Kozloff 1983; McLachlan & Brown 2006).

The supratidal zone hosts isopods and talitrid amphipods, detritivores that consume large quantities of the high, stranded wrack of mixed algae, kelp, and decomposing terrestrial plants (McLachlan & Brown 2006). These forage at night closer to the water's edge, and use the moon to guide them back upland before daybreak (Kozloff 1983). Although they are adapted to live in the relatively harsh conditions of the supratidal zone, isopods and talitrid amphipods require high relative humidity to survive (McLachlan & Brown 2006). By day they remain buried in sand or other cool, sheltered microhabitats—such as the underside of drift logs; by night they find shelter and food in the cool, moist wrack (Kozloff 1983).

Amphipods and isopods are an important link in the detritus-based food web, playing a critical role in nutrient cycling as they decompose the accumulation of wrack and make its nutrients available to other organisms (Polis & Hurd 1996;

McLachlan & Brown 2006). They also serve as prey for larger organisms, such as carnivorous beetles, arachnids, shorebirds and other avian predators, and are accessible more frequently than suspension-feeding organisms (McLachlan & Brown 2006; Dugan et al. 2008). One of those predators is the rove beetle, which emerges at night to prey on amphipods and smaller insects. Kozloff (1983) describes how a large rove beetle “pierces the armor of the prey and the juices are then sucked out” (p. 268).

In addition to shorebirds, several bird species nest, roost, and/or overwinter in the supratidal zone. These include gulls, seabirds, and smaller birds such as sparrows, longspurs and buntings (National Park Service 1980; Dugan et al. 2008).

2.4 Interstitial Biota

Less obvious to most beach observers are the great quantities of microscopic organisms that occupy the interstitial spaces in the beach substrate. These include fungi, algae, bacteria, protozoans and metazoans. McLachlan and Brown (2006) assert: “A high proportion of plant biomass, both living and dead, may occur below ground—where it is more available to the interstitial biota than to the macrofauna” (p. 265).

Fungi, in the form of mycorrhizae, are particularly important in binding together sand particles, thereby reducing wind erosion (McLachlan & Brown 2006; Ievinsh 2006). Mycorrhizae are not particularly salt tolerant, and are generally found further back from strong marine influences, although ascomycetes are more resistant

than basidiomycetes to moderate levels of sodium chloride (Ievinsh 2006). The spores of the more salt-tolerant mycorrhizae are delivered inland to inoculate the beach via the sea foam (McLachlan & Brown 2006).

The presence of mycorrhizae in the supratidal zone is significant because they play a symbiotic role with the roots of backshore vegetation: the fungi are able to access carbohydrates produced as the plant photosynthesizes, while the plant can tap into water and nutrients captured from a broad area by an extensive mycelial network. Mycorrhizae particularly assist plants in gaining access to phosphorus ions, which are limited in sandy substrates. Because of the great extent of the mycorrhizal hyphae in the soil matrix, additional benefits to the associated plant might include defense against pathogens. When mycorrhizae are associated with the roots of plants, there is a substantial increase in the size of the root system (Maun 1994; Smith & Read 1997; Ievinsh 2006).

2.5 Flora

Backshore vegetation provides habitat for the animals discussed above—including amphipods, insects, and birds—and may provide services that improve fish habitat. Romanuk and Levings (2003 and 2006) found the richness of fish species and the abundance of arthropods positively correlated with both supralittoral and marine riparian vegetation.

Backshore vegetation is an important part of the nearshore food web. It can provide temperature control and create microclimates; it provides habitat complexity

and refuges; and it increases the availability of food and nutrients (Romanuk & Levings 2003). Backshore vegetation—and associated drift logs—help stabilize fine beach sediments and increase the height of backshore berms (Brennan 2007; Tonnes 2008).

Backshore vegetation is adapted to a harsh environment that includes limited water availability, salt spray, sand salinity, sand burial, and extreme exposure to high-intensity light, wind, and blown sand (McLachlan & Brown 2006). Although these conditions are challenging, Ievinsh (2006) asserts that vegetation of coastal dune systems—which are similar to backshore vegetative communities—must be adapted to conditions that are “heterogenous,” rather than “stressful.” He points out that there is a misconception that conditions outside the optimal range for most plants are too frequently termed “stressful,” when these plants do not actually face continuously stressful conditions. Rather, the conditions are variable—for instance, in terms of the availability of water and nutrients. Thus, plants in these environments—whether outer coastal dunes or the more protected Puget Sound backshore—have evolved with a variety of strategies to survive in the conditions described above, and these are discussed below.

2.5.1 Adaptations of plants to backshore conditions

2.5.1.1 Salinity: To manage in saline environments, species may employ a few different strategies. In high-salinity environments, obligate halophytes are successful by outcompeting other species. In low- to moderate-salinity environments, plants

may simply use a strategy to avoid the effects of a high-salt environment, and these plants are referred to as facultative halophytes or less-salt-tolerant glycophytes. Many of the species found in the backshore are not obligate halophytes, but rather need only to have adapted mechanisms for surviving in low- to moderate-salinity conditions influenced primarily by salt spray (Ievinsh 2006). These adaptations include thick, succulent leaves; removal of excess ions through salt glands and leaf drop; increased cell volume; reduced transpiration; and reduced uptake of ions (Maun 1994; McLachlan & Brown 2006).

Tsang and Maun (1999) showed that associations with arbuscular mycorrhizae ameliorated the stresses of a leguminous species subjected to a saline environment. Compared to plants without mycorrhizal associations, those colonized by mycorrhizae showed greater vigor and enhanced growth, had increased levels of chlorophyll, and had more root nodules. Plants with mycorrhizal connections may be more successful in saline soils for a number of reasons: more vigorous plants are more resilient to environmental variables; mycorrhizae mitigate for reduced water availability in saline soils by enhancing water uptake through reduced root resistance, prolonged stomatal opening, and increased photosynthesis; and higher chlorophyll levels allow for increased uptake of carbon dioxide (Tsang & Maun 1999).

2.5.1.2 Sand burial responses include: creeping growth; climbing growth; formation of adventitious roots from newly formed subvertical rhizome when buried; increased

seed, node, root, shoot, and rhizome or stolon development; and rapid increase in distance between internodes (Maun 1994; McLachlan & Brown 2006; Ievinsh 2006).

Ironically, sand burial can create improved microclimate conditions for affected plants, thereby increasing potential for survival. Sand accretion increases moisture and the availability of nutrients (primarily through increased mycorrhizal symbiosis), while decreasing soil temperatures, light intensity, and competition (Maun 1994; Ievinsh 2006). Although no species can survive complete burial for an extended period, high levels of partial burial can stimulate more rapid growth and significant increases in overall biomass (Zhang & Maun 1992; Maun 1994).

While partial sand burial tends to stimulate both growth and carbon dioxide uptake, for some species, the combination of burial and colonization by arbuscular mycorrhizae produces an even greater increase in leaf area and/or overall biomass. The benefits of mycorrhizal colonization in conjunction with sand burial appear to be variable depending on the species, as the extent of mycorrhizal root colonization varies by species (Perumal & Maun 1999).

Burial also can increase germination and survival rates for seeds, and some species have used this strategy particularly well by producing exceptionally large, heavy seeds that become more deeply buried. The larger seed likely provides greater nutrition during germination, and deeper placement in the substrate ensures more moisture and protection from some predators (Maun 1994; Ievinsh 2006), as well as greater mechanical support, helping plants resist wind forces (Ben Alexander, personal communication, 2009).

Some species are adapted to sand burial by producing polymorphic fruits. For example, species of *Cakile* produce fruits with deciduous distal segments that allow colonization of distant areas, along with proximal segments that remain with the parent plant and so take advantage of proven habitats (Maun & Payne 1989). In one study, attached fruits that were buried produced a deeper root system and had higher survival rates than attached fruits from unburied plants (Maun 1994).

2.5.1.3 Limited moisture, high light intensity and temperatures, wind

exposure: During the warm months, sandy substrates are dry five to ten centimeters below the surface, and the inherent dryness of sand may be exacerbated by salinity (Maun 1994; McLachlan & Brown 2006). Moreover, substrates can be so hot as to cause mortality in seedlings, although plants can develop resistance as they mature. As an example, Maun (1994) observed girdling at the point of the contact with the hot sand.

Plant species exposed to these conditions have evolved various adaptations: leaf roll; dense leaf hairs; leaf drop and drought dormancy; succulent leaves; epicuticular wax layer; thickened or hardened foliage (sclerophylly); efficient water use; ability to absorb dew; root adaptations, such as rapid vertical elongation, widespread roots, and long roots to reach the water table; and germination emergence when moisture is plentiful (Maun 1994; McLachlan & Brown 2006). Seed germination in some species is increased by shelter from nurse plants, which provide

shade, reduced evaporation, and cooler temperatures; however, that benefit may be offset by subsequent root-zone competition from the nurse plant (Maun 1994).

2.5.1.4 Nutrient deficiency: Sandy supratidal substrates are generally deficient in nitrogen, phosphorus, and potassium. Maun (1994) found that increasing nutrients did not affect germination but did affect growth of surviving backshore plant species. Backshore plants are generally adapted to growing and reproducing in nutrient-limited substrates; they may be nitrogen-fixers, such as leguminous species; or they may take advantage of an association with these nitrogen-fixing plant species. Backshore vascular plants are believed to receive most of their phosphorus through mutualistic relationships with mycorrhizal fungi, especially arbuscular mycorrhizae (Maun 1994; McLachlan & Brown 2006).

2.5.1.5 Other reproductive strategies: Backshore plant species have adapted additional strategies for ensuring survival, including: cloning, via stolons and rhizomes; buoyant seeds for dispersal; and differential germination periods, with emphasis on spring and fall, when moisture is more available and temperatures are lower (Maun 1994; Ievinsh 2006).

2.5.2 Potential zonation: In the absence of literature about vegetation on Puget Sound's backshore, we can look to information about supratidal vegetation in outer-coastal dune systems. Classic zonation and succession patterns are an important

feature of coastal dune systems, just as zonation and succession are well documented in salt marshes, and even minor changes in elevation can affect which plant species will occupy that zone. McLachlan and Brown (2006) describe the progression from the seaward side as follows:

Zone 1 – Pioneers: These species may establish at the outer edges of wave influence, but generally have a short life span: they may be terminated in a severe storm or just die back after a few years. These plants must employ all the mechanisms discussed above to survive the particularly harsh conditions in this most seaward zone. Vegetation associated with this zone includes creeping grasses, plants with rhizomes or stolons, as well as those with succulent leaves. Successful species relevant to the Puget Sound backshore include creeping grasses as well as *Honkenya* and *Cakile* species.

Zone 2 – Shrubs: McLachlan and Brown (2006) point out that in many narrow dune systems, this zone and Zone 1 may be the only ones that develop. In their description, the shrubs occupying this zone are generally low and creeping.

Zone 3 – Thicket: This is a zone of minimal sand distribution and may contain dwarf trees and shrubs whose canopy is flattened due to “wind pruning.”

Zone 4 – Forest: This develops in areas of high rainfall behind the shelter of the larger dunes.

2.5.3 Backshore associates: Literature regarding Puget Sound’s backshore vegetation is scant, and plant associations are not well known. When describing the

vegetation associated with the Puget Sound backshore, researchers usually refer to the dune grass, *Elymus mollis*, (Poaceae, Grass Family). But many other backshore associates are commonly listed as well, including:

- *Abronia latifolia* (yellow sand-verbena; Nyctaginaceae, Four o'clock Family);
- *Ambrosia chamissonis* (silvery beachweed; Asteraceae, Aster Family);
- *Artemisia* spp., (beach sageworts; Asteraceae, Aster Family);
- *Atriplex patula* (saltbush; Chenipodiaceae, Goosefoot Family);
- *Cakile* spp. (sea rocket; Brassicaceae, Mustard Family);
- *Carex macrocephala* (large-headed sedge; Cyperaceae, Sedge Family);
- *Convolvulus soldanella* (beach morning-glory; Convolvulaceae, Morning-glory Family);
- *Glehnia littoralis* spp. *leiocarpa* (beach silvertop; Apiaceae, Carrot Family);
- *Grindelia integrifolia* (entire-leaved gumweed; Asteraceae, Aster Family);
- *Honkenya peploides* (sea purslane; Caryophyllaceae, Pink Family);
- *Lathyrus japonicus* (beach pea; Fabaceae, Pea Family);
- *Lupinus littoralis* (seashore lupine; Fabaceae, Pea Family);
- *Oenothera cheiranthifolia* (beach evening primrose; Onagraceae, Evening Primrose Family);
- *Plantago maritima* (seaside plantain; Plantaginaceae, Plantain Family); and
- *Polygonum paronychia* (beach knotweed; Polygonaceae, Knotweed Family).

Other backshore associates are also found in the upper intertidal zone and saltmarshes, such as *Distichlis spicata* (saltgrass; Poaceae, Grass Family); *Jaumea carnosa*,

(fleshy jaumea; Asteraceae, Aster Family) and *Salicornia virginica* (pickleweed; Chenopodiaceae, Goosefoot Family) (Kozloff 1993).

2.5.3.1 Descriptions for common species (summarized from Kozloff 1993; Pojar & MacKinnon 1994):

Abronia latifolia is a prostrate mat-forming perennial of the Nyctaginaceae. Its leaves are fleshy and hairy and often have sand particles adhering. Its flowers are in bright yellow rounded clusters—making it a striking sight when it is blooming. It has scattered distribution along sandy beaches.

Ambrosia chamissonis is a mat-forming herbaceous perennial of the Asteraceae. Its leaves are slightly succulent and hairy. It has crinkly-edged, deeply divided, silvery-gray leaves and heads of tiny, greenish flowers. It is found in both sandy and gravelly substrates.

Atriplex patula is a morphologically variable shrub-like annual in the Chenopodiaceae that grows from 10 to 100 cm high. Its leaves usually resemble arrowheads, but also can appear lance-shaped. The younger stems are covered with a whitish, mealy substance, but become green and hairless with maturity. *Atriplex* is found within tidal marshes, sandy or gravelly beaches, and is associated with saline soils.

Cakile edentula and *C. maritima* are pioneering annuals of the Brassicaceae, both of which are likely introduced, from the Atlantic coast and

Europe, respectively—although there remains a possibility that *C. edentula* is native to the Pacific Northwest (Pojar & MacKinnon 1994). Both species have naturalized on Puget Sound and outer coastal beaches. These two *Cakile* species have fleshy leaves and sprawling growth habits, and are noted for their sediment-holding qualities and their ability to colonize the seaward-most edges of the supratidal zone (Ievinsh 2006). They are found on sandy beaches within Puget Sound and the outer coast. Both species produce two-part fruits, with a distal portion encased in a cork-like substance that allows it to float to new sites, and a proximal portion that remains attached to the parent plant (Maun & Payne 1989).

Carex macrocephala is distinctive and aptly named: “large-headed sedge.” It is patchily distributed in sandy substrates. It spreads by long rhizomes, and its leaves reach 10 to 40 cm in height. Male and female inflorescences are borne on separate spikes; the male inflorescence is much smaller than the female flower—which resembles a large drumstick.

Distichlis spicata is a mat-forming perennial grass with solid stems and vigorous rhizomes, and grows 10 to 40 cm tall. It is found in tidal marshes, beaches, and the upper-intertidal zone—where it receives regular swash. There is a non-coastal subspecies (*D. spicata* var. *stricta*) that colonizes saline and alkaline meadows and sandy lakeshores.

Elymus mollis (syn. *Leymus mollis*) is a tall (0.5 to 1.5 m) native dune grass that stabilizes loose sandy sediments with its creeping rhizomes and can migrate further upland beyond the supratidal zone.

Glebnia littoralis is a perennial of the Apiaceae, growing from a stout woody taproot. Its large, deeply lobed leaves are somewhat succulent and hairy. Its flowers are in several small ball-shaped clusters attached to hairy stalks, and form a slightly flat-topped inflorescence that protrudes only a few centimeters above the prostrate leaves. It is found in scattered distribution on sandy beaches.

Grindelia integrifolia is an Asteraceae perennial, 15 to 80 cm tall, which produces a profusion of bright yellow flowers; it can undergo many cycles of flowering from late winter/early spring until late fall/early winter. It is found in a range of habitats, including salt marshes and beaches with fine to coarse substrates.

Honkenya peploides, a sandwort of the Caryophyllaceae, is a broad mat-forming perennial (80 cm or more) with distinctively arranged small, succulent leaves. It is associated with drift logs in the upper intertidal and supratidal zone. It responds to sand burial by producing adventitious roots, and it can be found in sandy, gravelly and rocky beaches, and in salt marshes.

Lathyrus japonicus (syn. *Lathyrus maritimus*) is a trailing perennial of the Fabaceae with purplish-pink pea flowers and compound leaves with six to twelve leaflets, tipped with curling tendrils. It is associated with protected parts of the beach, drift logs, and sandy to gravelly substrates.

Polygonum paronychia is a low mat-forming semi-woody perennial of the Polygonaceae. It is noted for its narrow leaves and small but attractive flowers marked with “featherlike green ‘veins’” (Kozloff 1991, p. 270), which bloom from spring to early fall. It has a scattered distribution in dunes or other sandy beaches.

SECTION 3: STUDY APPROACH & METHODS

3.1 Study Questions

Purpose: My aim was to contribute to an understanding of the backshore zone by surveying the physical and vegetative characteristics of Puget Sound backshores. I sought to address several research questions:

3.1.1 Defining plant community and role in ecosystem: Are there specific plant species that occur with such frequency as to define a backshore community? Can the presence or absence of specific species define “backshore” versus other beach zones? What distinguishes “backshore” vegetation from “salt marsh” vegetation? Are there observed and reported interactions between backshore vegetation and specific animal species? How does backshore vegetation support nearshore food webs?

Expectations: Based on my review of the literature, I expected to see plants noted for their presence in Puget Sound’s backshore, including *Elymus mollis* and the many mat-forming species described above. I expected to see sharp delineations between backshore species and salt marsh species, with occasional cross-over species at the margins of both ecosystems.

3.1.2 Geomorphological connections: Do backshore plant species require specific shoreforms to provide adequate stability and substrates? Are backshore species likely to occur at specific points within drift cells? Are there connections with

shoreforms or drift cells in a consistent pattern that would permit simple mapping of backshore vegetation Sound-wide?

Expectations: I expected to find backshore vegetation primarily on depositional beaches, which include any of the wide variety of barrier beaches, as defined by Shipman (2008). I also expected to find backshore vegetation primarily where drift cells converge.

3.1.3 Role of plants on sediments and vice versa: Are stable sediments required for backshore species to colonize? Do backshore plant species play a role in sediment accretion and/or stabilization?

Expectation: I expected to find backshore species on substrates that showed evidence of long-term stability.

3.1.4 Physical requirements: Given the physical challenges of the supratidal zone, what are the adaptations that permit backshore plant species to be successful? I considered these physical features:

3.1.4.1 Elevation: What is the relationship between (1) the presence of backshore plants and (2) the presence of particular species and the distance from approximate MHHW? Do concepts of classic zonation from outer-coastal communities apply to Puget Sound's backshore vegetation?

Expectations: Based on my review of the literature, I expected to find backshore vegetation well above MHHW, and to observe different species of

backshore plants dominating at different points along the gradient from seaward to landward side. I expected that narrow backshores would exhibit fewer vegetative zones, and therefore have less species diversity than wider backshores.

3.1.4.2 Aspect: Does backshore vegetation occur more frequently on beaches with specific aspect?

Expectations: Aspect could affect frequency and severity of storm events, and I expected that I might find a pattern that showed less abundant vegetation or a change in the composition of vegetation on beaches that were more prone to disturbance from severe storms.

3.1.4.3 Substrate: Does backshore vegetation require a substrate of a particular grain size, or will plant species occur in a variety of substrates? Do the plant communities vary by substrate?

Expectation: I expected to find backshore vegetation only in areas with highly sandy substrates.

3.1.4.4 Salinity: Is backshore vegetation associated with specific salinity ranges?

Expectation: Given observations of salt marsh species in Puget Sound's backshore, I expected to find the substrates high in salinity, suggesting that the backshore species were halophytes.

3.1.4.5 Water and nutrient availability: What are reported and observed mechanisms for survival in water- and nutrient-limited substrates?

Expectation: I expected to find backshore plants with widespread and deep root systems to allow for broader access to water and nutrients.

3.1.5 Restoration potential: Can backshore vegetation be successfully re-established as part of broader nearshore restoration activities? Does backshore vegetation respond favorably to transplanting from nearby sources or planting from nursery stock? What observations have others made about natural recruitment of backshore species following beach restoration activities or disturbances?

3.1.6 Anthropogenic effects and socio-economic implications: What ecological services does backshore vegetation provide to the nearshore that are lost as a result of human activities, both public and private, along the shoreline? What human activities are observed that impact the habitat and success of backshore vegetation?

3.2 Methods

3.2.1 Sites: I searched for candidate sites by reviewing high-resolution aerial photos of Puget Sound shorelines, taken in 2006-07 by the Washington Department of Ecology. The resolution on these photos allows one to obtain a detailed view of specific sections of shoreline under magnification.

I reviewed the entire shorelines of Mason, Thurston, Pierce, Island and Kitsap counties looking for sites that showed the following combination of features: (1) accumulation of large drift logs; (2) the bluish color associated with *Elymus mollis*; and (3) accretional shoreforms. I then used Google Earth to determine which sites might be physically accessible. I also queried individuals familiar with shorelines in different

areas to discover additional sites that might fit the criteria of backshore and were publicly accessible—which led me to expand my study area to include Jefferson and Skagit counties.

I visited sites in Kitsap, Island, Skagit and Jefferson counties by car and foot. Most of these sites were on private property, but I was able to obtain permission from the landowners to survey many of them; however some were inaccessible (e.g. military sites) or I was unable to contact the landowners. I visited sites in Mason, Thurston, and Pierce counties by renting a small boat at Boston Harbor Marina in Olympia, and traveling from there to the study sites. Most of these sites were on private property, but were not marked with “No Trespassing” signs, and so were considered accessible. If the landowner’s home was in sight, I attempted to communicate with the residents and was never denied access. Some sites were marked with “No Trespassing” signs, and I was not able to study them.

My ability to survey more sites was vastly increased when I was able to use the boat, as I could stop when I saw evidence of backshore vegetation, rather than seeking only the sites I had identified in advance from the aerial photographs. This enabled me to survey smaller sites, and different shoreforms, that I could not have seen from the photographs—particularly low-bluff-backed beaches in which the riparian canopy vegetation obscured the backshore vegetation.

When I surveyed a site that I had not pre-selected, I took a GPS reading so I could later locate it precisely within the landscape to note its larger geographic context, so I could determine its shoreform and position within the drift cell.

From fall 2007 to spring 2009, I was able to survey a total of 43 sites in Mason, Thurston, Pierce, Kitsap, Jefferson, Island, and Skagit counties (see Fig. 2).

3.2.2 Vegetation Survey Methods: I surveyed sites using the relevé method, described in Mueller-Dombois and Ellenberg (1974), to obtain a complete list of plants present at each site at the time of my visit. This method can be used for studying a single community type across its distribution range and is especially useful in gathering data in communities containing a large number of species.

I used the Braun-Blanquet Cover Abundance Scale to assign a combined percent-cover/abundance value to each species I encountered. After early reconnaissance surveys of different backshore communities, I chose the Braun-Blanquet scale because it attempts to describe “the spatial floristic variation of a regional vegetation cover, [and] the emphasis is put on more relevés with semiquantitative estimates rather than fewer vegetation samples with exact measurements of species quantities” (Mueller-Dumbois and Ellenberg 1974).

The Braun-Blanquet Scale is as follows:

- 5 = cover >75%
- 4 = cover 50-75%
- 3 = cover 25-50%
- 2 = cover 5-25%
- 1 = cover numerous but scattered, up to 5%
- + = few, with small cover
- r = solitary, with small cover

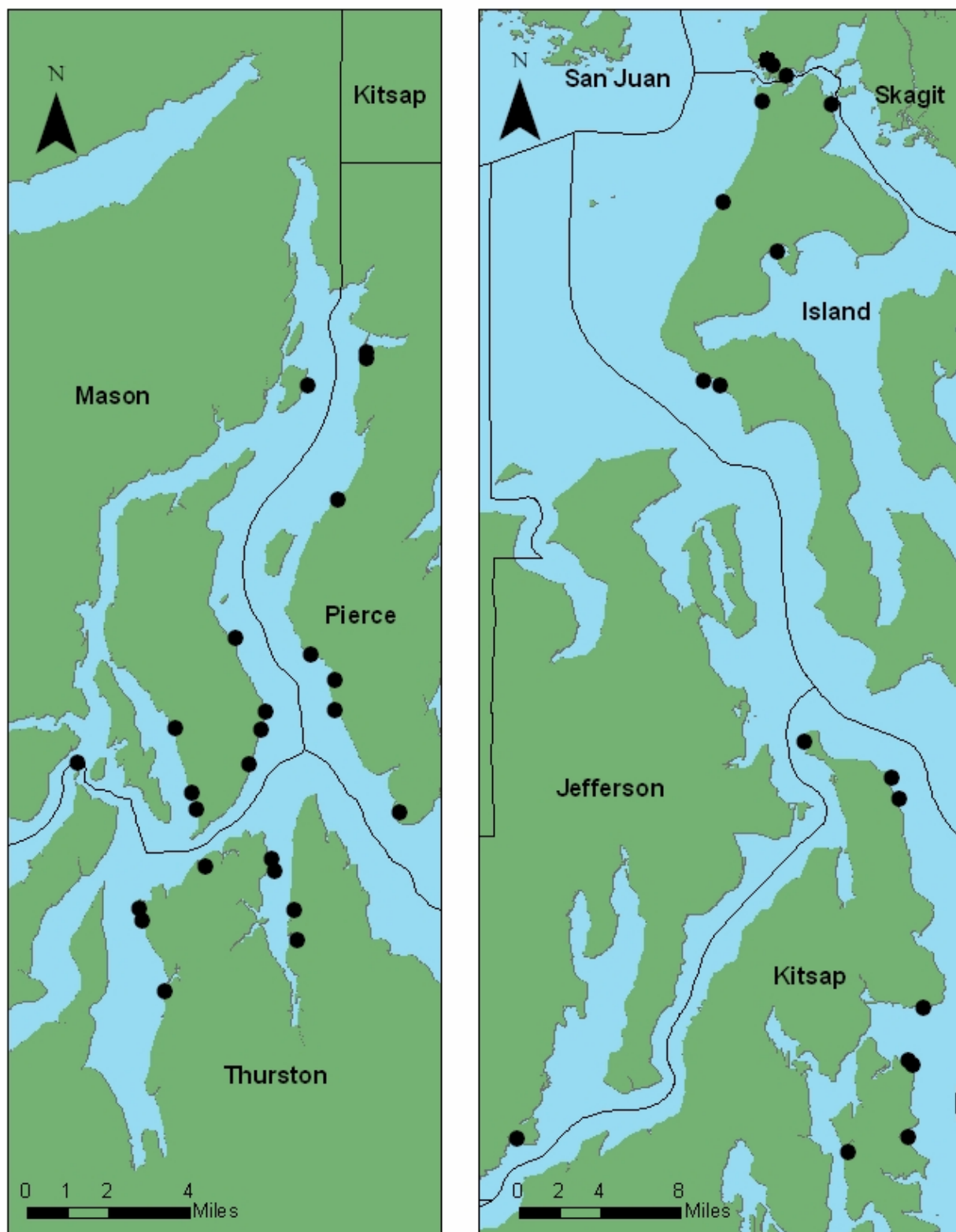


Figure 2. Puget Sound backshore vegetation study sites, by county. *Map courtesy of Guy Maguire.*

This method involves creating a complete plant list for each site by walking the entire site thoroughly. Once all species have been listed, one then re-assesses the site to assign a relative rating from the cover-abundance scale for each species.

3.2.3 Environmental Site Data: In addition to a floristic assessment, I gathered the following site data:

3.2.3.1 Type of landform: Using Shipman (2008), I characterized the landform of each site. If it was a barrier beach, I specifically noted which type, such as cusped foreland, recurved spit, semi-enclosed lagoon, etc. If it was a bluff-backed beach, I noted if the shoreline was straight, curved out, or curved in. In some cases, it wasn't clear exactly what landform I was seeing, and so I later confirmed its type using aerial photos.

3.2.3.2 Location within drift cell: Following my field visit, I located each site within its drift cell using the Internet-based Washington Coastal Atlas mapping system.

3.2.3.3 Width of the backshore and simple beach profile: I measured the backshore width, using the upper wrack line as an approximation of MHHW. Early calculations to correlate precise MHHW indicated that the upper wrack line was an adequate approximate measure for my purposes. From the upper wrack on the seaward side, I measured to the landward terminus, whether that was a salt marsh, the uplands, or a bisecting road or path. I arbitrarily chose three categories to represent

backshore widths from narrow to wide: less than 10 meters; up to 30 meters; and greater than 30 meters.

I also made simple drawings of beach profiles, using a laser level to accurately gauge elevational changes on wider backshores with varying topography. As part of these drawings, I made notes regarding the presence of first drift logs, first appearance of vegetation, and location of different plant species.

3.2.3.4 Determination of aspect: I noted the predominant aspect of each site, to the nearest intermediate point between the four cardinal directions.

3.2.3.5 Characterization of the substrate: I noted the composition of the substrate at each site based on sediment grain size. I dug into the substrate to determine if its composition was uniform below the surface or if the predominant substrate was covered with a veneer of a different composition. Pebbles and cobbles were classified according to the Wentworth size scale for sediments (McLachlan & Brown 2006). Pebbles range from 4 to 64 mm, and cobbles range from 64 to 256 mm. The Wentworth scale allows for classifying varying sizes of sand particles. In initial reconnaissance investigations, I sifted the sand particles and found that fine to coarse sediments were well mixed in the purely sandy substrates. Therefore, for simplicity, I decided not to distinguish sand grain sizes as part of characterizing the substrates.

3.2.3.6 Substrate salinity assessment: To answer my question regarding the ranges of salinity that the vegetation is exposed to, I took 11 samples of different grain sizes of sandy and sandy/woody substrate from backshore study sites in South

and Central Puget Sound. I took the samples randomly from different locations along the gradient from the seaward to landward side of the backshore, as well as at different depths (two feet was the maximum that I could dig before the sediments began refilling the hole from above). I was prepared to measure salinity of beach groundwater if I encountered it, but I did not. I also took some sand samples from low in the intertidal zone to compare sediments subjected to daily inundation.

Later, I analyzed all the samples in the laboratory using this standard laboratory procedure: I placed 50 grams of sediment from each sample into beakers containing 150 ml of de-ionized water and stirred it to dissolve the salt and other minerals. After approximately 30 minutes, I measured each sample using a YSI conductivity meter. I conducted two tests for each sample, and if the results were not within 10 percentage points of each other, I conducted a third test for each sample. I then re-measured each sample after it had dissolved for over an hour to see if there were any changes in the readings. I converted the conductivity measurement in microsiemens to mg/L of potassium chloride equivalent, using methods described by Clesceri et al. (1998).

3.2.3.7 Plant root-system data: To answer my question regarding possible adaptations to survival in water- and nutrient-limited substrates, I observed the root systems of several species of backshore plants to determine their growth patterns—including depth into the substrate. I observed the root systems of these species, either identified in the literature as backshore associates or those that I saw most frequently: *Abronia latifolia*, *Ambrosia chamissonis*, *Atriplex patula*, *Cakile* spp., *Carex*

macrocephala, *Distichlis spicata*, *Elymus mollis*, *Glebnia littoralis*, *Grindelia integrifolia*, *Honkenya peploides*, and *Polygonum paronychia*. I took care not to cause permanent harm to the specimens I observed. To do this, I used a small shovel and my hands to dig into the substrate to reveal the roots. Often, I was unable to dig deeply enough (because the sandy substrates would fill in the hole too quickly after a certain depth) to find the end of the plants' root systems without harming them, but it was deep and widespread enough to gain information about how widespread their roots were and what they were anchored to in the substrate.

3.2.3.8 Observations of fauna: I noted any animals within the backshore, but did not attempt to identify amphipods, isopods, or insects.

3.2.4 Potential for Restoration: To learn about the possibilities for restoring backshore areas, I communicated with ecological restoration professionals and individuals who have replanted backshore vegetation on their property.

3.2.5 Observations of Human Uses: I noted any specific use of or disturbance to the backshore by humans, including structures, filling, dumping, parking, trampling, armoring, etc.

3.2.6 Statistical Analyses: To see if I could discern patterns or correlations between environmental factors and species diversity or richness, I used methods

suggested by McCune and Grace (2002) and a combination of software to conduct various statistical analyses, including PC-ORD version 5, Microsoft Excel, and JMP.

Since the Braun-Blanquet scale is considered semi-quantitative, I used the values derived from the vegetative sampling to look for possible patterns in vegetative presence and abundance rather than in precise numeric accounting for each species. I converted my Braun-Blanquet scale values to averages so that I could observe patterns and trends in the data, using this method: (1) Calculate the midpoint of each category; (2) multiply the midpoint by the number of times the species was classified in that category; (3) add together all of these values for that species; and (4) divide the total by the number of samples. I remind readers that these averages are based on a scaled value, rather than a precise count, and therefore mean percent cover/abundance values should not be construed to imply precise cover for each species.

SECTION 4: RESULTS

4.1 Vegetative Sampling

4.1.1 Categorization: I recorded a total of 46 species on 43 sites (see Tables 1 and 2). I also maintained two categories that included aggregations of similar vegetation: (1) all grasses except *Elymus mollis* (American dunegrass), *Ammophila arenaria* (European beachgrass), *Distichlis spicata* (seashore saltgrass), and *Festuca rubra* (red fescue); and (2) all non-native species (except grasses) not separated out for special note, mostly of the Asteraceae, including *Hypochoeris radicata* (hairy cat's ear), various species in the genus *Hieracium* (hawkweed), and *Cirsium vulgare* (bull thistle), as well as occasional annual mustards.

I noted only the four grass species listed above based on two factors: (1) predicted backshore associates from the literature and (2) my limited knowledge of Poaceae taxonomy. I did not make specific note of the native dune associate *Poa macrantha* (dune bluegrass). I was confident of seeing it in only one site and therefore did not want to misrepresent its presence or absence due to my unfamiliarity with keying grasses. Most of the aggregated grasses I observed were non-native species such as *Holcus lanatus* (velvet grass).

I also aggregated the following species for various reasons, explained below:

- (1) I maintained one category of *Cakile* spp. for the two Puget Sound species of *Cakile*: *C. edentula* and *C. maritima*. Their leaf morphology can vary, so the best identification is through the fruit, or pod, which is not

always present (Hitchcock & Cronquist 1973; Kozloff 1993; Pojar & MacKinnon 1994).

(2) In processing my data, I aggregated *Artemisia suksdorfii* and *Artemisia campestris* because I found them only in Island County, and in low abundance. They occupy the same primarily sandy or mixed sandy/gravel substrates and occur along the gradient from seaward to landward terminus of the backshore.

(3) I encountered three species of *Rosa*: *R. nutkana* and *R. pisocarpa* (both native), and *R. rugosa* (non-native and invasive). I found all three generally near the landward terminus of the backshore, in a variety of substrates, and sometimes growing together. For purposes of data management, I aggregated the two native roses into one category to see the general patterns of their placement and occurrence in backshore communities. I maintained a separate category for *R. rugosa*, to observe any patterns in its distribution.

4.1.2 Associations

4.1.2.1 Predominant species: I was able to observe six obviously predominant species, although not all of these occur together, nor on every sampled site (see Fig. 3). Averaged values of cover/abundance for these six species are well above 10 percent, and range from 14 to almost 36 percent. Below these species in

relative ranking, there is a dramatic break, with the next highest value at just under 6 percent. The six species are, in order of relative abundance observed:

- *Elymus mollis*
- *Grindelia integrifolia*
- *Ambrosia chamissonis*
- *Cakile* spp.
- *Atriplex patula*
- *Distichlis spicata*

Elymus mollis occurs most frequently and has an averaged cover/abundance value of 35 percent. Other averaged values are as follows: *Grindelia integrifolia*: 26 percent; *Ambrosia chamissonis*: 20 percent; *Cakile* spp.: 19 percent; *Atriplex patula*: 16 percent; and *Distichlis spicata*: 14 percent.

4.1.2.2 Geographically restricted species: I was interested in several species that are widely recognized as backshore vegetation in the literature (e.g., Pojar & MacKinnon 1993; Kozloff 1994), but were, for the most part, geographically limited to the Island and Kitsap County sites. For lack of a better term, I am referring to them as “restricted” species. On sites where they occur, they are likely to be abundant, but their distribution is limited by unknown factors. These species include, in order of abundance observed:

- *Abronia latifolia*
- *Carex macrocephala*
- *Polygonum paronychia*
- *Honkenya peploides*
- *Glehnia littoralis*
- *Convolvulus soldanella*
- *Artemisia suksdorfii* and *A. campestris*

- *Lupinus littoralis*
- *Oenothera cheiranthifolia* (syn. *Camissonia cheiranthifolia*)

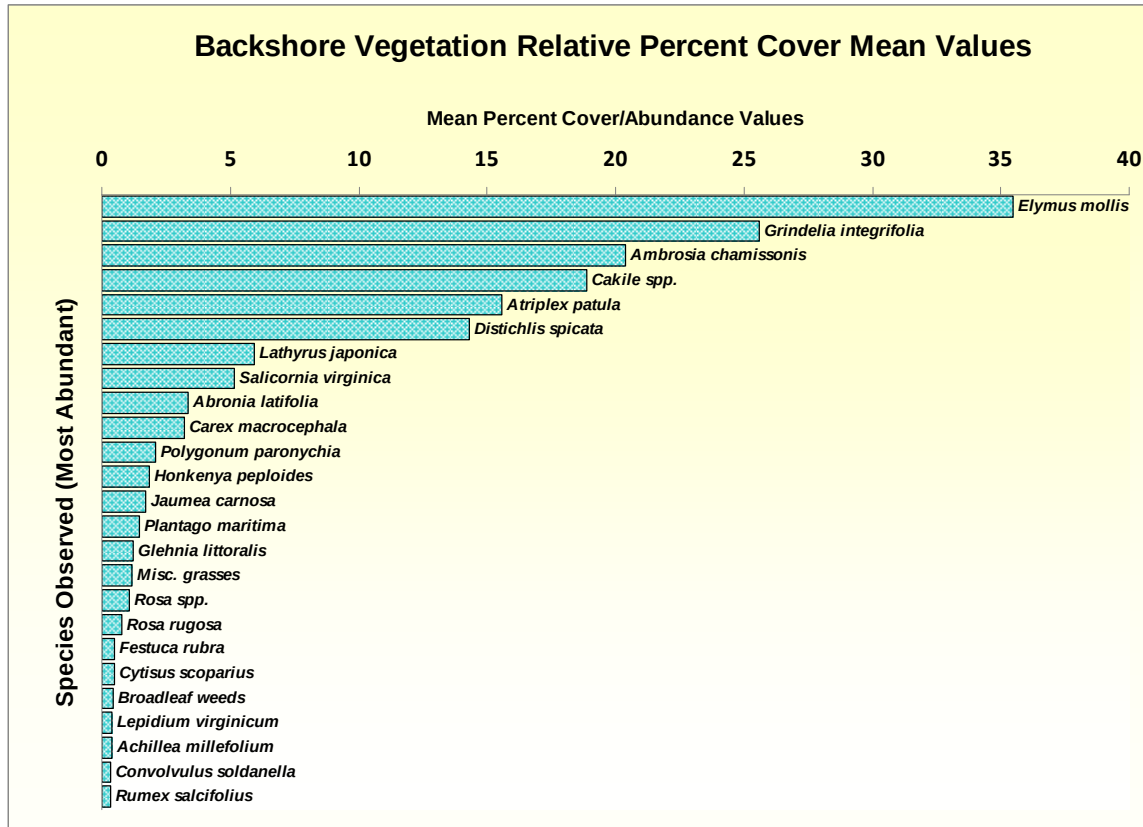


Figure 3. Mean values for relative percent cover/abundance for all sites observed. Combined cover/abundance is derived from Braun-Blanquet cover scale. Only most abundant 25 species are shown; for a complete listing of all species/categories observed by relative cover/abundance, see Table 2.

4.1.2.3 Other associations

4.1.2.3.1 Salt marsh associates: Three species prominently associated with salt marshes also occupy the backshore, sometimes continuing from an associated marsh in a more patchy distribution pattern on the sandy substrates—or entirely independent of an associated salt marsh. These include *Distichlis spicata* (one of the six predominant species), *Jaumea carnosa*, and *Salicornia virginica*. Some sites also contained the salt marsh associates *Potentilla pacifica* and *Symphiotrichum subspicatum* (syn. *Aster subspicatus*) in the sandy substrates—sometimes in thickets, sometimes in patches.

4.1.2.3.2 Native woody species: For the most part, the native woody species occurred in mixed-woody-species thickets at the landward edge of the backshore, though not always. Occasionally, solitary individuals were found at the top of the berm, often embedded in highly decomposed nurse logs, or—particularly in the case of *Mahonia aquifolium*—very near the upper intertidal zone, in small patches close to salt spray.

4.1.2.3.3 Non-native species: Non-native species were found throughout the sites, especially *Daucus carota* and *Lepidium virginicum*. Higher concentrations of non-native species—especially more invasive ones such as *Rubus armeniacus*, *Cytisus scoparius*, and *Rosa rugosa*—were associated with more disturbance to the site, especially road building and filling.

Table 1. Cross Reference of Scientific and Common Names for All Defined Categories		
Scientific Name	Common Name	Non-native?
<i>Abronia latifolia</i>	Yellow Sand-verbena	
<i>Achillea millefolium</i>	Common Yarrow	
<i>Ammophila arenaria</i>	European Beachgrass	Yes
<i>Ambrosia chamissonis</i>	Heath Bursage	
<i>Armeria maritima</i>	Sea Thrift	
<i>Artemisia suksdorfii</i> & <i>A. campestris</i>	Mugworts	
<i>Atriplex patula</i>	Orache	
<i>Cakile edentula</i> & <i>C. maritima</i>	Sea Rocket	Probably
<i>Carex macrocephala</i>	Large-headed Sedge	
<i>Convolvulus soldanella</i>	Beach Morning Glory	
<i>Cytisus scoparius</i>	Scot's Broom	Yes
<i>Daucus carota</i>	Queen Anne's Lace	Yes
<i>Distichlis spicata</i>	Seashore Saltgrass	
<i>Elymus mollis</i> (<i>Leymus mollis</i>)	American Dunegrass	
<i>Festuca rubra</i>	Red Fescue	
<i>Glehnia littoralis</i>	Beach Carrot	
<i>Grindelia integrifolia</i>	Entire-leaved Gumweed	
<i>Honkenya peploides</i>	Sea Purslane; Sandwort	
<i>Jaumea carnosa</i>	Fleshy Jaumea	
<i>Lathyrus japonicus</i>	Beach Pea	
<i>Lepidium virginicum</i>	Tall Pepper-grass	Yes
<i>Lonicera involucrata</i>	Black Twinberry	
<i>Lupinus littoralis</i>	Beach Lupine	
<i>Mahonia aquifolium</i>	Tall Oregon-grape	
<i>Malus fusca</i>	Western Crabapple	
<i>Myrica californica</i>	California Wax-myrtle	
<i>Oenothera cheiranthifolia</i> (<i>Camissonia cheiranthifolia</i>)	Beach Evening-primrose	
<i>Picea sitchensis</i>	Sitka Spruce	
<i>Plectritis congesta</i>	Sea Blush	
<i>Plantago maritima</i>	Seaside Plantain	
<i>Poa</i> , etc.	Miscellaneous grasses	Some
<i>Polygonum paronychia</i>	Beach Knotweed	
<i>Potentilla pacifica</i>	Silverweed	
<i>Ribes divaricatum</i>	Wild Gooseberry	
<i>Rosa nutkana</i> ; <i>R. pisocarpa</i> ;	Nootka Rose; Clustered Wild Rose	
<i>Rosa rugosa</i>	Rugosa Rose	Yes
<i>Rubus armeniacus</i> (formerly <i>R. discolor</i>)	Himalayan Blackberry	Yes
<i>Rumex salicifolius</i>	Willow Dock	
<i>Salicornia virginica</i>	Pickleweed	
<i>Sedum lanceolatum</i>	Lance-leaved Stonecrop	
<i>Symphoricarpos albus</i>	Common Snowberry	
<i>Symphyotrichum subspicatum</i> (<i>Aster subspicatus</i>)	Douglas Aster	
<i>Vaccinium ovatum</i>	Evergreen Huckleberry	
<i>Viola adunca</i>	Dog Violet; Early Blue Violet	
Broadleaf Weeds	Non-native spp. not noted above	Yes

Table 2. Relative Percent Cover for All Defined Categories		
Scientific Name	Common Name	Mean Value (rounded)
<i>Elymus mollis</i>	American Dunegrass	35.47
<i>Grindelia integrifolia</i>	Entire-leaved Gumweed	25.58
<i>Ambrosia chamissonis</i>	Heath Bursage	20.41
<i>Cakile</i> spp.	Sea Rocket	18.90
<i>Atriplex patula</i>	Orache	15.58
<i>Distichlis spicata</i>	Seashore Saltgrass	14.30
<i>Lathyrus japonica</i>	Beach Pea	5.93
<i>Salicornia virginica</i>	Pickleweed	5.17
<i>Abronia latifolia</i>	Yellow Sand-verbena	3.37
<i>Carex macrocephala</i>	Large-headed Sedge	3.20
<i>Polygonum paronychia</i>	Beach Knotweed	2.09
<i>Honkenya peploides</i>	Sea Purslane; Sandwort	1.86
<i>Jaumea carnosa</i>	Fleshy Jaumea	1.69
<i>Plantago maritima</i>	Seaside Plantain	1.45
<i>Glehnia littoralis</i>	Beach Carrot	1.22
<i>Poa</i> , etc.	Miscellaneous Grasses	1.19
<i>Rosa nutkana</i> ; <i>R. pisocarpa</i>	Nootka Rose; Clustered Wild Rose	1.05
<i>Rosa rugosa</i>	Rugosa Rose	0.76
<i>Festuca rubra</i>	Red Fescue	0.50
<i>Cytisus scoparius</i>	Scot's Broom	0.49
Broadleaf weeds	Miscellaneous weeds not noted elsewhere	0.43
<i>Lepidium virginicum</i>	Tall Pepper-grass	0.37
<i>Achillea millefolium</i>	Common Yarrow	0.37
<i>Convolvulus soldanella</i>	Beach Morning Glory	0.35
<i>Rumex salicifolius</i>	Willow Dock	0.35
<i>Mahonia aquifolium</i>	Tall Oregon-grape	0.23
<i>Lonicera involucrata</i>	Black Twinberry	0.23
<i>Rubus armeniacus</i>	Himalayan Blackberry	0.19
<i>Artemisia suksdorfii</i> , <i>A. campestris</i>	Mugworts	0.17
<i>Daucus carota</i>	Queen Anne's Lace	0.17
<i>Potentilla pacifica</i>	Silverweed	0.12
<i>Symphoricarpos albus</i>	Common Snowberry	0.12
<i>Symphyotrichum subspicatum</i>	Douglas Aster	0.12
<i>Lupinus littoralis</i>	Beach Lupine	0.06
<i>Ribes divaricatum</i>	Wild Gooseberry	0.06
<i>Plectritis congesta</i>	Sea Blush	0.06
<i>Viola adunca</i>	Dog Violet; Early Blue Violet	0.06
<i>Ammophilla arenaria</i>	European Beachgrass	0.06
<i>Malus fusca</i>	Western Crabapple	0.02
<i>Myrica californica</i>	California Wax-myrtle	0.01
<i>Picea sitchensis</i>	Sitka Spruce	0.01
<i>Vaccinium ovatum</i>	Evergreen Huckleberry	0.01
<i>Armeria maritima</i>	Sea Thrift	0.003
<i>Oenothera cheiranthifolia</i>	Beach Evening-primrose	0.003
<i>Sedum lanceolatum</i>	Lance-leaved Stonecrop	0.003

4.2 Environmental Factors

To answer my study questions regarding geomorphological questions and physical requirements of backshore vegetation, I attempted to find correlations or patterns between the distribution or abundance of backshore species and the environmental characteristics of the sites.

4.2.1 Landforms: I found backshore vegetation on the following types of landforms: closed marsh or lagoon (14 sites); semi-enclosed lagoon (4 sites); cusped foreland (5 sites); recurved spit (1 site); barrier estuary (1 site); open coastal inlet (5 sites); and various bluff-backed beaches (13 sites), noting whether the shoreline was straight, curved out, or curved in.

Using nonmetric multidimensional scaling (NMS) ordinations and other multivariate analyses, I was unable to see any patterns of distribution of specific species or overall cover/abundance of backshore vegetation relating to shoreform, and no patterns emerged when I further simplified the categories to just two: barrier beach and bluff-backed beach.

4.2.2 Drift cells: Surveyed sites were located at various points along drift cells, sometimes in close proximity to each other. I could find no discernable pattern between position within drift cells and backshore species' presence or abundance.

4.2.3 Width of backshore: I found a strong correlation between percent cover/abundance and the width of the backshore—as measured from the seaward side to the landward terminus. I chose three rankings for backshore width:

- (1) less than 10 meters (21 sites);

- (2) up to 30 meters (12 sites); and
- (3) more than 30 meters (10 sites).

As the backshore widens, mean percent cover increases for most of the six predominant species (Fig. 4), and there is a gradual increase of total cover by the predominant species as the backshore widens: 17 percent average in narrow backshores; 25 percent in medium-width backshores; and 28 percent in wide backshores.

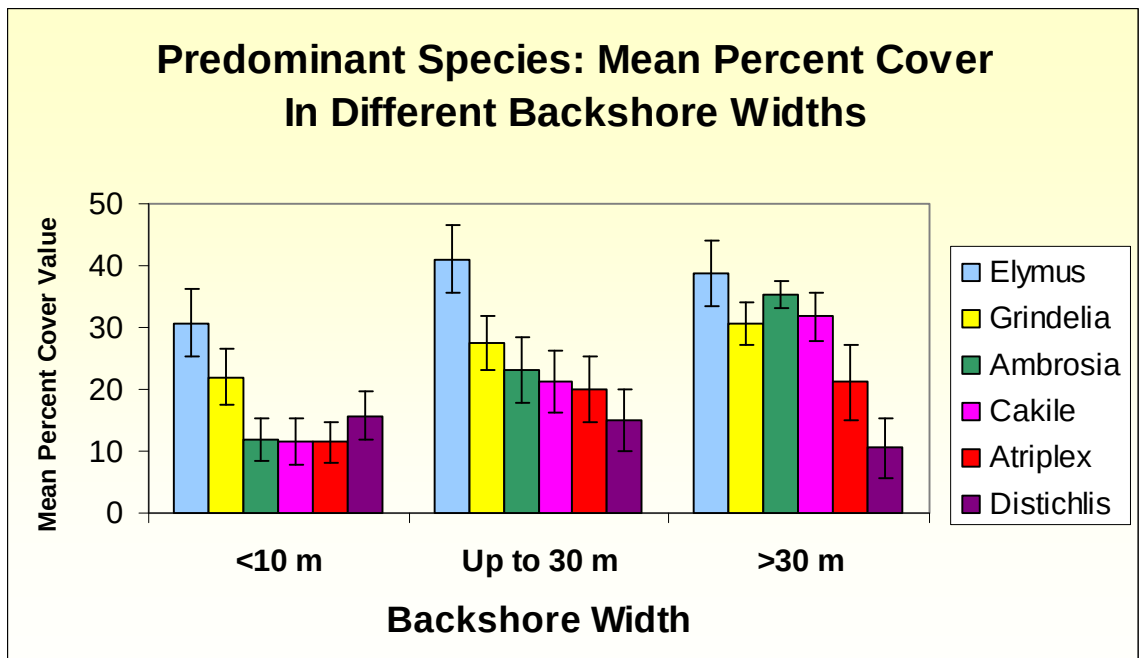


Figure 4. Mean combined percent cover/abundance value for the predominant species for narrow, medium-width, and wide backshores. As the backshore widens, overall average cover and abundance of the predominant species increases gradually. Combined cover/abundance value is derived from the Braun-Blanquet cover scale.

Moreover, the “restricted” species show a strong association with wider backshores: only two species occur in narrow backshores, for total combined mean cover/abundance of 2 percent; three occur in backshores up to 30 meters, for a combined mean cover/abundance of 3 percent; and all nine restricted species occur in the wide (over 30 meters) backshores, for a combined mean cover/abundance of 10 percent for all species. Of these species, *Honkenya peploides* appears to be different, in that it is more abundant in the narrow vs. wide backshores (Fig. 5).

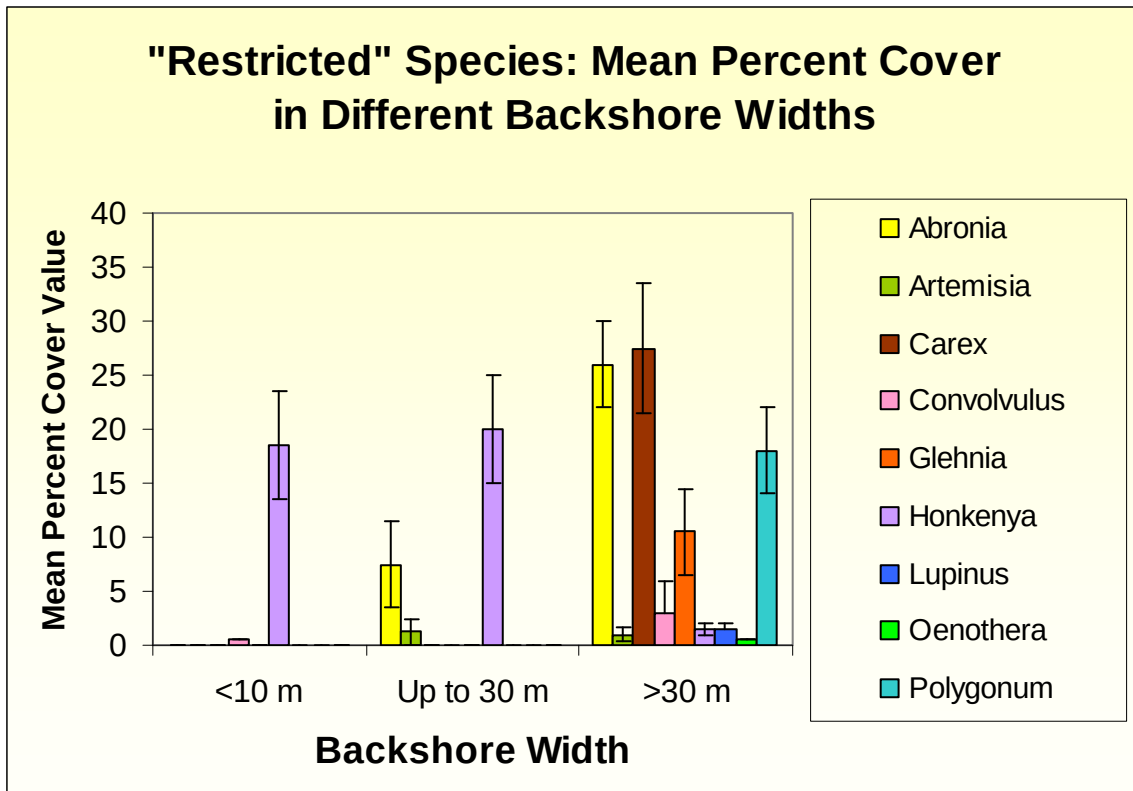


Figure 5. Mean percent cover/abundance value for “restricted” species in narrow, medium-width, and wide backshores. As the backshore widens, more restricted species are present and with greater overall cover. Overall combined cover/abundance rises from an average of 2% in narrow backshores to 10% in the wide backshores.

4.2.4 Position along elevation gradient: Location along the gradient from MHHW to the terminus of the backshore affects environmental factors such as proximity to tidal/storm influence, which can influence salt spray, drift log deposition and wrack deposition; access to beach ground water; potential changes in substrate and height of storm berm; and associations with animals that occupy different niches along the seaward to landward gradient.

I did not observe clear vegetation zonation, such as that described by McLachlan and Brown (see section 2.5.2, above). However, I did observe that some species appear to be more tolerant of environmental stresses closer to the seaward side of the backshore berm. These include *Cakile* spp., *Elymus mollis*, and *Distichlis*. In one case, the *Elymus* and *Distichlis* were clearly subjected to regular swash by the tides, as their rhizomes were exposed, yet the patches were robust. This was not a surprising finding for *Distichlis*, which is equally at home in the upper intertidal zone (Kozloff 1993), but was not expected for *Elymus*, which is usually more distant from regular exposure to tidal influence.

Honkenya peploides also can be found near the seaward side of the backshore, as well as further back along the gradient. *Atriplex patula*, *Ambrosia chamissonis*, and *Grindelia integrifolia* are also found near the seaward side, but not as close to the wrack line as are those noted above.

Where it was present, *Carex macrocephala* was found growing throughout the more protected parts of the backshore. However, occasionally I also found it very close to the shoreline—but always on the landward side of a large drift log. Other

species that I observed mostly in the more landward reaches of wide backshores include *Polygonum paronychia*, *Abronia latifolia*, and *Glehnia littoralis*. For instance, at one site, I observed the first vegetation, *Cakile* spp., at approximately 0.6 meters from MHHW, while the first *Carex macrocephala* and *Abronia latifolia* did not appear until about 29 meters from MHHW.

From my observations, it appears that these four species—*Carex macrocephala*, *Polygonum paronychia*, *Abronia latifolia*, and *Glehnia littoralis*—are generally adapted to the more protected sections of the backshore. However, on one site I observed *Abronia* patches on the edge of an eroding seacliff, four to five meters above the beach, fully exposed to regular strong winds.

4.2.4.1 Drift logs: I frequently observed the first patches of backshore vegetation in association with substantial drift logs. Logs were not found at consistent distances from MHHW, but the location of drift logs is linked to beach elevation, as well as the influences of major storms, and their presence marks an important threshold in substrate stability, as well as colonization of vegetation (Tonnes 2008).

4.2.5 Aspect: Sampled sites ranged across six aspects: southeast, east, southwest, northeast, northwest, and west. I found no patterns between aspect and the overall cover/abundance or distribution of specific species.

4.2.6 Substrate: I was able to see relationships between species presence and abundance according to substrate (Figs. 6 and 7). I identified five substrate types:

- (1) Sand (fine to coarse);
- (2) Sand with gravel veneer;

- (3) Mixed sand/pebbles;
- 4) Mixed shell hash/gravel, no discernable sand; and
- (5) Small cobbles/large pebbles with wood chunks, no discernable sand. In

this substrate—seen only once—particles were on the high end of the scale for pebbles, but the low end for cobbles (about 50 to 75 mm) according to the Wentworth size scale (McLachlan & Brown 2006). Because I found this substrate only once, I do not have a sufficient number of sites to be statistically valid, but I share the results for the qualitative observations.

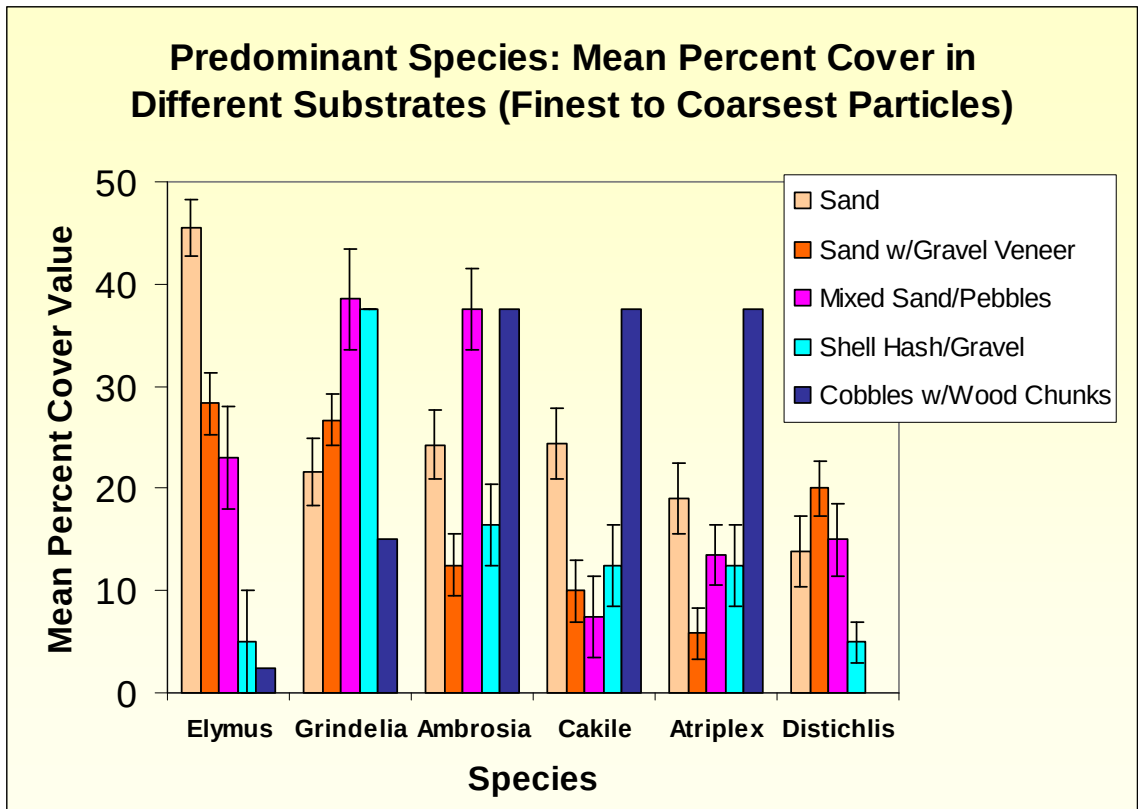


Figure 6. Mean percent cover/abundance value for predominant species in different substrates. Substrates are shown in order from finest to coarsest particle size.

4.2.6.1 Predominant species

Elymus mollis: The data show a strong relationship between *E. mollis* and sandy substrates. It had the largest percent cover in sand, sand with a gravel veneer, and mixed sand/pebbles. On sites with shell hash/gravel, *E. mollis* was either absent or very sparse. I sampled only one site with small cobbles/large pebbles and wood, where *Elymus* was present, but sparse.

Grindelia integrifolia: *G. integrifolia* appears to flourish across all substrates, and has a higher mean percent cover on substrates where *E. mollis* is absent or sparse.

Ambrosia chamissonis: *A. chamissonis* was found on all substrates, although it is greater in abundance on less coarse substrates.

Cakile spp.: The *Cakile* species appear on all substrates fairly equally.

Atriplex patula: *A. patula* can occupy all substrates, including those that are very coarse.

Distichlis spicata: *D. spicata* was present in all substrates except the coarsest (cobbles). According to the literature, *Distichlis* is generally associated with finer substrates.

4.2.6.2 “Restricted” species

The restricted species were present only in predominantly sandy substrates. All nine were found in pure sand, while four also were found in mixed sand/pebbles substrates: *Abronia latifolia*, *Artemisia suksdorfii*, *Convolvulus soldanella*, and *Honkenya peploides* (see Fig. 7). Overall, mean percent cover was greater for almost all species in

the pure sand vs. the coarser mixed substrate, with the exception of *Artemisia* spp., which were slightly more abundant in the sand/pebbles.

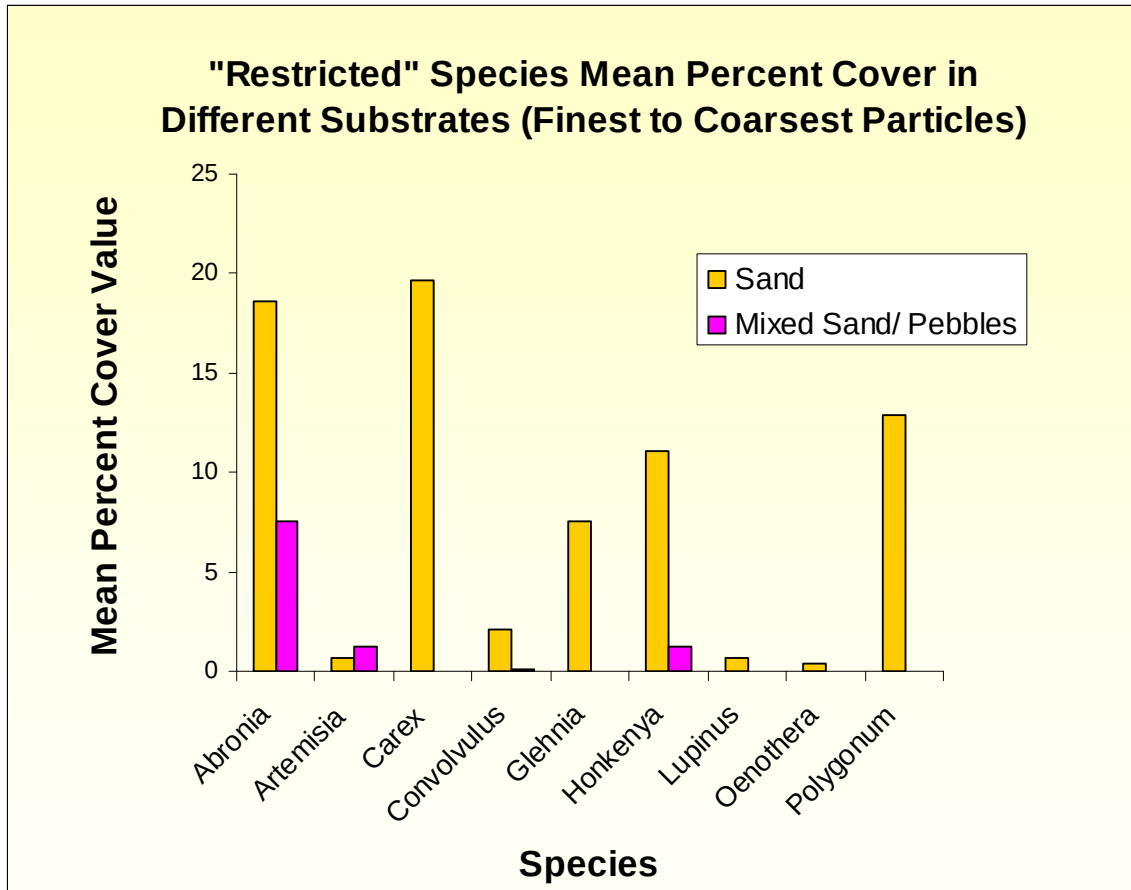


Figure 7. Mean percent cover/abundance values for geographically restricted species in different substrates. Substrates are shown from finest to coarsest particle sizes.

4.2.6.3 Buried wood in substrate: As part of my investigations of both the substrates and root systems, I frequently dug holes in the substrate when not on private property. I consistently found small chunks of wood, generally 20 cm or less in diameter, buried at various depths in the substrate. These wood chunks seemed to

provide an additional substrate for the plants' roots: If I dug near the root zone of one of the backshore plants, its roots were invariably anchored into this woody substrate.

4.2.7 Analysis of salinity in sediments: Salinity concentrations in the sandy sediments of the backshore were very low compared to concentrations of sediments in the intertidal zone. In the backshore, the range of salinity concentrations was fairly consistent along the gradient from MHHW to as far landward as 46 m (150 ft.) from MHHW (see Fig. 8). Concentrations ranged from 7.5 mg/L (in potassium chloride equivalents) to a high of 20.75 mg/L.

Moreover, the salinity concentrations remained about the same or were slightly higher 0.6 m (2 ft.) into the sediments. The only deviations were in substrates containing wood (sand/fine wood mixed or chunks of wood), where the salinity levels were 63.75 and 52.5, respectively (see later discussion).

In contrast, the samples taken low in the intertidal zone were over 1,700 mg/L, about two orders of magnitude higher than those found anywhere in backshore sediments.

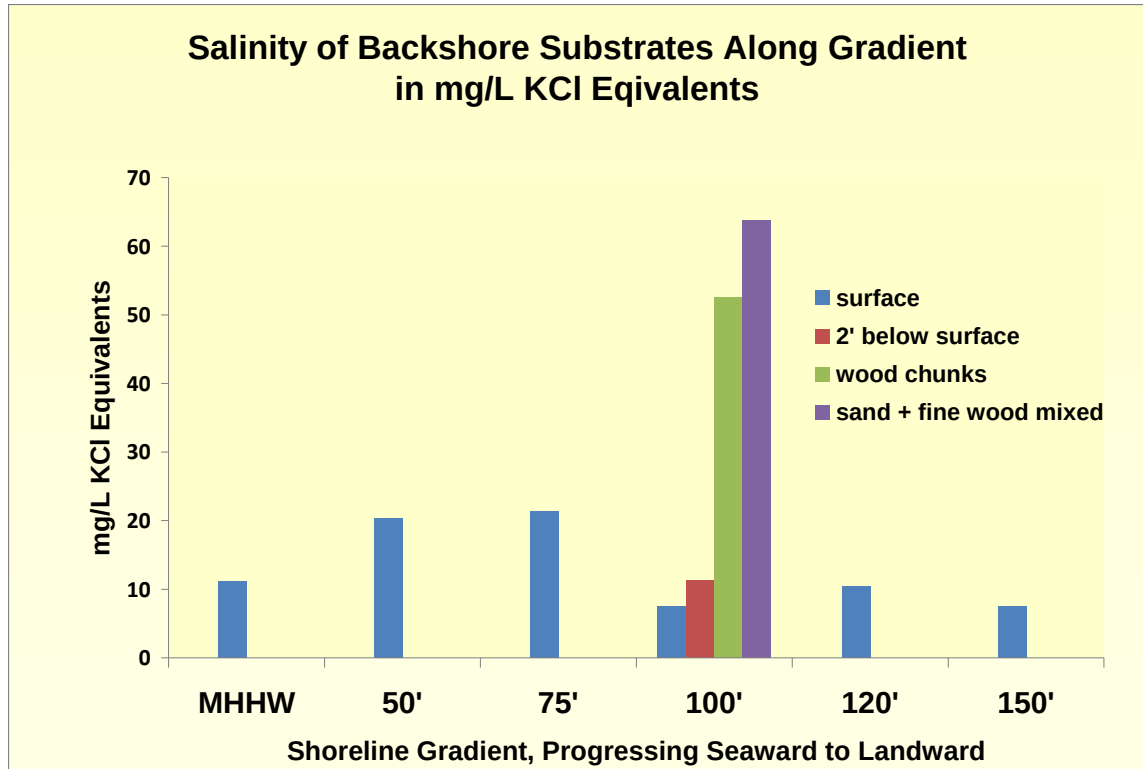


Figure 8. Averages of substrate salinity along the gradient, from MHHW to 150 feet landward, in mg/L KCl equivalents. Substrates included sand, sand and fine wood, and wood chunks. Samples taken near MLLW (not shown), averaged over 1725 mg/L KCl equivalents.

4.2.8 Observations of Root Systems: Exposing the main root systems of several plant species revealed some general patterns. Most have a deep tap root—in some cases I did not find the end after digging a half meter or more. They also tended to have an extensive lateral branching root system that is quite widespread—some nearly a meter or more.

Grasses and sedges had vigorous rhizomatous root systems, generally less deep than the forbs, but widespread. Occasionally I found evidence of recent burial by sand, in response to which plants developed adventitious roots along their former stems. I noted this especially in *Honkenya* and *Elymus* stems.

In a later part of my research, I participated in a revegetation project that transplanted sections of *Elymus mollis*, *Ambrosia chamissonis*, and *Grindelia integrifolia* from a nearby intact backshore. Even in these circumstances, in which concern for protecting the plants' root systems was not a factor, I was not able to dig fully to capture the entire root systems of these species. This experience reinforced my findings that the root systems are both deep and widespread.

4.2.9 Fauna sighted: Besides amphipods, I observed several small bird species and one mammal in backshores during my site visits. I saw Townsend's chipmunks scurry in and out of layers of drift logs. I observed the following songbirds, high in the backshore and closer to the upper intertidal zone, foraging and perching in the vegetation: Purple Finch; Song Sparrow; Savannah Sparrow; Lapland Longspur (fall, expected to overwinter); and Snow Bunting (fall, expected to overwinter). I observed these shorebirds near the seaward side of the backshore and into the upper intertidal zone: Black Turnstone, Semipalmated Plover, sandpipers, and yellowlegs.

4.3 Revegetation Project Investigations

I communicated with four people regarding completed backshore revegetation projects. Jim Johannessen of Coastal Geologic Services Inc. has installed several soft shore-protection systems, and he referred me to some of his clients who had installed backshore plantings so I could query them regarding their success in establishing plants. He also provided me with a series of photos taken from the same points over the course of several years following some of his projects. Using these, I could see

that the backshores were largely revegetated with a combination of naturally recruited plants and those transplanted by his clients (personal communication, 2008).

4.3.1 Padilla Bay Site: I communicated with Mary Heath, whose project was constructed in 2005, in Padilla Bay, near Mt. Vernon, Washington. This site is very close to MHHW, and smaller cobbles wash away regularly. After construction, Ms. Heath replanted the site with *Elymus mollis*, *Achillea millefolium*, *Symphyotrichum subspicatum* (syn. *Aster subspicatus*), and *Distichlis spicata* by transplanting patches of vegetation from a nearby site on the beach. In addition to these transplanted species, *Cakile* spp. and *Grindelia integrifolia* have naturally recruited. The vegetation has been more or less successful in establishing over time, depending on the intensity of storm events. Some patches are very robust, including some associated with sections of her beachfront in which some old stumps had been buried in the substrate. These stumps provide a small lift in elevation, which may provide the vegetation some refuge from the tidal influences (personal communication, 2009).

4.3.2 Penn Cove Site: I spoke with Bob Boyden, whose soft shore-protection installation by Mr. Johannessen occurred in November 2002 on a site in Penn Cove, Whidbey Island, Coupeville, Washington. Mr. Boyden revegetated the site in spring 2003 by transplanting *Elymus mollis* from a nearby section of the beach, as well as a species of *Erysimum* (wallflower), which may or may not be a native species. The *E. mollis* has been successful, and other species have naturally recruited as well, although

Mr. Boyd could not identify them. From his description, I surmised that one was probably a species of *Cakile* (personal communication, 2009).

The photos supplied by Mr. Johannessen show that the site is well vegetated. The *Elymus* above the installed drift logs has flourished, and another grass, which could be *Distichlis*, is also robust. The *Erysimum* planted by Mr. Boyden has reseeded itself and is robust. There are additional backshore plants further seaward in the sandy substrates, including *Cakile* spp. and *Ambrosia chamissonis*.

4.3.3 Robinson Road Levee Removal/Duckabush Backshore Revegetation

Project: In November 2008, I participated with Smayda Environmental Associates, Inc. and Sound Native Plants, Inc. in a revegetation project following restoration of a semi-enclosed estuary. For about 70 years, the estuary had been blocked by an access roadway built across its mouth, which extended along the length of a former spit. Test pits showed a clear delineation between the fill and the original backshore berm sediments, which were classified as gravelly native sand. Smayda Environmental removed the road and a four- to six-foot-deep layer of fill materials covering the original spit substrates.

Following construction, Kathy Smayda and a crew from Sound Native Plants replanted the site with plugs from species still present on the spit (*Elymus mollis*, *Potentilla pacifica*, *Grindelia integrifolia*, and *Ambrosia chamissonis*) to preserve local genetic diversity. The crew also transplanted small mats of *Distichlis spicata*, *Jaumea carnosa*, and *Salicornia virginica* from an intact section of the intertidal area adjacent to the

restored estuary. In addition, the crew took seed heads from resident *Elymus*, *Grindelia*, *Ambrosia*, and *Symphyotrichum subspicatum* (syn. *Aster subspicatus*), and liberally seeded the site.

Since the planting, Ms. Smayda has been able to monitor the site only twice, in February and August 2009. She reports that in February the plugs appeared to be succeeding, that the plants looked “healthy but dormant.” Her summer monitoring results were not analyzed in time for this publication, but Ms. Smayda reports anecdotal evidence for success of transplanted *Elymus* plugs, mats of *Salicornia* mixed with *Jaumea*, even when “high and dry,” and at least limited survival of transplanted or seeded *Ambrosia* and *Grindelia*. The *Elymus* in particular appeared to be thriving, with new rhizomatous shoots apparent in many cases. In previous projects, Ms. Smayda has successfully established some backshore species by broadcasting seed heads; however it is too early to tell how successful the seed propagation strategies have worked on this site (personal communication, 2008 and 2009).

4.4 Observations of Anthropogenic Impacts

I observed many human impacts to the backshore ecotone, and the backshores where I sampled often had been altered in various ways.

4.4.1 Fragmentation: The most common alteration was fragmenting the ecotone, usually by the construction of roadways or paved trails at the high point of the berm, which effectively cut off the natural sediment-transport processes and the spread of

vegetation. Despite this, I would usually find backshore plants growing right to the edge of the disturbance. On sites with roadways in particular, I observed an abundance of invasive plant species, especially aggressive woody species, such as *Rubus armeniacus*, *Cytisus scoparius*, and *Rosa rugosa*.

Roadways often were constructed between a backshore and a salt marsh with which it was formerly associated, potentially divorcing these two systems from the materials exchange, vegetation transitions, and occasional inputs of overwash that would have been part of their dynamic interactions.

4.4.2 Building construction: The addition of fill and construction of homes is another human impact to the backshore. Most of the homes along the backshore berm likely were built as vacation homes decades ago, before permitting agencies took note of impacts to the nearshore. Many of these homes had now been remodeled as year-round residences. In some cases, I saw obviously recent construction of condominiums and associated large sea walls protruding into the upper intertidal zones. On either side, natural backshore vegetation and substrates extended landward beyond the footprints of these structures. Despite its ecological significance in recent literature, there are very few regulatory restrictions to construction in the backshore, as it is neither a jurisdictional wetland nor seaward of MHHW (Doug Myers, personal communication, 2009).

In most cases of construction in the backshore, backshore vegetation had been replaced by lawn, and landowners were actively preventing backshore vegetation

from encroaching on the lawns. Much of the lawn turf exhibited one of two responses to the conditions: (1) turf was obviously stressed and struggling to survive in the challenging fast-draining substrates beneath the sod; or (2) turf was excessively green and perfect, indicating heavy irrigation, and the application of fertilizers and possibly pesticides.

4.4.3 Recreation and storage: Uses of the backshore that echoed those found by Gabriel and Terich (2004) included recreation and storage. I observed backshores adjacent to uplands being used to store large boats, seasonal docks, and even tool sheds. I also observed backshores with volleyball nets, parking areas, and sites where neighbors dumped their yard trimmings.

The backshore is also a component of several popular parks, including Point No Point in Kitsap County, and Rocky Point and Deception Pass State Park in Island County. Visitors regularly walk over the plants on their way to the shoreline, and plants show suppressed growth or are absent in areas where they are trampled. To urge visitors to stay on trails and avoid damaging backshore plants, park managers at Deception Pass have installed signs that read: “Dune plants are adapted to a harsh environment of wind, sand and salt, but not the insult of crushing and trampling. Help these plants continue to thrive—please walk around them, not on them.”

Table 3. Summary of Key Study Questions and Findings

Study Question Category	Study Question(s)	Findings	Comments
Defining Plant Community	Several; see p. 26.	6 predominant species	See results pp. 38-44; discussion pp. 59-61.
Geomorphological Connections	Do backshore plants need specific shoreforms?	Found on variety of shoreforms.	
	Do backshore plants occur at specific points within drift cells?	Found at various points within drift cells.	More study and mapping might produce more obvious patterns.
Plants & Sediments	Do plants stabilize sediments?	Several features help sediments accrete, stabilize, and re-establish following disturbance.	See discussion pp. 66-67.
Physical Requirements	Elevation: Relationships between presence of plants and distance from MHHW?	Links to presence of most seaward drift logs and pioneer plant species supporting sediment accretion.	See discussion pp. 68-69.
	Elevation: Do outer-coastal dune zonation concepts apply to Puget Sound backshores?	Some similarities, but more integration of woody species than in classically described systems.	See discussion pp. 68-69.
	Aspect: Relationship between plants' presence and aspect?	No evidence found.	More study might produce more obvious patterns.
	Substrate: Do plants require particular grain size?	Plants found in range of substrates, though species composition varies; some species limited or absent in coarser substrates.	See results pp. 49-52; discussion p. 69.
	Salinity: Do plants require specific range?	Salinity concentrations throughout backshore are very low in comparison to intertidal zone. Most species likely not halophytic.	See results pp. 53-54; discussion pp. 70-71.

Study Question Category	Study Question(s)	Findings	Comments
Physical Requirements, continued	Water/nutrient availability: What mechanisms might permit plant survival?	Many mechanisms described from literature. Potentially significant finding in association of plants' roots with presence of buried wood in substrates.	See pp. 15-19 for literature results, and discussion on pp. 71-75 on theories regarding associations with buried wood.
Restoration Potential	Several: see p. 29.	Strong potential for transplanting, reseeding, and recolonization.	More restoration projects and monitoring data needed to better assess which species and methods will be most effective. Incorporation of buried wood should be tested and evaluated. See results pp. 55-58; discussion pp. 76-77.
Anthropogenic Effects	Ecological services provided by backshore vegetation?	Several services, including buffering, habitat/food web, sequestration of carbon in extensive root systems.	
	Impact of human activities on backshore habitat and plants?	Multiple impacts: disruption of habitat; non-point pollution; fragmentation; invasive species; narrowing of backshore/reduction in natural buffering; reduction in species diversity; reduced public access.	See results pp. 58-60; discussion pp. 77-83.

SECTION 5: DISCUSSION

I was able to answer several of my research questions, at least preliminarily:

5.1 Defining Plant Community and Role in Ecosystem

Original study questions: Are there specific plant species that occur with such frequency as to define a backshore community? Can the presence or absence of specific species define “backshore” versus other beach zones? What distinguishes “backshore” vegetation from “salt marsh” vegetation? Are there observed and reported interactions between backshore vegetation and specific animal species? How does backshore vegetation support nearshore food webs?

Discussion: My study showed six obviously predominant species common to most Puget Sound backshores I observed. The presence of some combination of these six species should indicate a backshore community. Although *Elymus mollis* is the primary backshore associate, not all backshores are necessarily defined by the presence or absence of *E. mollis*, and I observed backshores that lacked *E. mollis*, likely because the substrate was too coarse. Nonetheless, a description of Puget Sound backshores should note that they usually are associated with *E. mollis*, as well as the other predominant species. I would suggest that a broader definition of the backshore vegetative community include all six of the predominant species, with notes of other expected species if the conditions are sufficient for their needs.

My study showed that species typically associated with salt marshes, especially *D. spicata*, *S. virginica*, and *J. carnosa*, are able to survive in the drier, harsher conditions of the backshore as well. However, only *Distichlis* emerged as one of the six

predominant species. Other associates such as *Potentilla pacifica* and *Symphyotrichum subspicatum* (syn. *Aster subspicatus*) were also occasionally present on the backshore edges. But I did not find species such as *Triglochin maritima* or *Carex lyngbeyi* in the backshore, although they were often present in nearby associated salt marshes. My study indicates that a few species are well adapted to exist in a variety of conditions associated with low to high salinity and dry to hydric substrates, and can therefore cross back and forth from the upper intertidal zone, where they receive regular tidal influence, to the dry backshore, and beyond to the mucky soils of the salt marsh.

The mere presence of the salt marsh associates *Distichlis*, *Salicornia*, or *Jaumea* should not be adequate to define the backshore, as these species alone would probably indicate presence of a salt marsh. Rather, the presence of these species would not necessarily suggest the presence of a salt marsh if they also are found in conjunction with the other predominant backshore species.

The literature (e.g., Kozloff 1983; Romanuk & Levings 2003; McLachlan & Brown 2006; Dugan et al. 2008) reports many interactions between backshore vegetation and several species of animals, both terrestrial and aquatic. In my site visits, I was able to observe associations between the backshore vegetation and several species of birds, who were actively feeding amongst patches of *Cakile* spp., *Ambrosia*, *Honkenya* and other species. Backshore vegetation provides animals with cover, forage, and nesting materials, and contributes to the detritus-based food web.

Backshore plants add complexity and increase habitat in the supratidal zone, as well as other parts of the nearshore. Their biomass becomes part of energy and

nutrient transfers and cycling within the nearshore and the uplands. Even small plants cool temperatures and retain moisture in the substrates, creating micro-habitats that provide small animals with refuge from predators, temperature extremes, and desiccation.

Perhaps the most important role of backshore vegetation cannot be seen with the naked eye. Given the likelihood that backshore plants engage in mutualistic relationships with mycorrhizal fungi in the substrates, they likely support a large community of interstitial species, including bacteria, fungi, and meiofauna. Moreover, these associations probably produce additional nutrient inputs into the nearshore system as mycorrhizae make nutrients more accessible.

5.2 Geomorphological Connections

Original study questions: Do backshore plant species require specific shoreforms to provide adequate stability and substrates? Are backshore species likely to occur at specific points within drift cells? Are there connections with shoreforms or drift cells in a consistent pattern that would permit simple mapping of backshore vegetation Sound-wide?

Discussion: My expectation was that backshores were only formed in depositional features, or at specific points within drift cells. But both of these expectations proved false. I found backshores along many bluff-backed beaches, including several beaches within the same drift cell, sometimes separated by less than 50 meters between them.

Although my study was not comprehensive in characterizing sites throughout the Sound, I found that it is not possible to easily map backshore vegetation Sound-wide based on shoreform type or patterns within drift cells. My original expectation was that one might be able to determine where backshores were likely to exist based on observing maps of shoreforms and drift cells. But backshores can be very small systems occupying hidden stretches of shoreline apparently at any position within drift cells. Additional evidence against this notion is that I sometimes observed that good candidate sites for backshore vegetation were in fact depositional features that received daily tidal influence. Though occupied by drift logs and salt marsh/backshore associates such as *Distichlis spicata* and *Salicornia virginica*, they were too low in elevation to sustain the backshore ecosystem.

5.3 Role of Plants on Sediments and Vice Versa

Original study questions: Are stable sediments required for backshore species to colonize? Do backshore plant species play a role in sediment accretion and/or stabilization?

Discussion: Taken together with the literature, my study sheds some light on this question. The geomorphology of given shorelines supports accumulation of sediments adequate to allow plants to begin to colonize—possibly with support from large drift logs. This stability may be temporary, and on time scales as small as a few years. However, once sediments accrue, pioneer backshore species may find adequate substrate to begin establishing.

Due to adaptations enabling certain plants to survive in the heterogeneous conditions of the backshore, plants play a role in stabilizing sediments. Their various growth habits—including prostrate and creeping top growth as well as underground stolons and rhizomes—probably provide accretion opportunities for finer sediments. The plants’ deep and widespread root systems, and their ability to respond to burial by producing rapid growth and new adventitious roots, further bind sediments in place.

These plants’ various strategies for reproduction, as well as their deeply anchored roots and underground shoots, support rapid re-colonization following a major storm event—thereby working hand-in-hand with hydro-geomorphologic processes and drift logs to re-stabilize the supratidal zone until the next major disturbance.

5.4 Physical Requirements

Given the physical challenges of the supratidal zone, what are the adaptations that permit backshore plant species to be successful? I considered these physical features:

5.4.1 Elevation. Original study questions: What is the relationship between (1) the presence of backshore plants and (2) the presence of particular species and the distance from approximate MHHW? Do concepts of classic zonation from outer-coastal communities apply to Puget Sound’s backshore vegetation?

Discussion: From my observations, the backshore can begin at essentially MHHW or just a little above it. Providing stability for substrates and vegetation to accumulate often begins with drift logs, which are probably offering protection from the harshest marine influences. Since placement of drift logs is related to MHHW, the two are linked. In addition to drift logs, aggressive pioneer species such as *Cakile* spp., *Honkenya peploides*, or *Elymus mollis* can begin to bind sediments and provide protection from strong winds and other challenging features of the seaward side. The presence of the pioneer species on the seaward side probably enhances conditions for other species to colonize further landward.

I did not observe classic zonation seen on outer-coast backshore systems, as described by Brown and McLachlan (2006). Although Puget Sound's backshores are significantly different than those found in higher-energy outer-coast systems, I observed some similarities. As noted above, there is a zone of pioneer species, just as Brown and McLachlan report for outer-coast communities. It is unclear if these are more "short lived" than plants found further landward, as noted in Brown and McLachlan's characterization of the Zone 1 pioneers. Landward of the pioneers—and possibly in conjunction with wider backshores—the species composition may become more diverse and include those that appear further landward, such as *Carex macrocephala*, *Glehnia littoralis*, and *Abronia latifolia*.

According to zones described by Brown and McLachlan, as one moves landward sediments become more stable and species composition changes to include an increase in woody plants. In my observations, where woody plants occurred, they

were frequently just as likely to be just behind the pioneers as to be well back from the seaward side of the backshore. On some sites, certain woody plants created a shrub zone of sorts, far from the sea, and at the landward edge of the backshore; but even on these sites, I found other woody plants well distributed throughout the backshore, sometimes in association with obvious nurse logs, but not always.

5.4.2 Aspect. Original study question: Does backshore vegetation occur more frequently on beaches with specific aspect?

Discussion: Although aspect can affect frequency and severity of storms, I found no patterns between aspect and frequency or abundance of any vegetation, including the geographically restricted species.

5.4.3 Substrate. Original study questions: Does backshore vegetation require a substrate of a particular grain size, or will plant species occur in a variety of substrates? Do the plant communities vary by substrate?

Discussion: My study shows that backshore vegetation occurs in a variety of substrates, ranging from very fine sands to larger cobbles. The mix of species will be different from substrate to substrate, and *E. mollis* is clearly much more limited in coarser substrates. Moreover, from my sampling, there is evidence that the restricted species may be limited to finer substrates.

5.4.4 Salinity. Original study question: Is backshore vegetation associated with specific salinity ranges?

Discussion: I took sediment samples from several sites, and although my readings varied slightly, for the sandy substrates, all were within a similar very low range of salinity. Moreover, the readings were very close to each other from the most seaward to the most landward side of the backshore, which differed from my expectation that concentrations would decline the further landward the samples were collected. This implies that the entire backshore is under the influence of salt spray carried by the winds and deposited on the sediments. This low range of salinity is fairly constant to a depth of nearly a meter, at least, below the surface. It probably is maintained at a consistent level by either percolation or shifting and accumulation of more layers of sediments already infused with salts. The salinity range for the sediment samples I took in the supratidal zone was two orders of magnitude lower than the salinity of the sediments from my samples near MLLW, suggesting that the backshore vegetation needs only to be moderately adapted to withstand salt influence, and not necessarily to be halophytic. Further evidence for this can be found in the presence of many upland species in the backshore, particularly non-native Asteraceae plants, which are not normally associated with a saline environment. These observations are supported by the Ievinsh's (2006) assertions that backshore species need only be adapted to "heterogeneous"—rather than truly stressful—conditions.

The higher salinity readings of wood-containing substrates are probably due to the sponge-like ability of wood to absorb and store water and minerals over time.

The higher salinity readings in these substrates suggest that buried wood may play a role in absorbing and maintaining moisture and nutrients; this may have a significant bearing on the discussion below regarding adaptations and the role of buried wood. Although the salinity readings of the woody substrates were higher, they are still relatively low compared to readings of substrates in the intertidal zone.

5.4.5 Water and nutrient availability. Original study question: What are reported and observed mechanisms for survival in water- and nutrient-limited substrates?

Discussion: The literature cited in Section 2 reviews many of the known adaptations that permit vegetation to survive in water- and nutrient-restricted soils with harsh light, winds, and salt influence. However, I could find no literature documenting what I found at site after site by digging into the substrate: the presence of small chunks of old drift logs, often penetrated by the roots of nearby plants. I have developed three distinct hypotheses about possible benefits to the vegetation from its association with buried wood:

(1) Nurse Log: Buried wood chunks may act as miniature nurse logs in the sediments, providing nutrients and allowing the plants to receive moisture during the months of limited rain fall. The substantially higher salinity readings of these woody substrates support the notion that these pieces of wood act as long-term “sponges” to benefit the vegetation.

(2) Physical Anchor: Buried wood chunks may help anchor the plants, enabling them to better withstand violent winter storm events. Since many of the plant species are dormant in winter, their above-ground parts are not subject to the impacts of storms. However, berms are ripped apart when drift logs move (Finlayson 2006), so having an anchor a meter or more below the surface may allow certain individuals to survive these disturbances and renew the population more quickly.

(3) Fungal Associations: In addition to the usual mycorrhizae associated with backshore plants' roots, buried wood may host higher concentrations or more species of mycorrhizal and/or saprotrophic fungi—providing greater benefits to plants able to access the wood. In addition, buried wood might provide a pathway for various microbiota to enter the ecosystem and affect nutrient and carbon cycling, habitat complexity, competition dynamics, and pathogen defense.

Although I could not find literature relevant to my specific observations, some related literature supports these hypotheses. Many reports confirm the historical presence of wood on beaches and associated salt marshes (Gonor et al. 1988), as well as its role as nurse log or refuge on beach surfaces and marshes. These reports support the notion that interactions between backshore plants and wood may have been occurring for millennia and possibly that the vegetation has evolved based on the wood's presence.

In an historical review of literature about large trees in the marine environment within the Pacific Northwest region, Gonor et al. (1988) describe the long-time association of wood with the shoreline, including noting early European

settlers' journal accounts describing the vast quantities present. Gonor et al. point out that the quantity and historical size of drift logs in the Pacific Northwest differ from other coastlines, and acknowledge that the size is on the decline following the loss of large trees due to logging: "More important even than the great size of individual trees or logs is the massiveness of the overall deposits, each of which may cover many acres of beach to a depth exceeding 10 feet" (p. 103).

Large drift logs buried deep in the backshore—often criss-crossing—are revealed when a major storm event washes away long-term sediment accumulations, highlighting the logs' role in promoting sediment accretion and stability for 10 to 15 years (Gonor et al. 1988). Hood (2007) also notes that the larger size of drift logs may be particularly important when serving as nurse logs in the challenging nearshore environment, as larger logs are more likely to resist rolling by tides and waves. The depth of burial and size of drift logs—and their role in providing long-term stability—give weight to the possibility that once a plant has its roots embedded in a log a meter or more into the substrate, it may survive extreme disturbances more successfully than an individual with nothing anchoring it into the fine sediments.

Gonor et al. (1988) recognize that the zone at the base of drift logs can help support colonizing backshore vegetation by offering moister and more hospitable substrates, as well as potentially increased nutrients. Hood (2007) studied the potential for large drift logs to ameliorate the many stresses of vascular plant establishment in tidal marshes, focusing on the nitrogen-fixing shrub *Myrica gale*. His observations that pioneer species benefited from nurse logs in salt marsh colonization

supports a similar function of buried wood in the backshore. Summarizing others, he notes many benefits of nurse logs in this environment: "... reduced moisture stress as a result of greater water-holding capacity, ... reduced infection by pathogenic fungi, specific mycorrhizal communities, ... greater nutrient availability, and warmer microhabitat" (p. 448).

Research from strictly terrestrial ecosystems (Brais et al. 2005) suggests that buried wood may increase nutrient availability to plants by providing more capacity for effective exchange of soil cations. Particularly where soils are nutrient limited, the introduction of organic matter enhances both cation-exchange capacity and water-holding capacity. Brais et al. (2005) observed the roots of jack pine seedlings preferentially growing in buried wood at their study sites, but could not definitively determine why.

Although the world of mycorrhizal research is a complicated one challenged by researchers' attempts to isolate specific factors while studying an inherently complex and interconnected ecological system, some research supports my third hypothesis that fungal interactions with buried wood that may benefit backshore vegetation. In her thesis, Tuininga (1995) considered possible interactions between wood-decomposing (saprotrophic) fungi and mycorrhizal fungi associated with the same nurse log substrates. She suggests that there is evidence that these two fungi interact when they occupy the same common space, and suggests that there could be competition or intermingling of their mycelia. Intermingling could result in neutral, commensal, or mutual interactions. Possible outcomes could include mycorrhizae

obtaining nutrients from saprotrophic fungi, and in turn making these more available to the roots of the vascular plants.

In addition to these possibilities, buried wood might also supply pathways for different species of mycorrhizae than those inoculated via sea spray, which might allow plants to benefit from life cycles of additional species. This could make nutrients available at different times of year, coinciding with the plants' different needs at different points in their growth cycle.

Casper and Jackson (1997) affirm the complexity of this research from multiple fields in biology and support the need for further investigations: "While much is known about how roots respond to their soil environment, we are far from linking the physiological and growth responses of roots to the ways that plants [and fungi] affect each other. ... The ways in which mycorrhizae alter root interactions are likely very complicated. ... Much is yet to be learned about these mechanisms and the role of mycorrhizae in affecting community composition and population structure" (p. 563).

5.5 Restoration Potential

Original study questions: Can backshore vegetation be successfully re-established as part of broader nearshore restoration activities? Does backshore vegetation respond favorably to transplanting from nearby sources or planting from nursery stock? What observations have others made about natural recruitment of backshore species following beach restoration activities or disturbances?

Discussion: Although I investigated a very small number of revegetation efforts, my communications suggest that it is relatively easy to re-establish certain vegetation through planting and that other pioneer species will self-recruit if they are in the area. Initial findings suggest excellent promise for restoration and revegetation projects.

The projects I investigated all involved transplanting species from healthy intact patches of vegetation nearby. While this might increase transplant success by using plants adapted to the specific conditions to the local area, transplanting should be undertaken selectively and ethically in order to not cause long-term harm to or significant reduction of the existing vegetation.

Many species of backshore vegetation can be procured from native plant nurseries, and evidence shows that some can be easily propagated. Smayda Environmental Associates, Inc. and Sound Native Plants, Inc. are some of the few firms in the region that I could locate that are taking revegetation of backshore restoration projects seriously; most projects focus on the engineering and construction components and trust that revegetation will take care of itself. Smayda Environmental Associates is committed to monitoring, maintaining by early hand weeding to reduce competition from opportunistic invasive species, and experimenting with propagation techniques. The firm is currently planning future backshore restoration and revegetation projects, and its monitoring data will help inform future projects regarding the potential for all options for replanting, including re-seeding from existing seed heads (versus disrupting healthy stands of vegetation).

Based on my observations and literature review, I would recommend that ecological restoration professionals plan to incorporate buried wood and stumps into their projects whenever possible. For whatever reasons, the plants in natural settings take advantage of chunks of wood to support themselves, and in some cases, where revegetation projects occur very close to MHHW, the addition of buried wood might elevate the plants enough to get established. This point is supported by Hood's (2008) findings, as well as potentially by Ms. Heath's reports of her healthy vegetation in relation to decomposing stumps.

However, restoration professionals should be considerate about sources for wood when undertaking revegetation projects along the shoreline, as the work done by Tonnes (2008) reinforces the importance of not disturbing accumulations of wood on shorelines. Rather, restoration professionals should look to abundant upland sources of cast-off wood from logging and land-clearing operations that would likely dispose of the wood by burning slash piles.

5.6 Anthropogenic Effects and Socio-political Implications

Original study questions: What ecological services does backshore vegetation provide to the nearshore that could be lost as a result of human activities, both public and private, along the shoreline? What human activities are observed that impact the habitat and success of backshore vegetation?

Discussion: Left in their natural state, the supratidal zone and backshore vegetation provide many ecological services, including natural buffering from the

impacts of storm events and even sea-level rise; support of several food webs between the uplands and the marine environment; nutrient and energy cycling and exchanges on both the landward and seaward side; and—likely—sequestration of enormous quantities of carbon associated with below-ground roots and fungal associations.

The literature cited in Section 2 discusses the many impacts and disruptions to natural systems associated with human intrusion and disturbances in the backshore zone. Among these are serious impacts on sediment transport and food webs, and eliminating the natural functions of estuaries or salt marshes by filling and diking to take advantage of the high storm berm as a basis for development.

Gabriel and Terich (2005) point out that the rate of installation of hard armoring systems rose from 4 percent to 83 percent between 1953 and 1998 in one section of south Puget Sound, and from 15 percent to 80 percent in another section from 1965 to 1998. Currently, over one-third of Puget Sound's total shoreline is armored (with a greater proportion in the parts of the Sound that lack rocky shorelines and are thus most dependent on natural sediment-transport processes to maintain beaches and ecosystems). Dugan et al. (2008) assert that with sea-level rise, more shoreline landowners are expected to construct seawalls, with cascading effects to the supratidal zone especially.

Interestingly, in Gabriel and Terich's (2005) profiles of shoreline property owners, they found a correlation between properties with hard armoring and properties with damage to the backshores from modifications for recreational or

storage purposes. Gabriel and Terich pose the possibility that once landowners develop their backshores for recreational and storage uses, they have a stronger motivation to construct bulkheads to protect those modifications.

Gabriel and Terich (2005) also report that clearing both upland and slope native vegetation is more often associated with landowners employing hard armoring, despite these landowners self reporting at high rates (40 percent) that they had left “natural” vegetation as an erosion-control strategy. Rather than native vegetation and mature trees, which support the nearshore ecosystem in numerous ways and reduce erosion, these homes were more likely to have replaced native vegetation with lawns and gardens.

In addition to the threat to the backshore from hard armoring, development continues to occur in the backshore, as evidenced by sites I visited with new construction surrounded by backshore vegetation (and often compounded by the construction of new armoring). Tonnes (2008) reported that one-third of his study area had been filled and armored to allow residential development. Tonnes cites rapid alterations to the natural shoreline in his study area: Between 1977 and 2007, beachfront homes increased from 5 to 108, and bluff-top homes rose from 5 to 85.

Construction fragments the backshore and eliminates natural exchanges between the uplands and the marine environment. Construction brings unwanted inputs close to the marine environment, including non-point source-pollution from vehicles, pets, lawn chemicals, and septic systems. Moreover, lawns are a source for invasive species to colonize in the backshore, as I observed many lawn grasses and

dumping of yard trimmings—with the potential for introducing invasive seeds and rhizomes—on backshore sites. Feagin et al. (2005) echo this concern and note that non-native lawn grasses present a barrier that blocks the potential landward expansion of the backshore vegetation, a point of particular concern with expected sea-level rise.

My study suggests an additional concern about human interference in the backshore: The backshore areas most likely to be disturbed by humans are the widest ones. Wider backshores allow more space for road building, home building, storage, anchoring docks, and recreational activities such as ball games and driving off-road vehicles. My findings suggest that wider, undisturbed backshores support more species richness and diversity, and that the uncommon backshore associates I identified as “restricted species” are dependent on wider backshores. This raises concerns about the impact to species diversity of the wider backshores particularly at risk from human encroachment, as human development may convert high-diversity wide backshores to lower-diversity narrow backshores.

There are many socio-political considerations inherent in this discussion of human impacts. Clearly, the greatest threats to the backshore come from those living along the shorelines:

- (1) Hard armoring anywhere along the drift cell cuts off sediment supply, narrows the beach, and lowers the beach profile, so even armored shorelines in areas without existing backshore zones impact backshores downdrift of them.

- (2) Filling, diking, and building over time reduce the backshore, and bring unwanted inputs of pollution and invasive species.
- (3) Fragmentation interrupts natural materials, nutrient, and energy exchanges between the backshore, the salt marsh, the uplands, and ultimately the intertidal zone.
- (4) Wider backshores are more likely to be disturbed, with potentially larger consequences to habitat, biomass production, and carbon sequestration, both above and below ground.
- (5) Shoreline landowners alter the functions of the backshore by removing vegetation and drift logs and replacing them with storage sites, recreation equipment, and even invasive, monoculture lawns.

If we are to address restoration of Puget Sound decisively and cohesively, we must be willing to recognize the serious impacts to the entire system that result from a few landowners' choices.

Further inherent in this discussion is the matter of public access to Puget Sound. Although the Sound itself is a public resource, and citizens' rights "to enjoy the physical and aesthetic qualities of natural shorelines of the state ... with the overall best interest of the state and the people generally" are guaranteed in the Washington Shoreline Management Act (1971), access to it is made difficult because so many shorelines and beaches are in private ownership. Thus, the few places that most citizens of Puget Sound have to access the shoreline are public parks, whose numbers have not kept pace with Puget Sound's burgeoning population. These parks

are some of the few places citizens have to interact with the natural wonders of Puget Sound, including the beautiful and intriguing backshore vegetation. While we can be justifiably concerned about potential trampling of this vegetation by those using the public resources, we might be more concerned about the limited availability of access points such that trampling in these limited public options is more likely. Without access to observe the unique plants and animals native to the ecosystem, citizens will not cultivate an appreciation for these organisms and the systems on which they depend, and will have no context in which to support a call to protect the overall ecosystem for the good of all.

Feagin et al. present this same question of public good vs. private land-use practices in coastal Texas, particularly in light of expected sea-level rise: “A small increase in sea-level rise can result in a large amount of coastal erosion. It may soon be necessary to reassess the importance of sand dune plant communities, in the same way that coastal wetlands were re-evaluated by the last generation of coastal zone statutes and laws. As it is our duty to maintain these coastal plant communities alongside our private developments and shoreline protection structures, we must publicly consider the impacts of squeezing the sand dune plant habitat between the land and the sea” (p. 363).

As policy makers, planners, and others engaged in the protection of Puget Sound grapple with the same question, we would be wise to consider the other parts of the Shoreline Management Act and ensure that in addition to public access, we remember to protect shoreline natural resources, including “... the land and its

vegetation and wildlife, and the waters of the state and their aquatic life” (Shoreline Management Act of 1971).

SECTION 6: STUDY CONSTRAINTS & FURTHER STUDY/MANAGEMENT RECOMMENDATIONS

My study begins the process of characterizing the species and understanding the role of backshore vegetation in the broader Puget Sound ecosystem, but it was very limited in scope. I recognize various constraints that might impact my findings, and suggest areas for other researchers to consider in expanding our understanding further.

6.1 Site Number and Location

I was limited in time and resources, and thus unable to visit as many shorelines as I would have liked in as many geographic locations as I would have liked. Access was a significant challenge: Car access proved very limiting, since most sites were only accessible via private property, including, often, private roads. Further, I found few options for renting a boat beyond South Sound, as well as finding field assistants who could dedicate a day to both assisting me and driving the boat. Finding the boat and the field assistants available on the same day was a greater challenge.

6.2 Seasonal Influences

I also observed most sites only once. Although my original intention was to choose a small number of sites and survey them throughout the year, after early reconnaissance investigations I modified my approach to attempt to see as many sites

as possible over as broad a geographic area as possible to get a beginning picture of the structure of this vegetative community.

Therefore, many species that may only be present for a short time on a given shoreline may well have been missed depending on the timing of my surveys. For instance, I found *Plectritis congesta* and *Viola adunca* on an Island County beach that I was able to visit twice; during my first trip to the site in the fall, these species were entirely absent, but were plentiful in the spring. Although this may seem a minor point since I was able to identify the likely predominant species associated with the backshore vegetative community, the entire picture of the community is reduced. Moreover, some of the species I may have missed may also have important ecosystem associations. For example, both the *Plectritis congesta* and the *Viola adunca* are important associates for three species of rare or listed butterflies in the Puget Sound region (Pyle 2002; E. Delvin, The Nature Conservancy, personal communication, 2009).

Similarly, when surveying in early spring, percent cover for species just emerging from dormancy was much reduced from the cover I would have observed in summer or fall, and some species may not have broken dormancy yet. Although the Braun-Blanquet scale likely has wide enough ranges to mitigate for the first concern, I can only wonder what species I missed due to seasonality.

Future coordinated studies could survey specific stretches of shoreline multiple times throughout the year, with several investigators focusing on different geographic areas throughout the region.

6.3 “Restricted” Species Requirements

An additional question that arose as a result of my study was: What factors are necessary for the “restricted” species to be present? With the exception of a solitary *Convolvulus soldanella* found on a beach in Thurston County, all the species I defined as restricted were limited to Island and Kitsap County beaches, highly correlated with sandy substrates on wide backshores. I also encountered sandy, wide backshores in Mason, Thurston, and Pierce counties, so those clearly aren’t sufficient to define the niche or niches for these intriguing species. Future studies on the requirements of these specific plants would provide more understanding of the backshore vegetative community as a whole.

6.4 Plant-animal Interactions

I was unable to find any study that specifically focused on interactions between the plants of the backshore and specific animals. Our knowledge of likely interactions comes from studies where the backshore and/or its vegetation are on the periphery of the research questions. A study of plant-animal interactions in this zone would be a significant contribution to our understanding of this ecotone.

6.5 Importance of Drift Logs

I noticed too late in my study the relationship between drift log placement and the first appearance of backshore vegetation, and Tonnes’ work (2008) was not yet

available for me to have been prompted to consider that question when drafting my own study plan. It is not always a straightforward relationship to observe, as the distribution and deposition of drift logs on many backshore sites is complex and sometimes overwhelming. A future study could look at this question more closely to clarify the relationship.

Tonnes' (2008) investigations of the role of driftwood accumulation in supporting the backshore and marine riparian ecosystems further support the need to retain and restore these areas that have been modified for road building and housing development.

6.6 Buried Wood

One of the most interesting and substantial findings of my study was the observation of wood deep in the substrate, and the plants' obvious use of it. A future study could examine this more closely to see how and if this functions in the ecosystem to support and anchor plants, including mycorrhizal and other fungal associations, as well as other possible functions.

6.7 Questions for Restoration Potential

If studies show mycorrhizal associations between backshore species and buried wood, additional research could be undertaken to determine if backshore restoration efforts or plant nursery success rates for backshore species could be improved by

inoculation with appropriate mycorrhizae. Moreover, early experiments in restoring backshores show that more study is needed to assess the potential for direct seeding from nearby backshore vegetation, including what factors are necessary to maximize survival rate and at what rate seeds can be ethically collected from intact patches of vegetation. Following on work by Maun and others, field experiments could also be undertaken to determine the extent to which burial increases survival rates on revegetation project, which species are most successful, and what the optimal burial depth is for different species.

6.8 Anthropogenic Impacts

There are many questions regarding the impact of human activities in the backshore and how these impacts translate into disruptions in the broader scope of habitat and natural processes. A study or studies to evaluate some of the impacts to the backshore ecosystem, including the vegetation, might shed light on the need for management recommendations to limit activities that are clearly impacting the natural functions.

Literature Cited

- Brais, S., F. Sadi, Y. Bergeron, and Y. Grenier. 2005. Coarse woody debris dynamics in a post-fire jack pine chronosequence and its relation with site productivity. *Forest Ecology and Management*, 220 (2205) 216-226.
- Brennan, J.S. 2007. Marine riparian vegetation communities of Puget Sound. Puget Sound Nearshore Partnership Report No. 2007-02. Published by Seattle District, U.S. Army Corps of Engineers, Seattle, WA. Available at www.pugetsoundnearshore.org.
- Casper, B. and R.B. Jackson. Plant competition underground. 1997. *Annual Review of Ecology and Systematics* 28:545–70.
- Clesceri, L.S., A.E. Greenberg, and A.D. Eaton. 1998. Standard Methods for Examination of Water and Wastewater. American Public Health Association.
- Downing, J. 1983. *The Coast of Puget Sound: Its Processes and Development*. Washington Sea Grant, University of Washington Press: Seattle, WA.
- Dugan, J.E., D. Hubbard, I.F. Rodil, D.L. Revell, and S. Schroeter. 2008. Ecological effects of coastal armoring on sandy beaches. *Marine Ecology* 29:160-170.
- Feagin, R.A., D.J. Sherman, and W.E. Grant. 2005. Coastal erosion, global sea-level rise, and the loss of sand dune plant habitats. *Frontiers in Ecology and the Environment* 3(7): 359–364.
- Finlayson, D. 2006. The geomorphology of Puget Sound beaches. Puget Sound Nearshore Partnership Report No. 2006-02. Published by Washington Sea Grant Program, University of Washington, Seattle, WA. Available at <http://pugetsoundnearshore.org>.
- Gabriel, A.O. and T.A. Terich. May 2005. Cumulative patterns and controls of seawall construction, Thurston County, Washington. *Journal of Coastal Research* 21-3: 430-440.
- Gelfenbaum, G., T. Mumford, J. Brennan, H. Case, M. Dethier, K. Fresh, F. Goetz, M. van Heeswijk, T.M. Leschine, M. Logsdon, D. Myers, J. Newton, H. Shipman, C.A. Simenstad, C. Tanner, and D. Woodson. 2006. Coastal habitats in Puget Sound: a research plan in support of the Puget Sound Nearshore Partnership. Puget Sound Nearshore Partnership Report No. 2006-1. Published by the U.S. Geological Survey, Seattle, Washington. Available at <http://pugetsoundnearshore.org>.

- Goetz, F., C. Tanner, C.A. Simenstad, K. Fresh, T. Mumford, and N. Logsdon. December 2004. Guiding restoration principles. Puget Sound Nearshore Partnership Technical Report No. 2004-03. Published by Washington Sea Grant Program, University of Washington, Seattle, WA.
- Gonor, J.J., J.R. Sedell, and P.A. Benner. 1988. What we know about large trees in estuaries, in the sea, and on coastal beaches (chapter 4), in: From the forest to the sea: a story of fallen trees. Maser, C., R.F. Tarrant, J.M. Trappe, and J.F. Franklin, eds. General Technical Report PNW-GTR-229.
- Hart Crowser, Inc.; Washington Department of Ecology; U.S. Environmental Protection Agency; and Puget Sound Partnership. October 2007. Phase 1: Initial estimate of toxic chemical loadings to Puget Sound. Ecology Publication Number 07-10-079. Olympia, WA.
- Hitchcock, L.C. and A. Cronquist. 1973. *Flora of the Pacific Northwest: An Illustrated Manual*. University of Washington Press: Seattle, WA.
- Hood, W.G. 2007. Large woody debris influences vegetation zonation in an oligohaline tidal marsh. *Estuaries and Coasts* 30 (3):441–450.
- Ievinsh, G. 2006. Biological basis of biological diversity: physiological adaptations of plants to heterogeneous habitats along a sea coast. *Biology* 710:53-79.
- Johannessen, J. and A. MacLennan. 2007. Beaches and bluffs of Puget Sound. Puget Sound Nearshore Partnership Report No. 2007-04. Published by Seattle District, U.S. Army Corps of Engineers, Seattle, WA.
- Kozloff, E. 1993. *Seashore Life of the Northern Pacific Coast: an illustrated guide to northern California, Oregon, Washington, and British Columbia*. University of Washington Press: Seattle, WA.
- Kruckeberg, A.R. 1991. *The Natural History of Puget Sound Country*. University of Washington Press: Seattle, WA.
- Leschine, T.M., and A.W. Petersen. 2007. Valuing Puget Sound's Valued Ecosystem Components. Puget Sound Nearshore Partnership Report No. 2007-07. Published by Seattle District, U.S. Army Corps of Engineers, Seattle, WA. Available at www.pugetsoundnearshore.org.
- Maun, M.A. and A.M. Payne. 1989. Fruit and seed polymorphism and its relation to seedling growth in the genus *Cakile*. *Canadian Journal of Botany* 67:2743-2750.

- Maun, M.A. 1994. Adaptations enhancing survival and establishment of seedlings on coastal dune systems. *Vegetatio* 111(1):59-70.
- McCune, B., J.B. Grace, and D.L. Urban. 2002. *Analysis of Ecological Communities*. MjM Software Design: Gleneden Beach, OR.
- McLachlan, A. and A. Brown. 2006. *The Ecology of Sandy Shores*. 2nd ed. Elsevier: Amsterdam.
- Mueller-Dombois, Dieter and Heinz Ellenberg. 1974. *Aims and Methods of Vegetation Ecology*. John Wiley & Sons: New York.
- National Park Service. Comprehensive plan for Ebey's Landing National Historical Reserve Washington. May 1980 (Reprinted January 1984). Ebey's Landing National Historical Reserve Planning Committee, Coupeville Planning Department, Island County Planning Department, & Pacific Northwest Region, National Park Service. Pacific Northwest Region, Seattle, WA.
- Penttila, D.E. 1995. The Fish and Wildlife's Puget Sound intertidal baitfish spawning beach survey project. In: Puget Sound Research-95 Conference Proceeding, Vol. 1:235-245. Puget Sound Water Quality Authority, WA.
- Perumal, J.V. and M.A. Maun. 1999. The role of mycorrhizal fungi in growth enhancement of dune plants following burial in sand. *Functional Ecology* 13:560-566.
- Pojar, J. and A. MacKinnon. 1994. *Plants of the Pacific Northwest Coast: Washington, Oregon, British Columbia, and Alaska*. Lone Pine Press: Renton, WA.
- Polis, G.A. and S.D. Hurd. 1996. Linking marine and terrestrial food webs: Allochthonous input from the ocean supports high secondary productivity on small islands and coastal land communities. *American Naturalist* 147:396-423.
- Puget Sound Action Team. 2007. State of the Sound 2007. Office of the Governor, Olympia, WA. Publication No. PSAT 07-01.
- Pyle, R.M. 2002. *The Butterflies of Cascadia*. Seattle Audubon Society: Seattle, WA.
- Romanuk, T. N. and C.D. Levings. 2003. Associations between arthropods and The supralittoral ecotone: dependence of aquatic and terrestrial taxa on riparian vegetation. *Environmental Entomology* 32(6): 1343-1353.

- Shipman, H. 2008. A geomorphic classification of Puget Sound nearshore landforms. Puget Sound Nearshore Partnership Report No. 2008-01 Seattle District, U.S. Army Corps of Engineers, Seattle, WA. Available at www.pugetsoundnearshore.org.
- Smith, S.E. and D. J. Read. 1997. *Mycorrhizal Symbiosis* 2nd edition. Academic Press: San Diego.
- Sobocinski, K.L., J.R. Cordell, C.A. Simenstad, and J. Brennan. 2003. Results from a paired sampling regime. 2003 Georgia Basin/Puget Sound Research Conference, Vancouver, BC.
- Tonnes, Daniel M. 2008. Ecological functions of marine riparian areas and driftwood along north Puget Sound shorelines. Master's Thesis, University of Washington.
- Tsang, A. and M.A. Maun. 1999. Mycorrhizal fungi increase salt tolerance of *Strophostyles helvola* in coastal foredunes. *Plant Ecology* 144:159-166.
- Tuininga, A.R. 1995. Interactions between Western Hemlock mycorrhizal fungi and wood rotting fungi in a system simulating Douglas-fir nurse logs in Pacific Northwest forests. Master's of Science Thesis, Oregon State University. Additional authors for some sections: Jeffrey K. Stone, Paul T. Rygielwicz, and Mark E. Harmon.
- Washington State. 1971. Shoreline Management Act of 1971. RCW 90.58.
- Zelo, Ian, H. Shipman, and J. Brennan. 2000. Alternative Bank Protection Methods for Puget Sound Shorelines, prepared for the Shorelands and Environmental Assistance Program, Washington Department of Ecology, Olympia, WA, Publication # 00-06-012.
- Zhang, J. and M.A. Maun. 1992. Effects of burial in sand on the growth and reproduction of *Cakile edentula*. *Ecography* 15:296-302.

Appendix: Photographs of Selected Backshore Profiles, Species, Substrates and Land Uses

Photos by Erica S. Guttman unless otherwise noted

Part 1: Backshore Profiles & Vegetation



Profile of backshore. Note seaward-most vegetation, *Cakile* spp., with *Elmus mollis* behind, above larger drift logs.



Cakile sp., one of the pioneering species with high tolerance for exposure at the most seaward edge of the backshore vegetation.



Backshore in winter. Note first line of drift logs provide opportunity for colonization by species such as *Ambrosia* and *Cakile*, and *Elymus* is colonizing behind the second line of larger logs.



Typical backshore berm with salt marsh on landward side. Plants on berm include *Cakile*, *Elymus*, *Ambrosia*; visible salt marsh species are *Salicornia*, *Jaumea*, *Distichlis*.



Narrow band of backshore vegetation adjacent to upland. Note *Cakile*, *Honkenya*, and *Elymus* in foreground; upland species such as *Thuja plicata* behind.



Atop this narrow backshore, *Atriplex patula* takes root in gravelly substrates.



On a wide, sandy backshore, mixed patches of *Ambrosia chamissonis* and *Carex macrocephala* occupy the most landward side of the berm.



Carex macrocephala: predominantly female plants on left, close up of male on right.



Ambrosia flower.

Mary Jo Adams photo.



Foliage (left) and flower (right) of *Cakile* sp.



Elymus mollis (left) dominates this backshore with occasional patches of *Grindelia integrifolia*. Above, a lady beetle alights on a blade of *Elymus*.



A robust patch of *Grindelia integrifolia* (left) and a single flower attracting a pollinator (above).



A cluster of *Honkenya peploides* colonizes sandy substrates on the seaward side of this backshore berm.



The woody *Polygonum paronychia* forms a prostrate mat in the landward sections of this wide, sandy backshore.



The beach carrot, *Glehnia littoralis*, finds a niche amongst the wood of this wide, sandy backshore (above left). In autumn, the seeds can be seen “mulching” the top of the parent plant (above). The flowers are best appreciated up close (right; flower photo courtesy of Mary Jo Adams).



Abronia latifolia forms large mats in this wide, sandy backshore. Above, note its widespread, deep, root system and spreading rhizomes.



Part 2: Substrates



In addition to sandy substrates, backshore vegetation is found in shell hash/pebbles (above, left), mixed sand/pebbles (left), sand with gravel/pebble veneer (above, right), and at least one site with large cobbles and wood chunks (below, left).



Part 3: Selected observed land uses



Fragmentation: This backshore (above) has been recently bisected by a paved trail. Healthy, vigorous vegetation still remains along both sides of the trail. In the backshore below, years-old fill and a road bisected the backshore; now invasive species such as *Cytisus scoparius* outcompete the backshore species.





Construction: These new condominiums and associated bulkheads (above) were built on top of this well vegetated backshore berm. Below, backshore vegetation flourishes between houses lining the shoreline.





New homes and armoring were placed on this backshore berm amidst vegetation and large drift logs.



A volleyball court featuring backshore vegetation is flanked by illegal yard-waste debris dumping grounds on the seaward side of this sandy backshore.

