

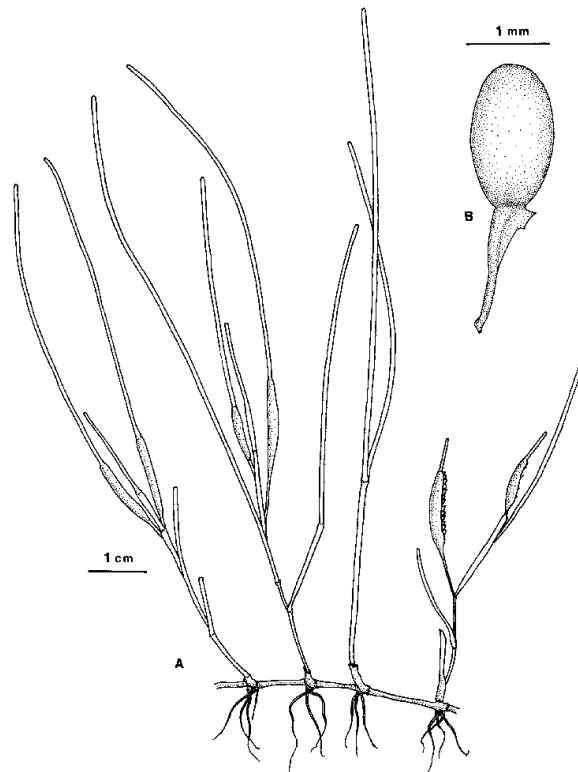
The Distribution and Abundance of a Non-native Eelgrass, *Zostera japonica*, in Oregon Estuaries

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Senior Thesis
Bachelor of Science Degree
April 2006

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ABSTRACT:

Biological introductions may considerably alter the composition and community dynamics of invaded areas thereby changing many ecosystem processes including productivity, decomposition, nutrient cycling and hydrology. The effects on native species may be obscured by a lack of information on distribution and abundance patterns. The Japanese eelgrass, *Zostera japonica*, was introduced to Pacific Northwest estuaries in the 1950's when used as packing material for industry seed oysters. To assess and further track the impacts of *Z. japonica* in PNW estuaries, the current distribution and abundance of *Z. japonica* was documented in Netarts Bay, South Slough National Estuarine Research Reserve (SSNERR), and Bandon Marsh National Wildlife Refuge (BMNWR). Transects were established through the center of contiguous eelgrass beds. The percent cover of *Z. japonica* was taken at 10-m intervals using a 50x50-cm quadrat.

In Netarts Bay, *Z. japonica* beds were intermingled with native eelgrass, *Zostera marina*, throughout most of its range with *Z. japonica* covering on average 44% of the substrate. Within the SSNERR, *Z. japonica* and *Z. marina* beds occupied different intertidal zones, seldom overlapping. Where present, *Z. japonica* occupied 17% of the substrate in March and 64% cover by August. Within BMNWR, *Z. japonica* was documented in small isolated patches at less than 25% cover. This study can serve as a baseline for documenting future range expansions and changes in abundance of *Z. japonica* within these estuaries.

In November 2005 and in April of 2006, control experiments were initiated at Bandon Marsh National Wildlife Refuge. Future researchers will visit the site and evaluate the efficacy of manually removing patches of *Z. japonica* (see Appendix).

INTRODUCTION:

Two species of eelgrass inhabit the Oregon coast, the native eelgrass *Zostera marina* and the non-native *Zostera japonica*. The native eelgrass, *Z. marina*, serves many ecosystem functions within estuaries. It provides invaluable habitat to a multitude of native fishes and prey species such as small crustaceans, bivalves, and gastropods. The blades of these plants create attachment area for algae, planktonic larvae, and snails. Eelgrass also serve as a nursery ground for juvenile crab, juvenile ling cod, salmonids, starry flounder, English sole, and other fish and invertebrates (Swayne, 2004). In essence *Z. marina*, as a primary producer, provides food and habitat for many commercially and ecologically important fish in the United States (Gilmore, 1987).

The non-native eelgrass *Z. japonica* was first introduced to the Pacific Northwest in the 1950's as packaging material for seed oysters, *Crassostrea gigas*, while being shipped across the Pacific from Japan (Harrison and Bigley 1982). *Z. japonica* was first established near oyster beds in the state of Washington and subsequently discovered in Oregon estuaries, British Columbia, and in one instance found in Humboldt County, CA. *Z. japonica* colonizes formerly bare, un-vegetated, tidal flats and typically occurs between 0.3 to 2.4 m above mean lower low water (MLLW) (Harrison and Bigley 1982). It can be found in broadly sheltered bays, on sandy or muddy coasts, sheltered tidal flats, or in estuaries at depths of up to 1-3 meters (Shin and Choi 1997).

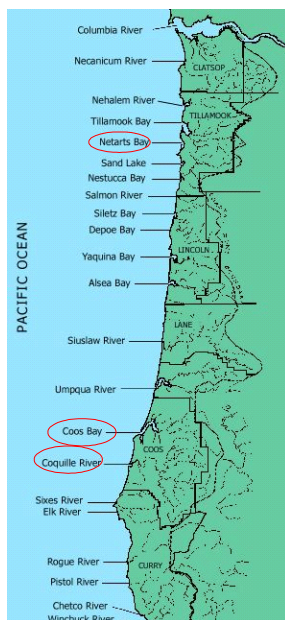
Leaf morphology of *Z. japonica* is influenced by the physical geography of the bay and tidal heights. When occupying the high intertidal and exposed to air and desiccation, leaves are short and narrow, but when found completely submerged in lagoons, leaves are longer and wider (NOAA 2004). The rhizomes of *Z. japonica* bind and stabilize soft substrate while the blades trap

suspended sediment, thus facilitating terrestrial succession. According to Baldwin and Lovvorn (1994), it dramatically alters the habitat structure where it becomes established. Sandpipers as well as other native shorebirds depended on these habitats to forage for clams and worms (Precision Identification Biological Consultants 2004).

The debate on the invasiveness of *Z. japonica* in the PNW has gone on for the last half century. Martin Posey (1988) found that the presence of *Z. japonica* changed the physical habitat and in turn altered the richness and densities of fauna. In the Pacific Northwest some managers feel that *Z. japonica* changes species assemblages, alters native ecosystems, and does not provide the same high-quality habitat for Pacific salmon and ground fish as *Z. marina* does (Hahn, 2001). On the other hand, the state of Washington's Hydraulics Code protects all eelgrass beds, including *Z. japonica* (Pawlak 1994; Carlisle et al., Undated). The Canadian Wildlife Service acknowledges that the presence of *Z. japonica* degrades sandpiper foraging habitat by binding soft sediments, and that the increased presence and density of *Z. japonica* may lead to changes in the invertebrate community within the mud or sand substrate (Durance, 2002). The University of California Extension Service, after yearlong discussions, took preventative measures and removed *Z. japonica* in Humboldt Bay before it could become established and spread (Rushton, 2005). Though the decision to eradicate *Z. japonica* from Oregon reserves has yet to be decided, it is important to document its spread and to understand its impacts on the native communities and ecosystem processes. Thus far, mapping projects of *Z. japonica* have not been established within the United States. Canada has encouraged the documentation of *Z. japonica* through community grass roots efforts (PIBC). These conflicting views on the invasiveness of *Z. japonica* and Canadian efforts to map this non-native eelgrass emphasize the importance of creating a baseline inventory of *Z. japonica* along the Oregon coast.

The goal of my study is two fold; to document the present distribution and abundance of *Z. japonica* in three Oregon Estuaries, and to evaluate the feasibility of eradication *Z. japonica* from Bandon Marsh National Wildlife Refuge. By documenting the increase in abundance of *Z. japonica* in 2005, managers and scientists will have a valuable tool to evaluate the rate of spread of this invasive non-indigenous eelgrass species in Oregon estuaries. This study will also be important in evaluating the transformation of soft sediment to a more consolidated substrate where *Z. japonica* is present.

STUDY SITES:



Three estuaries along the Oregon coastline were chosen for their importance to native wildlife and migrating waterfowl, the diverse land management practices of each estuary that have thus influenced the fauna and infauna, as well as previous documentation of *Z. japonica*, or lack thereof. These three estuaries are Netarts Bay, South Slough National Estuarine Research Reserve (SSNERR), and Bandon Marsh National Wildlife Refuge (BMNWR).

Netarts Bay is the most northern estuary and has the lowest intensity management practices of the estuaries in my study. This bay is located 60 miles south of the Columbia River and covers 2300 acres. About 60-90% of the total area is tidelands and is classified as "bar-built," in which a separate estuarine environment is created by a sand spit and receives very little freshwater input. The high salinity in Netarts provides favorable habitat for cockle, butter, gaper, geoduck and razor

clams. The important commercial fish found here include kelp greenling, salmon, perch, crab, flounder, and black rockfish. Netarts is also an important feeding, resting, and wintering spot for black brant and other migrating water fowl (Percy et al. 1974).

The South Slough National Estuarine Research Reserve is a 4,771 acre natural area located in the Coos estuary. Sediments of the SSNERR are primarily soft and unconsolidated. Here large mudflats are exposed for extended periods during low tide which are great feeding grounds for a number of small shorebirds, and for great blue herons, egrets, sandpiper and kingfishers. Cockles, gaper, bent-nose, and littleneck clams, ghost shrimp, mud shrimp, and juvenile Dungeness crab also inhabit the SSNERR. In late summer, up to 160 acres of eelgrass, *Z. marina* and *Z. japonica*, may be found in the Reserve (Posey, 1987). The SSNERR is the only estuary with records of the date, site of first introduction and abundance of *Z. japonica*. *Zostera japonica* has been present in South Slough since at least 1972. Martin Posey documented the first site of introduction at Fairy Marsh, occurring at <50%cover (1986). He also documented its presence along the west coast of Valino Island in two patches, also occurring at <50%cover but was absent on the north, east and south side. Sylvia Yamada, Steve Rumrill, and student from University of Oregon's Institute of Marine Biology surveyed all shores of Valino Island in the summer of 2004. This study found that *Z. japonica* previously limited to the west shore had spread to all shores of Valino Island, north, east, south, west shores were documented at 17%, 15%, 50%, and 46% respectively.

The Bandon Marsh National Wildlife Refuge is located near the mouth of the Coquille River. It protects the largest remaining tidal salt marsh within the Coquille River estuary (Percy et al. 1974). This reserve is an important feeding ground for waterfowl and migratory shorebirds. It is

also an important refuge for threatened and endangered species including the bald eagle, California brown pelican, and coho salmon (USFWS, 2006).

METHODS:

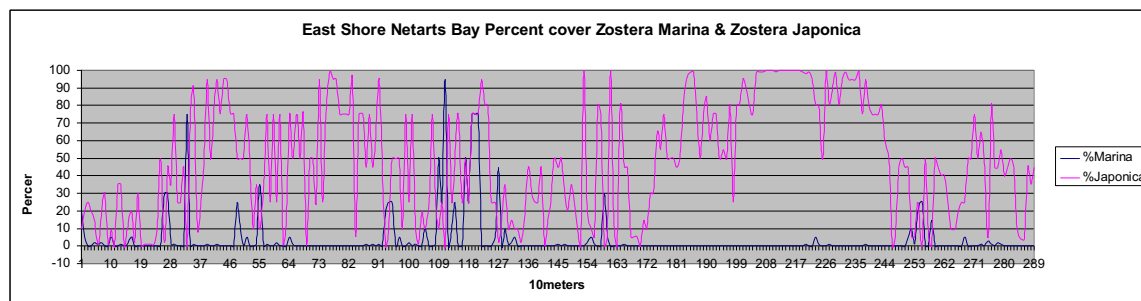
Mapping protocol for *Z. japonica* followed that of Posey and Rudy (1987) and Yamada et al. (2004). An initial assessment for the presence of *Z. japonica* in each estuary was conducted by foot and kayak. The initial patrol of each estuary was surveyed following the same rough visual scale used by Posey: absent, less than 50% cover, greater than 50% cover. A more detailed survey of the abundance of *Z. japonica* was then conducted using the method established by Yamada et al. (2004). Transects were established where *Z. japonica* beds formed a contiguous bed of eelgrass along the shoreline. *Z. japonica* field surveys can usually start two hours before and after the low tide. Using a 50x50-cm quadrat the percent cover of *Z. japonica* and *Z. marina* was recorded at 10-meter intervals along a meter tape that bisects the *Z. japonica* zone. A hand-held etrex summit Garmin GPS unit with 20ft accuracy was used to record the starting and ending points of each transect. A penetrometer reading was also taken at each 10m interval to document the relative substrate composition where *Z. japonica* was present. The knowledge of substrate composition is important in understanding the niches associated with *Z. japonica* beds (Orth, 1997). Netarts Bay was surveyed in early July (7-14) of 2005. The SSNERR was surveyed in late March (22-30) and again in early August (3-10) of 2005. BMNWR was surveyed in early August (1-13) of 2005.

Fifteen permanent eradication plots were established alongside BMNWR; from which 50% of *Z. japonica* cover was randomly selected and removed manually. The excavated material was deposited at least 25-m inland from the high water mark. These plots will be continually

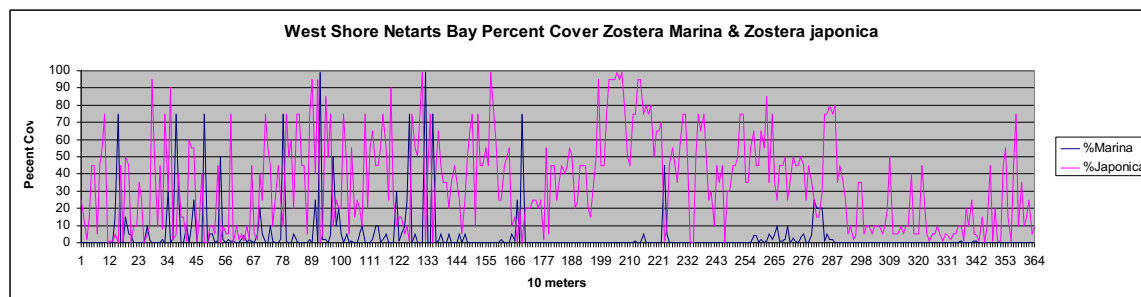
monitored and manipulated to assess the effectiveness of eradication efforts (see Appendix). Future ground surveys will help document range expansions and changes in abundance of *Z. japonica* within these estuaries.

RESULTS:

The topography of Netarts Bay is such that there is very little vertical intertidal variation which allowed for the intermingling of *Z. japonica* and *Z. marina*. This overlap did not occur at either of the other two estuaries, SSERR or BMNWR. As shown by Graphs 1 and 2, *Z. japonica* is the dominant eelgrass species along these transects. In Netarts Bay, *Z. japonica* covered on average 44% of the substrate. As illustrated in Figure 1, *Z. japonica* is found at lower densities, <24% cover in the more northern reaches of Netarts Bay, increases to >75% cover and tapers off at the southern reaches.



Graphs 1: Percent cover of *Z. japonica* along the east shore of Netarts Bay in July 2005



Graphs 2: Percent cover of *Z. japonica* along the West shore of Netarts Bay in July 2005

Percent Cover of *Z. japonica* in Netarts Bay 2005

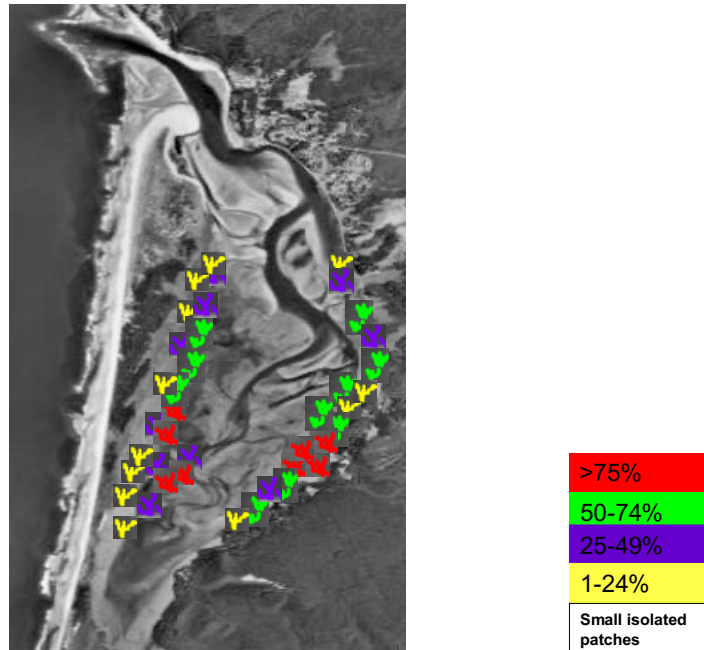


Figure 1: Percent cover of *Z. japonica* in Netarts Bay 2005

Within the SSNERR, *Z. japonica* occupied 17% of the substrate in March and 64% cover by August. This is an increase from less than 50% cover documented by Posey in 1986. As shown in Fig. 2, *Z. japonica* has further colonized this estuary since 1986. It had now been documented at >50% cover along the west shore of Long Island Pt. and has moved 2 miles upriver from the first point of introduction recorded by Posey in 1984. Along the shores of Valino Island the percent cover documented in this study are slightly lower than that recorded in 2004 by Yamada et al. (2004). As indicated in Table 1, the North shore of the Island increased from 17% to 23%, all remaining shores decreased, East from 15% to 9%, South 50% to 32%, and West 46% to 33%.

**Percent Cover of *Z. japonica* in
South Slough National Estuarine Research Reserve**

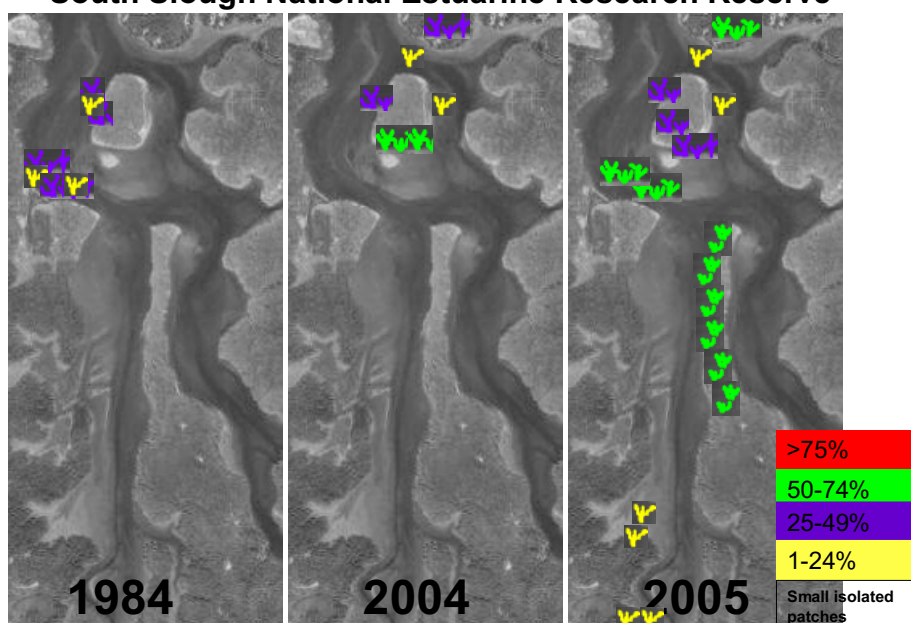


Figure 2: Percent cover of *Z. japonica* in SSNERR in 1984, 2004, and 2005

Site: SSNERR	# meters	% Cover 1986	Average % Cover 2004	Average % Cover 2005
Valino Island, North	310	Absent	17	23
Valino Island, East	290	Absent	15	9
Valino Island, South	200	Absent	50	32
Valino Island, West	420	< 50%	46	33

Table 1: Comparison of *Z. japonica* percent cover overtime (1986-2005)

Within Bandon Marsh National Wildlife Refuge *Z. japonica* was documented in two small isolated areas where percent cover was less than 25% (Figure 3). These patches did not form contiguous eelgrass bed that had been seen in Netarts and SSNERR. The northern area, just outside the refuge boundary, is comprised of about 200 small patches of *Z. japonica* that are confined to 500 m stretch of shore, directly across from Bullard State Park boat ramp. Although

these patches have not currently formed contiguous beds, it is feasible that if not controlled or eradicated these patches will form a contiguous bed of *Z. japonica* in the future.

**Percent Cover of *Z. japonica* in
Bandon Marsh National Wildlife Refuge, 2005**

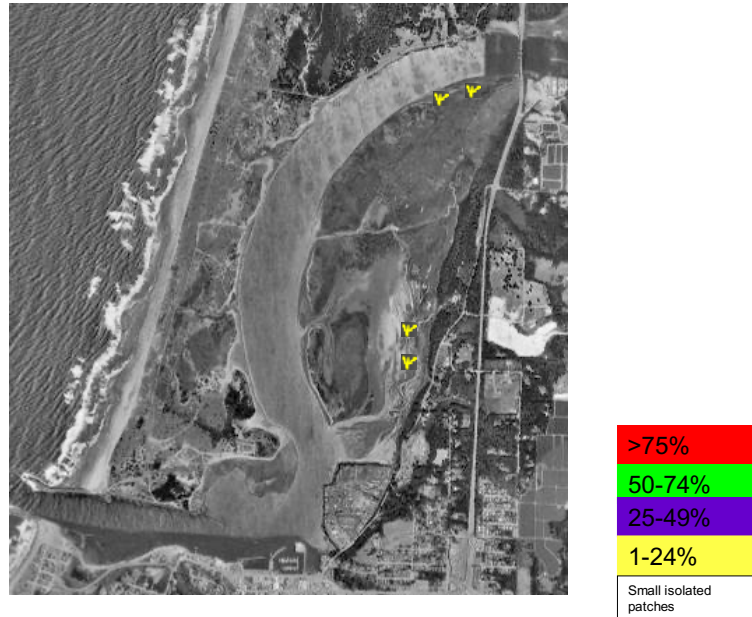


Figure 3: Percent cover of *Z. japonica* in BMNWR in 2005

CONCLUSION:

During the summer of 2005 a baseline inventory of *Z. japonica* was established for three estuaries along the Oregon coast, Netarts Bay, South Slough National Estuarine Research Reserve, and the Bandon Marsh National Wildlife Refuge. Within Netarts Bay *Z. japonica* is established at 44 % substrate cover and is found intermingled with native eelgrass. For the SSNERR, a seasonal increase from March to August, as well as the expansion in the distribution and abundance between 1984 and 2005 was documented. By August *Z. japonica*, on average, cover 64% of the substrate where established. Bandon Marsh NWR *Z. japonica* occurs in small patches at <25% cover.

Currently there is technology being developed that will aid in the mapping of this non-native eelgrass. The Environmental Protection Agency is perfecting aerial photography technology. Near infrared color aerial photography (~1:7200) of estuaries are taken at minus tides during summer months to produce digital stereo ortho-photographs covering tidally exposed eelgrass habitat allowing researchers to distinguish different habitat, substrate, and vegetation types. It remains difficult to distinguish between the native and non-native eelgrasses, therefore GIS analysis is coupled with GPS positioning of ground-truth data and aided by combining specifically tailored detection algorithms and "heads up" digitizing with digital bathymetry (Specht and Clinton 2000).

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Appendix

Zostera japonica removal experiment in the Coquille estuary

by

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June 2006

It becomes difficult to eradicate a non-native species once it becomes established and the negative effects on native communities are realized. Therefore, there is a short timeframe in which to conduct a cost-effective eradication (Oregon Invasive Species Council 2005). Because of the importance the Coquille estuary and Bandon Marsh NWR it would be beneficial to eradicate this invasive species before it becomes established. Since *Zostera japonica* was sparsely distributed in only a couple of areas in the Coquille estuary, we decided to look at the feasibility of manually controlling the spread of this species before it formed contiguous meadows.

On November 25, 2005, we selected 15 *Zostera japonica* patches on the mud/sand flat on southern shore of the Coquille River, across from Bullards Boat ramp, just down stream from the 101 Bridge. We mapped and measured each patch and randomly removed half of its area. When we returned in April, the experimental patches had not changed. It thus appears that not much growth occurs over the winter.

On April 6, 2006, we set up a large-scale removal experiment at the same site. Starting at the first piling near the bridge, we measured off 10 meters stretches along the shore. Our goal was to include most of the *Zoster japonica* patches in this area. We estimate that 95

% of the patches were included in 420 meters of shore line. We designated the center stretch of shore, from 140 to 280 meters, as our *Zostera japonica* Removal Treatment and the stretches on either side as the un-manipulated Control areas. We counted the numbers of *Zoster japonica* patches in each of the 10 meters sections of shore. Patches were typically smaller than 50 cm in diameter and only around 3 to 4 patches were found within 10 meters of shoreline (Table 1).

Table 1. Abundance of *Zostera japonica* patches in 10 m-stretches of shoreline along the upper intertidal mudflat bordering the northwest border of Bandon National Wildlife Refuge on April 6, 2006. 420 meters of shoreline were marked off in 10 meter intervals, starting at the first piling down-river from the 101 Bridge, and the number of patches of *Zostera japonica* in each 10 meter interval was counted. The *Zostera japonica* patches in the middle intervals, 140-280 meters, were then manually removed while the other two intervals were left as un-manipulated control treatments.

Treatment	Location	Total # of patches	Number of 10 meter sections	Mean # of patches per section	Range	Standard Deviation
Un-manipulated Control 1	0-140 meters	52	14	3.71	0-9	3.1
Removal Treatment	140-280 meters	54	14	3.86	0-6	1.99
Un-manipulated Control 2	280-420 meters	40	14	2.86	0-9	2.74

Three of us then spend about 2 hours manually removing the *Zostera japonica* patches in the Removal Treatment. We dug up the plants, including roots and sediment and carried these to the upper marsh. At an estimated number of 6 man-hours, it would have taken an additional 12 man-hours to remove the rest of the patches in this area.

Table 2. Abundance of *Zostera japonica* patches in 10 m-stretches of shoreline along the upper intertidal mudflat bordering the northwest border of Bandon National Wildlife Refuge on June 9, 2006.

Treatment	Location	Total # of patches	Number of 10 meter sections	Mean # of patches per section	Range	Standard Deviation
Un-manipulated Control 1	0-140 meters	228	14	16.29	0-37	12.95
Removal Treatment	140-280 meters	224	14	16	3-28	7.25
Un-manipulated Control 2	280-420 meters	187	14	13.36	1-35	9.59

We returned on June 9 and re-counted the *Zostera japonica* patches in the 420 meter of shoreline. We noted that patches larger than 10 cm were absent from the removal treatment but that many smaller patches were found in all the treatments (Table 2). Most of these new patches consisted of single shoots, suggesting that these sprouted from seeds since April.

Discussion:

Right now the Coquille is the only major Oregon estuary in which *Zostera japonica* does not form contiguous meadows. It is not known whether the distribution is so sparse because there has not been sufficient time for this invader to form contiguous meadows or whether the environment is not conducive for meadows to form. *Zostera japonica* has been present in the Coquille for at least 14 years. The map of the Coquille in the Oregon Estuary Plan Book (Hatfield Marine Science Center GC 97.8.0.C2 1987) shows 6 areas as having “seagrass” and “seagrass on sand/mud”. Since two of the sites correspond to the same sites where Chana Dudoit found *Zostera japonica* in 2005, it is likely that *Zostera japonica* was present in 1987. A positive identification of *Zostera japonica* in the Coquille was made in 1992 by Howard Crombie (1993, unpublished Honors thesis, University of Oregon).

While 14 years may not be sufficient to establish contiguous meadows of *Zostera japonica*, other factors may also be responsible for its sparse distribution in the Coquille estuary. In June 2006, we noticed evidence of major disturbance to our study site by hydraulic harvesting of sand shrimp. Bait fishermen use fire hoses to pump seawater into the sediment, thus welling up the shrimp. This action completely turns over the sediment and creates deep pits. If sand shrimp harvesting occurs on a regular basis, it would prevent the establishment of *Zostera japonica* meadows.

If the decision is made to keep the Coquille estuary free of *Zostera japonica*, it may not be too late. This species could be controlled by annual estuary-wide removals in late spring using volunteers. Because of the presence of residual seeds, it would take a continual effort to remove new shoots each year. Even if eradication is not feasible, it would still be possible to prevent the establishment of contiguous meadows by removing the larger patches.

We recommend that *Zostera japonica* be monitored in the Coquille estuary to determine whether the sparse distribution is maintained or whether this species is spreading and is becoming more abundant.