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ASSESSING THE EXTENT AND POTENTIAL FOR FURTHER INVASION OF *SPARTINA ANGLICA* INTO PUGET SOUND SALT MARSHES AND MUDFLATS

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WASHINGTON STATE DEPARTMENT OF ECOLOGY

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If you have special accomodation needs, please contact Linda Smith, Department of Ecology, at (360)428-1558 or (360)757-1549 (TDD).

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Assessing the Extent and Potential for Further Invasion of *Spartina anglica* into Puget Sound Salt Marshes and Mudflats

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Introduction

The invasion of *Spartina* species into Puget Sound and elsewhere in Washington state, is a matter of great concern throughout the region, and has prompted a state-wide eradication effort to rid the state's beaches, tideflats, and salt marshes of the non-native plant. Although these efforts are already in full swing, little is actually known about the preferred physical environment for these species in Puget Sound, or their effect on the species diversity of native marshes.

This study is an effort to improve on the basic knowledge of *Spartina anglica* and its invasion into Puget Sound. This is accomplished through three tasks: identifying the pattern of the invasion into Puget Sound and mapping its extent, identifying soil characteristics at a variety of infested sites, and documenting the native plant species diversity at those sites. The information and data resulting from this study will be useful in determining specific biological and physical characteristics of infested and eradicated sites, as well as in directing future investigations of *S. anglica* and its effects on native marshes.

Local History

Spartina anglica C.E. Hubbard was first "created" in England in the early 1900's through a natural hybridization of *Spartina maritima* and *Spartina alterniflora*. The sterile hybrid, originally named *Spartina townsendii*, then underwent a chromosome doubling event, termed allopolyploidy, resulting in a fertile new species (Thompson, 1991). In 1961, *S. anglica* was first introduced into the Puget Sound to provide forage for dairy cattle (Parker and Aberle, 1979; Frenkel and Kunze, 1984). It was later transplanted in other areas for use in stabilizing berms and banks.

The initial introduction occurred in Port Susan Bay a few miles south of Stanwood, Washington (Parker and Aberle, 1979; Frenkel and Kunze, 1984). Though this population eventually died out, it provided the seeds that were responsible for the ensuing invasion of many mud flats and salt marshes in the region. The invasion spread quickly through local marshes, bays and inlets of Port Susan Bay, and moved north into Skagit and Padilla Bays, and south through Possession Sound, Puget Sound, and the northern reaches of Colvos Passage. At this time, the population has not been found in the most southern reaches of Puget Sound.

Great effort has been exerted by various Washington State agencies to control the spread of the invasion of all *Spartina* species, and they have been successful to a point. Through the use of several eradication methods (including mowing, burning, and spraying with a herbicide), the state has been able to control and oftentimes eliminate *S. anglica* infestations of less than 5 acres. However, they have had little success controlling larger infestations.

Physical Characteristics

As a result of its unique genetic history, *S. anglica* has an exceptional ability to invade and dominate mudflats and existing salt marshes. In England, the invading *S. anglica* has taken over approximately 25,000 acres of intertidal salt marsh on the coast in a little over 100 years (Thompson, 1991). *S. anglica* also has the ability to colonize areas that neither of its parental species are able to penetrate, and it has been suggested that the plant is unique among the species in its ability to colonize "empty niches" and transform them into salt marshes (Stapf, 1908; Ranwell, 1972; Thompson, 1991).

Populations of *S. anglica* spread through floating seeds and rhizome fragments that travel with the tides and colonize new sites (Thompson, 1991). At these sites, small tussocks form from the seeds and rhizomes and then expand fairly rapidly via radial vegetative growth. This growth results in the formation of circular clumps, commonly called clones, which eventually coalesce into large meadows.

S. anglica is a fairly large plant with stout stems and a dense rhizomatous root system. As a result, water flow around its base is slowed. This causes sediment deposition at the base of the plant, and over time, large volumes of tidal sediment can be accreted around the plant. Accretion rates range from approximately 2-10 cm per year in English salt marshes, and sediments close to a meter thick have been found at fifty year old invasion sites (Thompson, 1991). This extreme accretion rate helps to completely transform open mud flats into marshes very rapidly.

The plant is found in a vast array of habitats throughout Puget Sound, growing in virtually every intertidal environment available, from lower sand and mud flats, to higher salt marshes, and even high on cobble and sandy beaches (Riordan, unpublished observations). However, surprisingly little is known about the preferred ecological and physical conditions of *S. anglica* in north Puget Sound. In this study, several measurements of soil characteristics of invaded sites were made to describe any patterns that do exist. Estimates of the size and location of each infestation throughout the Puget Sound were also made, and at selected sites data on infestation density as well as native plant representation were gathered.

Methods

Invasion Mapping

The Washington State Department of Agriculture (WSDA) is coordinating the eradication efforts throughout the state, with the help of several other state agencies, local county weed boards, and volunteer groups. These include: the Department of Ecology, the Department of Natural Resources, the Department of Fish and Wildlife, Adopt-A-Beach, and Washington Water Trails. Current information regarding the distribution and abundance of *S. anglica* within Puget Sound was obtained from these groups (Gohrman et al., 1998; Riggs, 1997; Rogers, 1998; Wirth, 1997). This information consisted primarily of beach surveys and eradication reports, which included the locations of *S. anglica* infestations along with estimates of the total acreage affected at each site.

Using this information as a guide, reconnaissance visits throughout the Sound were made to verify the information and explore other sites where invasion was considered likely. At each site, visual estimates of the amount of acreage affected were made. From this information, a map and tables were created showing the current spread of infestation (Figure 1 and Appendix 1). These figures included data on the total acreage containing *Spartina anglica* and the recent eradication efforts at each site.

Field Sampling

Study Areas

Based on the information obtained from the various state agencies and follow-up reconnaissance visits, ten sites of infestation were selected for finer-detailed field measurements. These sites represented a wide array of infestation degree and substratum type, as well as a range of locations throughout northern Puget Sound. The ten sites included: Ala Spit, Dugualla Bay, Hancock Lake, Kennedy's Lagoon, and Cultus Bay (on Whidbey Island),

Figure 1

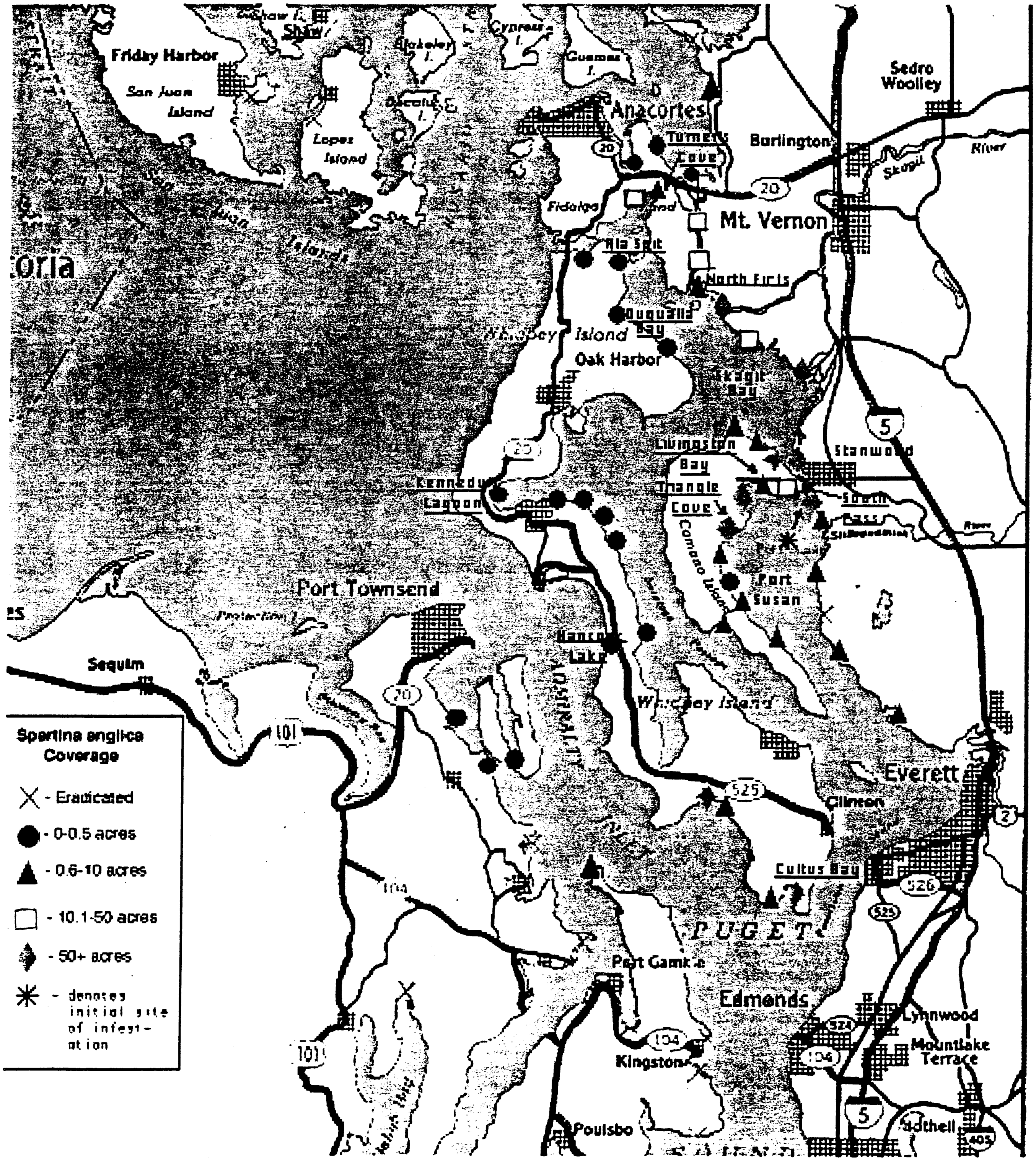

Figure 1. Sites of nonindigenous Spartina anglica infestation in northern Puget Sound. Study sites are indicated as underlined.

Turner's Cove and northern Fir Island (in Skagit County), South Pass (in northern Port Susan), and East Livingston Bay and Triangle Cove (on Camano Island) (Figure 1 & Table 1).

Data Collection

At each of the selected sites, data on *Spartina anglica* coverage and tiller density, native plant representation (% cover per m^2), soil salinity, redox potential, soil moisture, water potential, clone diameter (where present), and the maximum height of sampled clones were gathered. Soil samples were also collected for further analysis in the laboratory.

To measure tiller density and native plant representation, fifty 0.25 m^2 quadrats were haphazardly placed throughout the intertidal zone of each site. The number of *S. anglica* tillers in each quadrat was recorded as well as the percent cover of all plants in the quadrat.

At each site, ten plots containing *S. anglica* were sampled. At each of these plots, two soil samples were collected, one from within the *S. anglica* infestation and one from an uninfested area in close proximity. Salinity was measured by squeezing the water out of a small soil sample through cheesecloth and onto a Leica salinity refractometer.

The redox potential, a determination of oxygen content, was measured using a redox meter fitted with a platinum redox electrode and filled with AgCl solution. Ten measurements of redox potential were also collected from both areas of infestation and uninfested areas at each site in the same manner as the salinity measurements. At each of the plots with *S. anglica* present, the diameter and maximum height of the clone was measured.

Soil moisture and water potential were measured in the laboratory from the twenty soil samples collected at each site. These samples were frozen within a few hours of collection until further analysis in the laboratory could be done. Soil moisture was determined by weighing each sample before and after drying. Water potential, a measurement of the free energy of water to move into plant roots, was determined using a Tru-Psi soil psychrometer.

Calculations

Statistical analysis of the collected data was performed with the Analysis ToolPak included in the 1998 Microsoft Excel spreadsheet program. Analyses were made using the two sample student's t-test, assuming equal variances. A 0.05 level of significance was used on all tests.

Results

Invasion Mapping

The existing infestation of *Spartina anglica* in northern Puget Sound extends from northern Padilla Bay south to the southern tip of Whidbey Island, and west to the northeastern tip of the Olympic Peninsula. Figure 1 shows clearly that the pattern of infestation is centered around Port Susan Bay, the site of the original planting. The largest infestations are found in this area and the infestation sizes generally decrease as their distance from Stanwood increases.

At one time there were small infestations as far south as Vashon Island in southern King County. However these infestations were quite small and have been completely eradicated. No infestations have been found in southern Puget Sound or the southern reaches of Hood Canal.

Field Sampling

Sites were designated as either marsh sites or mud flat sites. Marsh sites are sites that contained salt marsh communities before invasion, and were never pure mud flats. Mud flat sites were pure mud flats before invasion with no salt marsh present.

At most sites salinity was significantly higher in areas without *S. anglica* than in areas where it was present. Among the marsh sites, this significant difference was found at 3 of the 5 sites, while among the mud flat sites, 5 of the 9 sites showed a significant difference ($p< 0.05$, t-test) (Table 1 & Figure 2).

Areas without *S. anglica* were generally devoid of all vegetation either because it was the natural state, or due to eradication efforts, where *S. anglica* had been sprayed and/or cut. In those areas that had been cut, salinity was also significantly higher where the cut thatch was removed (either manually or by the tides) than in areas where the thatch remained ($p< 0.05$, t-test) (Table 1 & Figure 2).

Redox measurements were also significantly different between areas with *S. anglica*, and those without it. The redox potential was more negative in

Table 1. Soil characteristics of infested site in Puget Sound, WA. Measurements were taken at roots of *Spartina anglica* (Spartina), areas without *S. anglica* (No Spartina), areas without *S. anglica* due to eradication but with thatch cover (Cut/Cover), and areas without *S. anglica* or thatch due to eradication (Cut/No Cover). NP= Not Present. At sites where two sets of measurements were gathered, the sets were differeniated between high in the intertidal zone and low in the intertidal zone, and are indicated as either high or low.

Site Name and Type	Salinity (ppt)	Salinity (ppt)	Redox (mV)	Redox (mV)	Water Potential	Water Potential	Soil Moisture(%)	Soil Moisture(%)
Mud Flat	With Spartina	No Spartina	With Spartina	No Spartina	With Spartina	No Spartina	With Spartina	No Spartina
Livingston Bay- High	41.4 +/- 1.9	45.7 +/- 3.1	-92 +/- 14	-161 +/- 20	-24.4 +/- 0.3	-27.0 +/- 0.6	36.4 +/- 1.2	34.0 +/- 1.4
Livingston Bay- Low	34.3 +/- 0.6	33.9 +/- 0.9	-91 +/- 19	-95 +/- 8	-22.5 +/- 0.2	-21.5 +/- 0.2	34.5 +/- 1.0	33.1 +/- 0.7
Dugualla Bay	31.8 +/- 0.7	38.0 +/- 2.1	-49 +/- 34	-100 +/- 33	-24.2 +/- 6.2	-23.1 +/- 7.9	38.9 +/- 3.4	40.7 +/- 3.7
Kennedy's Lagoon	33.0 +/- 0.7	39.5 +/- 1.8	30 +/- 16	-34 +/-30	-21.6 +/- 0.6	-23.6 +/- 0.9	59.5 +/- 4.6	52.1 +/- 6.4
Ala Spit	35.8 +/- 0.7	37.8 +/- 1.3	-57 +/- 41	-63.9 +/- 41	-10.4 +/- 1.6	-17.3 +/- 0.6	44.2 +/- 6.0	45.9 +/- 6.5
North Fir Island- Low	19.4 +/- 0.7	18.3 +/- 1.2	22 +/- 17	26 +/- 12	-8.3 +/- 0.9	-9.2 +/- 1.2	25.0 +/- 0.7	21.6 +/- 0.5
Cultus Bay- Low	33.0 +/- 0.6	36.8 +/- 1.2	-107 +/- 53	-180 +/- 44	-14.5 +/- 3.0	-25.0 +/- 0.6	38.0 +/- 2.9	32.1 +/- 1.6
Triangle Cove-High	33.8 +/- 0.4	NP	-125 +/- 42	NP	-11.9 +/- 2.1	NP	56.9 +/- 1.9	NP
Triangle Cove- Low	34.7 +/- 0.9	NP	-287 +/- 14	NP	-15.7 +/- 0.8	NP	56.2 +/- 1.1	NP
Marsh	With Spartina	No Spartina	With Spartina	No Spartina	With Spartina	No Spartina	With Spartina	No Spartina
Similk Bay	38.1 +/- 1.1	42.3 +/- 1.6	-133 +/- 27	-233 +/- 33	-18.4 +/- 1.8	-22.1 +/- 1.5	69.5 +/- 0.7	67.1 +/- 1.8
Hancock Lake	33.3 +/- 0.9	37.3 +/- 0.7	2 +/- 33	-100 +/- 40	-19.4 +/- 1.4	-23.5 +/- 0.7	47.1 +/- 4.7	44.0 +/- 4.3
North Fir Island- High	17.8 +/- 0.2	17.0 +/- 0.6	-200 +/- 37	-158 +/- 37	-4.0 +/- 0.9	-8.9 +/- 1.3	55.3 +/- 0.8	53.9 +/- 1.4
Cultus Bay- High	33.6 +/- 0.3	35.3 +/- 0.6	-155 +/- 40	-254 +/- 30	-21.8 +/- 1.3	-14.4 +/- 2.3	63.2 +/- 2.5	61.3 +/- 1.8
South Pass	32.5 +/- 1.6	32.5 +/- 1.4	-79 +/- 42	-82 +/- 36	-17.4 +/- 0.7	-17.7 +/- 0.6	42.2 +/- 0.9	42.5 +/- 0.8
Mud Flat	Cut/Cover	Cut/No Cover	Cut/Cover	Cut/No Cover	Cut/Cover	Cut/No Cover	Cut/Cover	Cut/No Cover
Triangle Cove- High	34.3 +/- 0.5	37.6 +/- 1.0	-287 +/- 16	-337 +/- 10	-20.1 +/- 1.1	-21.3 +/- 1.3	60.0 +/- 1.1	59.1 +/- 1.0
Triangle Cove- Low	34.3 +/- 0.3	42.5 +/- 1.3	-150 +/- 25	-273 +/- 25	-14.1 +/- 1.4	-7.3 +/- 1.4	56.2 +/- 1.6	55.8 +/- 0.8
Marsh	Cut/Cover	Cut/No Cover	Cut/Cover	Cut/No Cover	Cut/Cover	Cut/No Cover	Cut/Cover	Cut/No Cover
Cultus Bay- High	32.5 +/- 0.2	35.3 +/- 0.6	-279 +/- 30	-330 +/- 40	-13.4 +/- 2.8	-14.3 +/-2.3	63.2 +/- 1.8	61.3 +/- 1.8

areas without *S. anglica* at 3 of the 5 marsh sites compared to 4 of the 9 mudflat sites (Table 1 & Figure 3). This indicates a decrease in oxygen levels in the soils where *S. anglica* was absent. The measurements of water potential and soil moisture did not yield any significant patterns (Table 1, Figure 4 & Figure 5). Comparisons between the marsh sites and the mud flat sites, however, found no significant differences for any of the measurements ($p>0.05$, t-tests).

The measurements of infestation size and density showed that infestations in salt marshes had significantly higher % plant cover of *S. anglica* as well as larger clone diameters than that of mud flats ($p<0.05$, t-test). However, there was no difference in maximum height of the clones, or in the numbers of tillers per m^2 (Table 2).

Figure 2. Mean soil salinity of measurements gathered at each site with standard error bars. Measurements were taken at roots of *Spartina anglica* (W/Spartina), areas without *S. anglica* (W/O Spartina), areas without *S. anglica* due to eradication but with thatch cover (W/O Spartina Covered).

Fig. 2 Soil Salinity

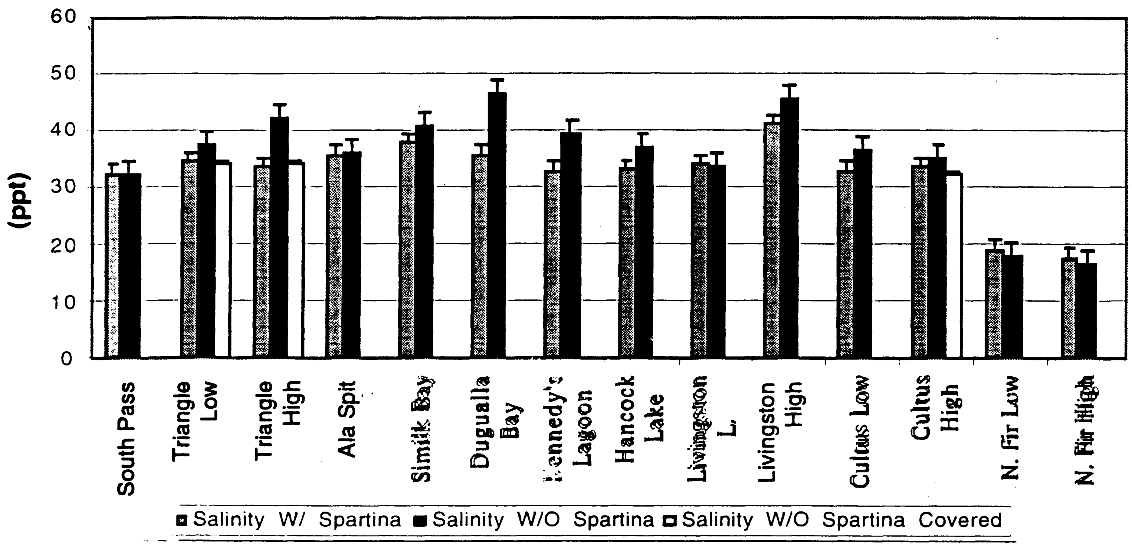

Figure 3. Mean redox potential of measurements gathered at each site with standard error bars. Measurements were taken at roots of *Spartina anglica* (W/Spartina), areas without *S. anglica* (W/O Spartina), areas without *S. anglica* due to eradication but with thatch cover (W/O Spartina Covered).

Fig. 3 Redox Potential

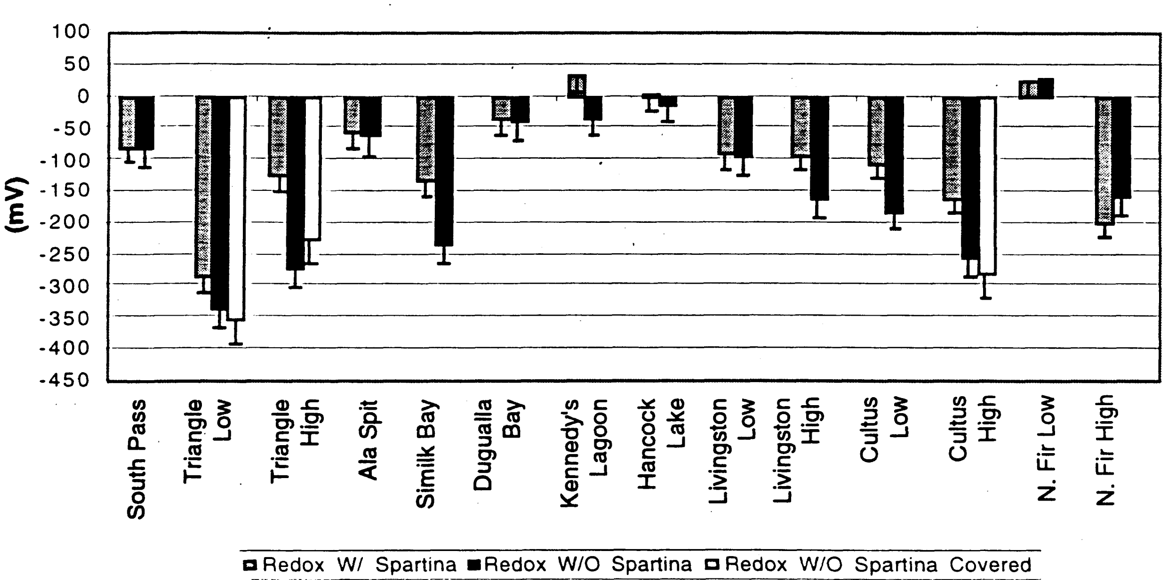

Figure 4. Mean soil moisture of samples gathered at each site with standard error bars. Measurements were taken at roots of *Spartina anglica* (W/Spartina), areas without *S. anglica* (W/O Spartina), areas without *S. anglica* due to eradication but with thatch cover (W/O Spartina Covered).

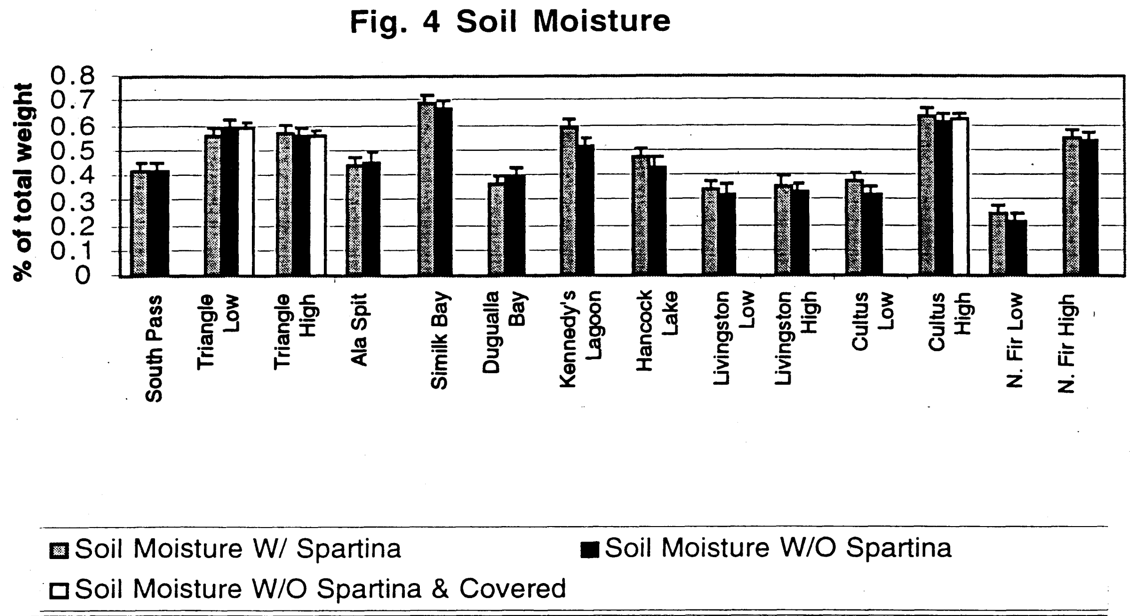

Figure 5. Mean water potential of samples gathered at each site with standard error bars. Measurements were taken at roots of *Spartina anglica* (W/Spartina), areas without *S. anglica* (W/O Spartina), areas without *S. anglica* due to eradication but with thatch cover (W/O Spartina Covered).

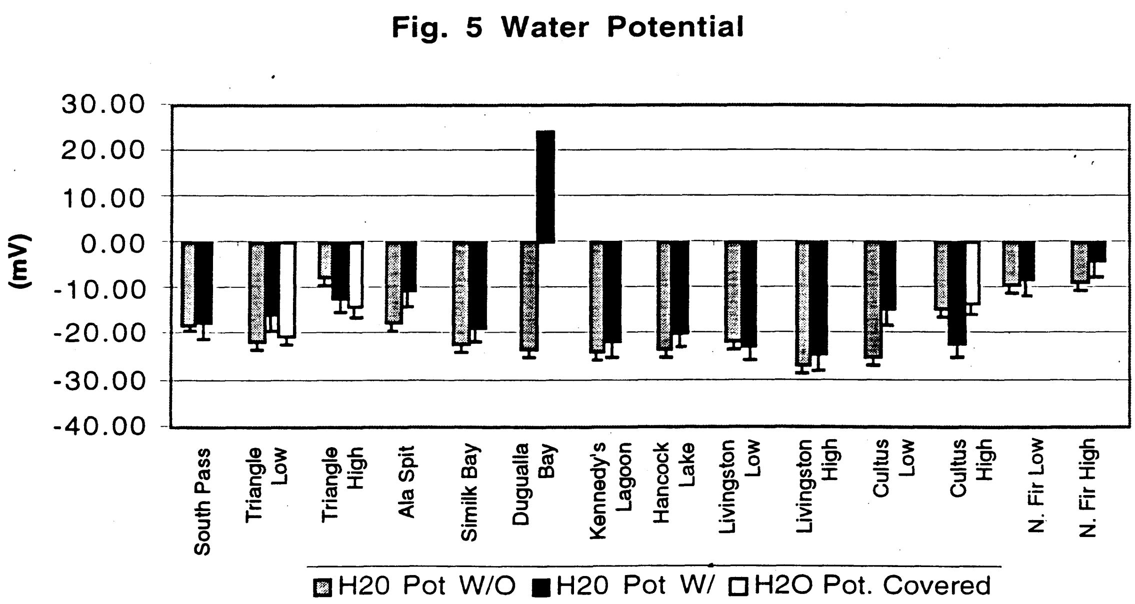

Table 2. Mean percent cover of *S. anglica* and native plants per m², mean clone diameter, and mean maximum clone height at each site. *-denotes absence of individual clones where meadows were predominant. At sites where two sets of measurements were gathered, the sets were differeniated between high in the intertidal zone and low in the intertidal zone, and are indicated as either high or low.

Site Type Name and										
Mud Flat	Clone Diameter (m)	Clone Height (m)	Spartina Tillers (#/m²)	*Spartina anglica* cover (%/m²)	*Scirpus americanus* cover (%/m²)	*Triglochin maritimum* cover (%/m²)	*Salicornia virginica* cover (%/m²)	*Distichilis* cover (%/m²)	*Spergularia* cover (%/m²)	*Fucus cover* (%/m²)
Livingston Bay-High	0.556	0.549	75.2	13.50%	8.70%	6.40%			3.90%	
Livingston Bay-Low	0.320	0.398	30.4	3.40%						
Dugualla Bay	1.093	0.480	78.8	5.40%			8.70%	0.50%		3.6%
Kennedy's Lagoon	1.706	0.649	110.4	11.30%	7.10%		8.70%			11.5%
Ala Spit	1.893	0.457	32.8	6.80%			44.40%	0.30%		
Triangle Cove-Hgih	*	0.761	191.2	71.30%						
Triangle Cove-Low	*	0.896	259.2	37.90%						
North Fir Island-Low	1.541	0.760	48.4	6.40%						
Cultus Bay- Low	3.062	0.708	36.4	7.20%						
Marsh										
Similk Bay	*	0.204	124.4	10.60%			12.60%		5.10%	
Hancock Lake	2.101	0.506	73.2	14.50%			33.90%			
North Fir Island-High	*	0.975	95.6	21.50%	24.90%	2.90%				
Cultus Bay-High	3.518	0.690	94.4	17.00%			22.10%	8.20%	2.40%	
South Pass	*	2.070	209.6	42.50%	30.50%					

The data on local species diversity show no significant patterns of native species that are associated with *S. anglica* infestations, however, *Salicornia* and *Scirpus* are found most often among areas of infestation (Table 2).

Discussion

The map of the *Spartina anglica* population in north Puget Sound shows that the spread of the infestation has been fairly equal in all directions. *S. anglica* has been found nearly as far north of Stanwood as it has been found south. The population has followed a fairly radial spread from the point of the initial planting, and the largest sites of infestation in both the northern and southern directions are also similar in distribution.

There is concern that the population will continue spreading southward and eventually invade the marshes of southern Puget Sound. However, no evidence of *S. anglica* in southern Puget Sound or southern Hood Canal has been found to date.

There are several possible explanations for the lack of infestation in these areas. First, there may be natural flow restrictions that block the spread of the infestation southward. Floating seeds and rhizomes may not be able to pass through certain passages of Hood Canal or Colvos Passage because of tidal flows in these areas. There may also be physiological restrictions barring *S. anglica* from successfully invading the southern marshes. Differing tidal patterns in southern Puget Sound compared to northern Puget Sound result in longer low tide periods that can increase soil salinity due to greater water evaporation. The prolonged tides may make southern marshes physiologically harsh and unsuitable for *S. anglica*. The eradication effort in central Puget Sound may also be a factor. Satellite populations at the southern end of the distribution have been effectively controlled. Most have been eradicated, and those that still exist are quite small. This may be restricting the seed source in the area and thereby inhibiting population spread further south. Lastly, the invasion into northern Puget Sound is fairly young (approximately 38 years) compared to similar but more established invasions of other *Spartina* species in England and Willapa Bay, Washington (approximately 100 years). Given enough time, populations may spread to the south.

Examinations of tidal currents at the entrances of southern Puget Sound and Hood Canal show no prohibitive tidal flows through the southward passages, and effectively rule out flow restrictions as a possible reason for the lack of infestation in the south.

The evidence of a fairly equal spread of the infestation discussed above supports the theory that the relatively young age of the infestation is a more likely cause. This equal radial spread of the population suggests that there has not been enough time for the population to reach the southern parts of Puget Sound and Hood Canal. An examination of physiological restrictions to *S. anglica* growth in the south was beyond the scope of this study, however, and therefore they cannot be ruled out as prohibitive impediments to southward invasion.

The data on percent cover, clone size, and tiller density suggest that *S. anglica* may be better suited to invade and flourish in pre-existing salt marshes than on tidal mud flats. This could be a result of lower salinity and higher oxygen levels generally found in the soils of marshes. In salt marshes, plants shade the soil surface decreasing water evaporation and thereby keeping salinity low (Bertness and Ellison, 1987; Pennings and Callaway, 1992; Castellanos et al., 1994; Hacker and Bertness, 1995). Their root systems and accompanying aerenchyma tissue can act to oxygenate the soil surrounding the roots and tissues (Pezeshki and Delaune, 1996). On mud flats in the absence of vegetation, however, these effects are lost, causing increased salinity and decreased oxygen levels.

Comparisons between marshes and mud flats in this study, however, failed to find any significant differences in the salinity and oxygen levels between the two. This is most likely a result of the data gathering procedure. The comparisons of areas without *S. anglica* between the two site types (i.e. mud flat and marsh) showed no significant differences because the soil measurements gathered at the salt marsh sites were taken from areas completely devoid of vegetation. No effort was made to compare areas of vegetated salt marsh soil without *S. anglica* and areas of bare mud flat. If this was done, it is likely that we would have seen significantly lower salinity and higher oxygen levels in the vegetated salt marsh soils.

Measurements of salinity and redox were made in areas where *S. anglica* had been recently cut and the cut thatch remained, partially or completely covering the soil beneath it. These areas were significantly lower in salinity and higher in oxygen content than in similarly cut areas where the thatch had been removed. These values were not significantly different, however, than those of areas where healthy *S. anglica* was present. This indicates that this residual thatch is helping to maintain the soil conditions that the *S. anglica* plant produces while alive.

Finally, although there were no significant patterns of native plant diversity among the sites of infestation, there are some general observations that can be made. At the mud flat sites, native plant diversity was fairly high, but abundance was low. At the marsh sites, however, *S. anglica* was found primarily with *Scirpus americanus* or *Salicornia virginica,* which were found in higher abundance. *Scirpus* and *Salicornia* are low marsh species and are found primarily at the lower edges of marshes throughout the region depending on the hydrology of the site (Ewing, 1983; Pidwirny, 1990).

At the salt marsh sites, *Spartina anglica* infestations were found primarily at the seaward edge of the existing marsh. As a result, there are two methods by which the invasion could be effecting the native marshes. The infestation could either be displacing native species by moving landward and outcompeting the species, or it could be extending the marsh by accreting soil at the edge of the marsh and expanding it seaward. This latter method would not be displacing native plants, and may in fact, facilitate the expansion of native species habitat by accumulating sediment and building marshes on former mud flat areas. In this scenario, *S. anglica* is a competive inferior and eventually the native plants outcompete it in this new habitat. Bertness and Ellison (1987) have shown that this occurs with another *Spartina* species, *Spartina alterniflora*, on the Atlantic coast.

The data from this study, however, is insufficient to make a confident conclusion as to which of these methods is actually taking place.

Conclusions

These results suggest that there may be some general ecological patterns that could be used to predict the future spread of the *S. anglica* population, and that the methods of eradication could be improved to more effectively fight that spread.

The data on salinity and oxygen levels indicate that determining the tolerance of *S. anglica* to varying levels of salinity and oxygen can help to identify what habitat types are most likely to be invaded. The effects of residual thatch on soil conditions suggest possible eradication strategy improvements. Though no evidence is documented here, some re-colonization of areas that have been subjected to eradication treatments is common (Gohrman et al. 1998, Riggs 1997, Rogers 1998, Wirth 1997). The maintenance of lower salinity and higher oxygen levels by the thatch produced by these eradication treatments may be a factor in allowing *S. anglica* to re-colonize these areas, either via new shoots or via remaining roots that may have survived the cutting and spraying treatments. Removing this thatch after the treatments (as well as in the fall when the plant dies back) could help prevent re-colonization.

These results are very preliminary, but they attest to the need for more research on the preferred physical environment of *S. anglica* and its effect on the habitats it invades. This knowledge is critical to any chance of real success in eradicating this plant from the state's marshes, mud flats, and beaches.

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Appendix 1. Sites of Spartina anglica infestation and eradication within Puget Sound. Data from reports to WSDA Noxious Weed Control Board and from surveys for this study. N/D= No data

County	Infested Site	Initial Area of Infestation (acres)	Eradication Results
Clallam	Gibson Spit	0.5	100% eradication No date
Island			
Whidbey Island	Ala Spit	0.5	0.1 acre remains
	Cornet Bay	0.5	0.3 acre remains
	Cultus Bay	65	60 acres remain
	Deer Lagoon	60	55 acres remain
	Dugualla Bay	1	0.5 acre remains
	Glennwood	N/D	1.25 acres remain
	Hancock Lake	0.5	0.5 acre remains
	Harrington Lagoon	0.1	0.1 acre remains
	Mariner's Cove	1	1 acre remains
	Oak Harbor	0.1	100% eradication 1996
	Penn Cove	1	0.5 acre remains
	Race Lagoon	0.1	0.1 acre remains
	Skagit Head	N/D	3 acres remain
	Snakelum	0.2	100% eradication 1996
	Sunlight Beach	8	6 acres remain
Camano Island	Arrowhead	2	1 acre remains
	County Club	0.1	0.1 acre remains
	Davis Slough	20	19 acres remain
	Driftwood Shores	0.1	100% eradication 1996
	Eagle Tree Estates	8	7 acres remain
	Elger Bay	5	6 acres remain
	English Boom	220	250 acres remain
	Livingston Bay Northeast	18.5	4 acres remain
	Livingston Bay West	94	110 acres remain
	Mt. View	1	2 acres remain
	Sandy Hook	N/D	N/D
	Sunny Shore	2	3 acres remain
	Triangle Cove	165	160 acres remain
Jefferson	Bywater Bay	0.5	100% eradication 1997
	Kala Point	0.5	0.5 acre remains
	Mat Mats Bay	0.1	100% eradication 1996
	Oak Bay	0.5	0.2 acre remains
	Tarboo Bay	N/D	100% eradication 1997
	Scow Bay	0.3	0.2 acre remains
King	Fern Cove, Vashon Island	0.4	100% eradication 1995
	Point Hayer, Vashon Island	0.2	100% eradication 1995
Kitsap	Apple Tree Cove	0.3	100% eradication 1994
	Blakely Harbor, Bainbridge Island	0.1	100% eradication 1996
	Church Wetland	N/D	N/D
	Doe-Kag-Wats	7	0.3 acre remains

Appendix 1. Sites of Spartina anglica infestation and eradication within Puget Sound. Data from reports to WSDA Noxious Weed Control Board and from surveys for this study. N/D= No data

	Foulweather Bluff	0.75	0.5 acre remains
	Murden Cove, Bainbridge Island	0.5	100% eradication 1997
	Point Monroe, Bainbridge Island	0.4	100% eradication 1997
	Port Gamble	0.4	100% eradication 1997
Mason	None		
Pierce	None		
San Juan	Argyle Lagoon	0.2	100% eradication 1998
	Fisherman's Bay	0.1	100% eradication 1998
Skagit	Bayview	10	8.8 acres remain
	Dredge Spoil Islands	4.5	3 acres remain
	Fidalgo Bay	N/D	1 acre remains
	Gallup's Property	27	20 acres remain
	Gallup's Property South	86	68 acres remain
	Kraft Island	105	89 acres remain
	Padilla Bay	1350 *	0.2 solid acre remain
	Similk Bay	N/D	15 acres remain
	Swinomish Channel	N/D	35 acres remain
	Turner's Cove	15	12 acres remain
	Whitmarsh	2	0.1 acre remains
Snohomish	Kayak Point to Warm Beach	0.5	100% eradicated 1997
	Port Susan Bay	1850	1400 acres remain
	South Pass	270	270 acres remain
	Steamboat Slough	0.25	N/D
	Stillaguamish River	7	7 acres remain
	Tulalip Bay	2.5	N/D
	Tulalip to King County Line	N/D	N/D
	Warm Beach	300	50 acres remain
	West Pass to Skagit County Line	176	161 acres remain
Thurston	None		
Totals		4891.7	2832.05 acres

*- estimate of total acreage affected by infestation, not acerage of infestation itself.