Shorebird Use of Smooth Cordgrass (*Spartina alterniflora)* Meadows in Willapa Bay, Washington

by

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Abstract

During the late 1800’s, *Spartina alterniflora*, a marsh grass native to the eastern United States began to colonize Willapa Bay in southwestern Washington. By the mid-1980’s, the grass had spread to such an extent that land managers and aquaculturists initiated steps meant to eradicate it and several congeners from Willapa Bay and other Washington intertidal areas. Among the reasons cited for the eradication efforts were the assumed impacts the grass would have on migrating shorebird populations that use the historically less vegetated intertidal mudflats during the fall, winter, and spring.

The purpose of the work presented here was to examine the validity of this contention. Five survey locations were chosen throughout Willapa Bay to determine whether or not shorebirds are using areas colonized by *Spartina* during spring migration.

The literature was consulted to put the Willapa Bay circumstance in perspective relative to invertebrate communities within *Spartina* marshes elsewhere, shorebird feeding ecology, and other studies designed to investigate the possible impacts of the grass on shorebirds.

Over the four weeks of surveys, shorebirds were regularly and consistently observed foraging within the colonized areas. There was a significant tidal effect observed, with birds feeding more frequently in the grass on the ebbing tide than on the flooding tide. Based on the literature and this research, it is clear that *Spartina* does not exclude feeding shorebirds during the spring migration at Willapa Bay.

Signature______________________

Jared R. Parks

Date______________________

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INTRODUCTION

Migrating flocks of shorebirds along the west coast of the United States can be quite impressive, most notably in the spring when 10's to 100's of thousands of birds can be seen in major bays and estuaries. These large flocks of birds tend to concentrate in large, shallow bodies of water that are characterized by expansive mudflats at low tide. The most common shorebirds using these sites are Western Sandpiper (*Calidris mauri*), Dunlin (*Calidris alpina*), Sanderling (*Calidris alba*), dowitcher spp. (*Limnodromus* spp.), Greater Yellowlegs (*Tringa melanoleuca*), Black-bellied Plover (*Pluvialis squatarola*), and Semipalmated Plover (*Charadrius semipalmatus*). In addition, large numbers of godwits (*Limnosa* spp.), turnstones (*Arenaria* spp.), phalaropes (*Phalaropus* spp.), other *Calidris* sandpipers, and members of the genus *Numenius* can be found in special locales or in certain years along the same flyway. This paper focuses on seven shorebirds that are most abundant in the shallow bays and estuaries of the West Coast: Western Sandpiper, Dunlin, Short- and Long-billed Dowitchers, Greater Yellowlegs, and Black-bellied and Semipalmated Plovers. Because these species rely on western bays and estuaries as migratory stopover sites, they are at greatest risk from changes to such areas.

Spartina, a genus of grass most commonly associated with wetland habitats, was introduced into the western coastal waterways in the late 1800's. The colonizing species are wetland obligates of saline waters from many parts of the world. The most common are *Spartina alterniflora*, *S. anglica, S. patens S., townsendii*, and *S. densiflora*. This paper focuses on *Spartina alterniflora* and its colonization of bays of the Pacific Northwest, most specifically Willapa Bay, Washington.

Spartina alterniflora (Smooth Cordgrass) was first introduced to Willapa Bay in the 1890's (Sayce 1988), but little concern over the introduction was voiced until the early to mid-1980's, almost 100 years after its initial colonization. In the beginning the cordgrass was not seen as a threat because it spread at an almost imperceptible rate. Recently, however, the pace and scope of the spread has increased to such an extent that public land managers, aquiculturists, and wildlife enthusiasts are concerned about the effects that the situation might have on livelihoods and the ecological stability of the bay.

Willapa Bay is a classic example of a shallow, western, coastal estuary. At low tide large expanses of mudflat dominate the basin. These flats are characteristically almost devoid of any native emergent vegetation, though *Triglochin maritimum* and *Plantago maritima* are found along a narrow band seaward of the upper marsh, and eel grass (*Zostera* spp.), an aquatic grass, is common at lower intertidal levels. The upper marsh is dominated by *Distichlis spicata* and *Salicornia virginica*. Historically, these expanses of mud have provided excellent oyster and clam beds as well as ideal feeding areas for migrating shorebirds. As *Spartina* has continued to spread, the concern has grown over how much of these mudflats will be lost to the expanding meadows of cordgrass and how this change will affect the aquatic and avian life in the region.

Since the 1980's, when the issue of *Spartina* invasion first began to draw the attention of the Washington state legislature, control of the exotic has become more and more of a priority in coastal watershed management. Concern over possible crippling losses to one of the area's principal industries, aquiculture interests have been the driving force behind this effort, though wildlife managers and enthusiasts and those involved in the fishing industry have also been influential in encouraging attempts to control *Spartina*. It is contended that the ecological stability of the Washington coastal waterways is threatened by the spread of *Spartina*, and that this in turn will have grave impacts on the native (and perceived-beneficial exotic) flora and fauna of these areas (Revised Code of Washington Chapter 17.26, Washington State Aquatic Nuisance Species Plan 2001).

Though individual species of *Spartina* have been introduced to many coastal areas around the world, the scientific literature is anemic with regard to the direct impacts of the plant on the native systems into which they are introduced. It is not unusual for ecological management decisions to be inadequately backed by scientific study, but in all circumstances it is preferable to find as much backing as possible to justify such decisions. The assertion has been made that migrant shorebirds will not forage (or do so less frequently) within the meadows that cordgrass forms as it spreads over native mudflats and eelgrass beds (Davis and Moss 1984, Millard and Evans 1984, Evans 1986, Nairn 1986, Aberle 1993, Daehler and Strong 1996, Jaques 2002, WSDA report 2002). Theoretically, then, shorebirds would have less space available for feeding and less time during the tidal cycle to feed. If these restrictions limited their access to food to the extent that they failed to prepare themselves appropriately for the long journey that they face and the conditions that they may encounter along the way, a negative population impact could result.

The research reported here was designed to examine whether these migrating sandpipers use or are excluded by the cordgrass. Both literature review and original field research were used to answer the question: do shorebirds utilize *Spartina* meadows in Willapa Bay, Washington and, if so, what species and how?

Willapa Bay

Willapa Bay is located on the southwestern coast of Washington state in Pacific County (Figures 1 & 2). The bay functions as the drainage for the Willapa Hills, receiving the water from nearly 2400 km^2 of land (Andrews 1965). Forest plantations and the logging industry dominate this area of southwestern Washington. The Willapa Hills border the eastern and southern shores of the bay while the western shore is formed by the Long or North Beach Peninsula. As of the 2000 census, 20,844 people lived in the 933 square miles that comprise Pacific County. Major population centers in Pacific County include Raymond, South Bend, and Tokeland in the north bay area, and Naselle, Ilwaco, Long Beach, and Ocean Park in the south and west bay areas. Compared to the rest of western Washington, Pacific County has a very low population density, with only about 22.5 persons per square mile (state average 88.6), and only about 14,000 housing units (Washington State web page). The economy of Pacific County relies heavily on logging, fishing. and aquiculture, as well as tourism and outdoor recreation.

Willapa Bay itself is a long estuary with a barrier beach (the Long Beach Peninsula) forming its western border. The barrier beach stretches from the mouth of the Columbia River approximately 25 miles north to Leadbetter Point. At Mean Higher High Water, MHHW, the bay is covered by about 350 km^2 of water, and at Mean Lower Low Water, MLLW, about 190 km^2 is exposed intertidal area, 55% of the bay’s area (Andrews 1965). Because the bay is a long estuary, there is a significant difference between tidal ranges at its north (7.5 feet or 2.3 m) and south (11 feet or 3.4 m) reaches (Sayce 1988).

The modern economic history of Pacific County began in the late 1700's with the emergence of a fur trade in sea otter pelts). This quickly gave way to fishing as the predominant industry in the area

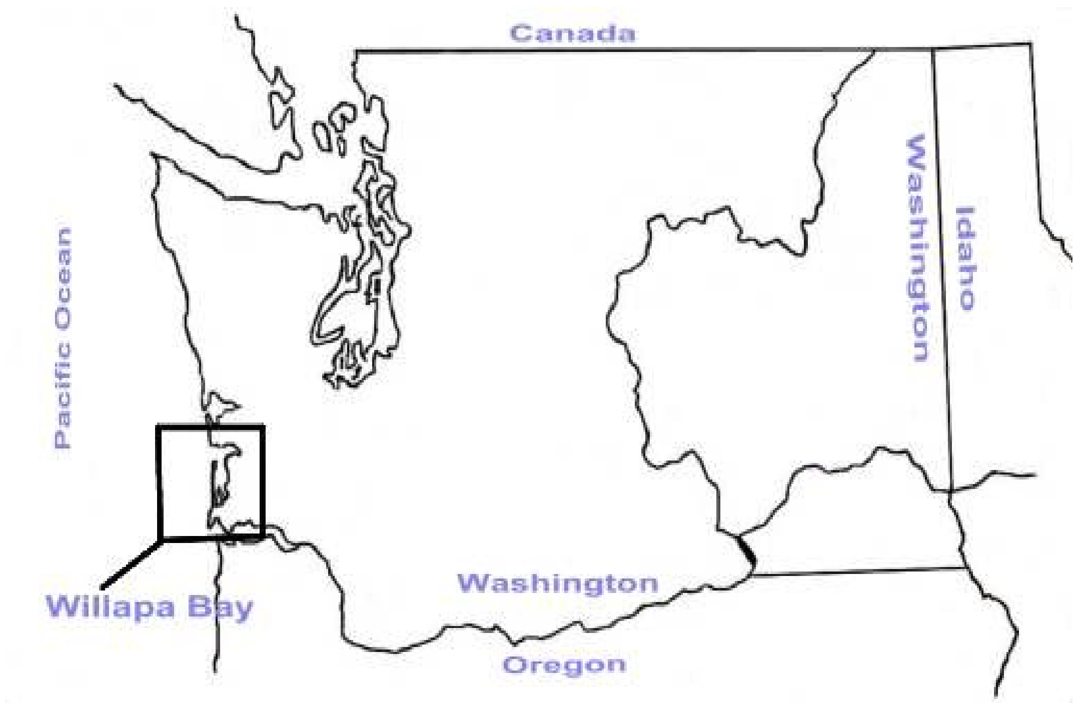

Figure 1. Map of Willapa Bay in southwestern Washington State.

when sea otter populations were decimated. Salmon were the primary piscatorial prize for the shoremen, but oysters, clams, mussels, and crabs were also taken. By the 1890's the lumber and logging industries had taken on the preeminent role in the area's economic sector, but fishing and aquiculture were still firmly established trades. The economic picture today is still very similar to that of 1900, but with two large exceptions—recreation and tourism. Because of the area's natural beauty and bounty, tourists and outdoor enthusiasts flock to Pacific County. Boating, recreational fishing and shellfishing, hunting, birdwatching, beachcombing, and shopping are now major players in the area's economy.

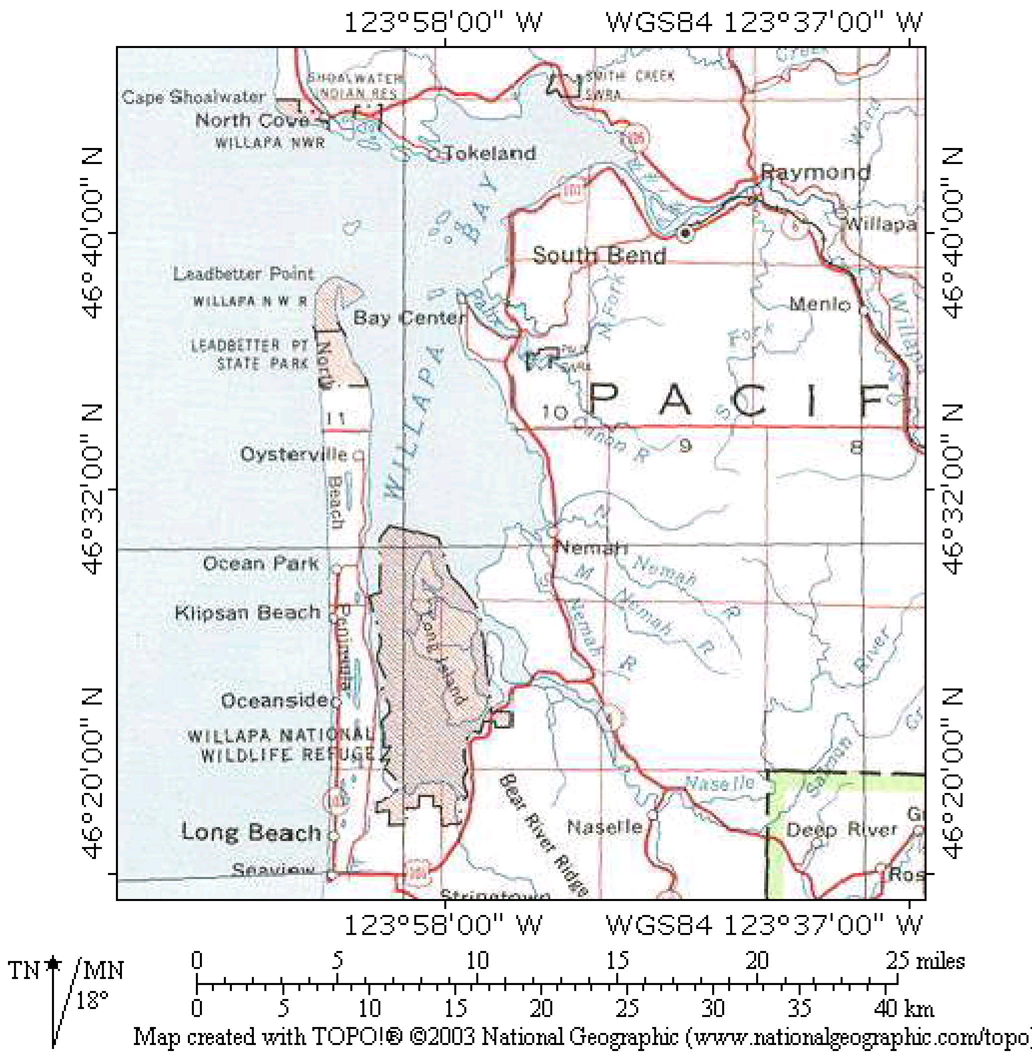

Figure 2. Map of Pacific County and its major population centers.

Spartina alterniflora

Spartina alterniflora Loisel. (Smooth Cordgrass) is the dominant marsh grass of low intertidal habitats along the East Coast of North America south through the West Indies and western South America (Mobberley 1956, Chapman 1960, Aberle 1993). In the northern part of its range Smooth Cordgrass comprises the lowest bands in the typical zonation within intertidal marshes. Two growth forms exist, though they are genetically identical (Valiela et al. 1978). The tall form inhabits the lowest intertidal band of vegetation, while the short form occupies the band just landward (Valiela et al. 1978, Bertness 1988). The phenotypic difference appears to be caused by differing nutrient availability in the two low marsh bands (Valiela et al. 1978). In the high marsh *Spartina patens* forms the seaward band, and *Juncus gerardi* forms the landward band (Bertness & Ellison 1987). This distinct pattern in the marsh community arises, in part, from *S. alterniflora's* ability to oxygenate its roots and rhizosphere through aerenchyma when submerged in saline waters, thus making it more suited than other marsh plants to the more frequently flooded lower marsh (Teal and Kanwisher 1966, Bertness 1991). Conversely, *S. alterniflora* is excluded from the upper marsh by *S. patens* and *J. gerardi*, due to the negative impacts increased peat accumulation and thick turf mass have on *S. alterniflora* (Bertness 1987, Bertness 1991).

The typical growth pattern of *Spartina alterniflora* begins when a seed or a viable root mass becomes established within the intertidal zone. These new plants form circular 'clones' which, in time, expand and coalesce with similar clones to form a solid, monospecific meadow (Figure 3). Both the clones and the meadows expand by trapping sediment. This in turn raises the level of the marsh above surrounding areas devoid of *Spartina*. Over time V-shape drainage channels become established, creating a mosaic of waterways and grass within the *Spartina* meadows.

Smooth cordgrass has been introduced intentionally in a number of locales worldwide, including England (Mobberley 1956, Ranwell 1967), France (Mobberley 1956, Ranwell 1967), China (Chung 1989) and New Zealand (Ranwell 1967, Partridge 1987) in order to take advantage of its ability to trap sediment in the intertidal area stabilizing coastlines and navigation channels. It has also become established unintentionally in many

Figure 3. Photographs depicting Spartina in two stages. The top is of an area in north Willapa Bay ('North Site') where the clones are beginning to coalesce into a meadow, the bottom of a meadow in east Willapa Bay ('Bruceport'). [Top picture by Lucas Limbach. Bottom picture by author.]

areas worldwide, including estuaries along the Pacific Coast of North America in Washington, Oregon, and California (Spicher and Josselyn 1985, Frenkel 1987, Aberle

1993). For a more detailed account of the worldwide distribution of *S. alterniflora* see Aberle (1993).

Spartina in Washington

In Washington State four species of invasive grasses of the genus *Spartina* have been found. *Spartina patens*, a native of the East Coast of North America, is known to exist in only one locale, Dosewalips State Park in Jefferson County. It is a small colony that was first discovered in the early 1990's, though its origin is not known (WSDA report 1999). *Spartina densiflora*, a South American native, was discovered in 2002 at two locations, one in Puget Sound and the other in Grays Harbor (WSDA report 2002). *Spartina anglica*, of English origin, has been found in seven Washington counties, all within the Puget Sound, and, as of 2002, covered over 700 acres (WSDA report 2002). *Spartina alterniflora*, however, is the species that has colonized the most intertidal acreage in Washington. It has been found in five counties, though only about 20 solid acres are known to exist (or have existed) in four of those counties (WSDA report 1999). The remaining county, Pacific (where Willapa Bay is located), had over 6,800 solid acres of *Spartina alterniflora* in 2002 (WSDA report 2002).

In Willapa Bay *Spartina* meadows are most prevalent along and at the mouth of almost every stream entering the bay. The largest meadows in southern portions of the bay can be found around Porter Point where the Bear River enters the bay and along the eastern and northern shores of Long Island near the mouth of the Naselle River. In northern portions of the bay, large meadows have colonized the mouths of the Palix, Bone, and Willapa Rivers. Smaller meadows are found along the eastern shore of the North Beach

Peninsula and in northern areas of the bay at the mouths of the Cedar and North Rivers and in protected waters surrounding Toke Point. As stated above, *S. alterniflora* covers 6,800 solid acres in the bay. However, 'solid acres' refers to the total area of coverage if all clones and meadows were contiguous. In actuality more than 6,800 acres are affected, and, before treatment efforts began, the grass had colonized nearly the entire shoreline ringing the bay.

Spartina Control in Washington

In 1989 *Spartina alterniflora* was added to the Washington State noxious weed list, and control efforts were begun immediately by the Washington State Department of Natural Resources (WDNR) and the United States Fish and Wildlife Service (USFWS). In 1995 the Washington State legislature mandated that the Washington State Department of Agriculture (WSDA) assume sole responsibility for the control of all *Spartina* species statewide in an attempt to facilitate an efficient and appropriate response to the newly declared ecological emergency (RCW 17.26.005 and 006). The legislature also loosened restrictions on control activities in aquatic environments to aid in the effort. Since the legislative action in 1995, the WSDA has been provided with an ever increasing budget for the control efforts. In fiscal year 2002 over $1.1million was spent statewide- of which over $766,000 was directed towards control efforts in Willapa Bay, and an estimated $1.9 million was earmarked for control efforts for fiscal year 2003 of which over $1.1million was to be spent in Willapa Bay (WSDA report 2002).

Though the WSDA is the lead agency in the *Spartina* control effort, a multitude of agencies and local groups play an integral role in management. The Washington State

Department of Fish and Wildlife (WDFW) and WDNR along with the USFWS, county noxious weed boards, tribal entities, private landowners, state universities, and WSDA treat *Spartina* and explore the impacts of the exotic and the treatment methods used to eradicate it. As lead agency, WSDA also allocates funds to the other entities, provides technical assistance, and reports to the state legislature on the progress of control efforts.

An integrated pest management plan is used in an effort to maximize control efficacy. The cordgrass is mowed, crushed, disked, rototilled, dug out, covered with black plastic, and sprayed with herbicide. The University of Washington- Olympic Natural Resource Center is also conducting a biological control project in Willapa Bay using planthoppers (*Prokelisia marginata*). If the control efforts are continued with adequate funding, the WSDA estimates that *Spartina* will be eradicated from Willapa Bay before 2010 (WSDA report 2002).

Though local support for control efforts is high, it would be a gross misstatement to say that everyone backs the control efforts or views *Spartina* in the same way. Many people are adamantly against the spraying of herbicide in any aquatic system, and others do not share the opinion that *Spartina* poses an imminent ecological threat. The managers mostly dismiss the concerns of the dissenting minority, though little scientific study is present to back their stance. Little is known about the possible implications of spraying pesticides in these aquatic systems, and very few studies have been conducted to quantify the effects *Spartina* has on estuarine communities where it is not native.

Shorebirds of Willapa Bay

Willapa Bay is a very important estuary for west coast migratory and wintering shorebirds, and meets the criteria to be considered a Site of International Significance for spring migratory shorebirds (Harrington and Perry 1995). Annually, hundreds of thousands of shorebirds use the bay during spring migration, and up to 90,000 use the bay as a wintering ground (Buchanan and Evenson 1997).

The first in depth study of shorebirds in Willapa Bay was conducted between June 1978 and June 1979 by Ralph Widrig (1979). The study, 61 survey days over twelve months, concentrated on the birds utilizing both sides of the Long Beach Peninsula. However, many of the birds that feed on the bay's northern, eastern and southern reaches roost along the outer beaches of the peninsula during high tide, so it is possible to get an idea of the numbers and species make up within the bay during the late 1970's. Since Widrig's census, there have been studies of the shorebirds in Willapa Bay at all seasons, but non have been as thorough.

Presently the Willapa National Wildlife Refuge (WNWR) is studying the possible effects that *Spartina* is having on shorebirds in the bay. This study includes many survey techniques to determine where the birds are feeding and roosting in the bay, and if and/or how they are using areas being occupied by *Spartina* and those that are being treated (Jaques 2002). Kim Patten, a biologist with Washington State University, has also developed a protocol for "watching" the birds remotely with cameras placed above areas in south bay in hopes of learning how or if the birds are using *Spartina* meadows and clone fields.

Common wintering shorebirds include Black-bellied Plovers (*Pluvialis squatarola*), Western Sandpipers (*C. mauri*), and Marbled Godwits (*Limosa fedoa*), but Dunlins (*Calidris alpina*) are by far the most common with up to 70,000 individuals present during the winter months (Widrig 1979, Buchanan and Evenson 1997). Many other species are found in lesser numbers during the same period. The birds can be found feeding all over the bay during rising and falling tides (Widrig 1979, Buchanan and Evenson 1997, Jaques 2002). It has been suggested that winter is the time of year that birds could be most affected by the continued spread of cordgrass, because, if it is true that the birds will not forage in the *Spartina* meadows, the loss of higher intertidal areas to *Spartina* spread coupled with shorter days could seriously impact the length of available feeding time for the birds (Goss-Custard and Moser 1988, Jaques 2002).

During spring migration, Dunlins, Western Sandpipers, and Short-billed Dowitchers (*Limnodromus griseus*) are the most common shorebirds found using Willapa Bay as a northbound, migratory staging area. From February to mid-May, groups numbering in the thousands can be found throughout the bay. Dunlins are the earliest migrants to move through the area. They slowly begin to increase from their wintering numbers by late January and reach their peak in late February, though their migration lasts into May (Widrig 1979). Western Sandpipers are the most abundant spring migrant, moving through between early-April and mid-May, though the bulk of the movement happens usually within a few days between mid-April and the first week of May (Widrig 1979, Jaques 2002). During this push, over 80,000 Western Sandpipers can be found in the bay at one time, though this is but a fraction of the number that can be found in Grays Harbor, just to the north, at the same time (Herman & Bulger 1981, Buchanan and Evenson 1997, Jaques

2002). Dowitchers, numbering in the thousands, can be found using the bay between early-April and early-May with a peak migration very similar in time to that of the Western Sandpipers (Widrig 1979).

The preferred feeding habitat for these wintering and migrating shorebirds (as well as that of Greater Yellowlegs, *Tringa melanoleuca*, and Semipalmated Plover, *Charadrius semipalmatus*: other fairly common shorebirds found in Willapa Bay) is estuarine mud flats (Hayman et al. 1986, Washington Dept. Fish and Wildlife [WDFW] 2002). The Western Sandpipers, Dunlins, both plovers, and Marbled Godwits can also be found on sandy coastal beaches (WDFW 2002). Pastureland and flooded fields are also suitable feeding and resting areas for many of these species, especially during high tide when the more preferred intertidal areas are unusable (Herman & Bulger 1981, Colwell & Dodd 1995, Colwell & Dodd 1997, WDFW 2002, personal observations). When not actively feeding, these birds tend to aggregate in large groups to roost on nearby outer beaches, sand islands, and upper marsh and pasture areas (Widrig 1979, Herman & Bulger 1981, Buchanan and Evenson 1997, Jaques 2002, personal observations). Most census techniques used to date in Willapa Bay employ methods for counting birds in these aggregations to estimate overall numbers of shorebirds in the bay (Widrig 1979, Buchanan and Evenson 1997, Jaques 2002).

METHODS

The field work for this study was done with one very precise purpose in mind—to determine if shorebirds utilizing Willapa Bay as a spring migratory staging area are employing the *Spartina* meadows and clone fields for foraging and/or roosting areas. All surveys were conducted during the peak migration period during the spring of 2003. The peak migration for the greatest variety of shorebird species was predicted using data collected by Widrig (1979), Buchanan and Evenson (1997), and Jaques (2002). Thus, it was decided that four surveys would be conducted at each site over the period April 11, 2003 to May 4, 2003 (Appendix A).

The surveys were conducted from the shore by two researchers at each site recording direct observations of birds within those sites (Figure 4). The researchers were

Figure 4. Author making observations at 'S-Curves' site. [Picture by Lucas Limbach]

each equipped with binoculars and 15-60x spotting scopes mounted on tripods. All observations including, but not limited to, shorebird activity, species and numbers; tidal movement; weather; and raptor presence were recorded on micro cassette and in field notebooks. One site was surveyed on each half of a tidal cycle, and only one full tidal cycle reliably fell within daylight hours each day. Thus, the maximum number of surveys conducted in one day was two. Each site was surveyed once each weekend over the four weekend period with surveys being conducted for each site twice during the falling tide and twice during the rising tide (See Appendix A for a summary of tide magnitude and timing during the survey dates for each site).

Survey times varied between 1 hour and 4 hours 10 minutes (Appendix A). The difference in survey time was necessary because each site had differing degrees of *Spartina* coverage and the magnitude of the tide varied by site and day. The actual survey length was determined by the distance *Spartina* had spread into the intertidal and the magnitude of the tidal movement for each site and each survey day. Since most shorebirds tend to feed at the edge of the ebbing or flowing tide line, the goal was to be present at each site as the tide line was passing through the band of cordgrass in order to determine if birds were feeding in the grass. Surveys were conducted between 2 hours after high tide to 2 ½ hours before low tide on falling tides and 1 ½ hours after low tide to 2 ½ hours before high tide on rising tides, though there was some variation due to availability of researcher time and differences in tidal magnitude.

Site selection began two weeks prior to the first survey in an attempt to ensure that *Spartina* cover was the same when the sites were chosen and when they were surveyed. Kim Patton was a great help in suggesting areas that fit the basic criteria needed for the study. The most important aspect for the site was its *Spartina* cover. Sites were chosen that had between 20 and 80% grass cover when the surveys began. Sites were also chosen based on their accessibility. The sites had to be within easy walking distance of public access areas and close enough to a public road to make travel between sites relatively fast. Finally, because bird use is not uniform throughout the bay, an attempt was made to choose sites that were distributed evenly around it.

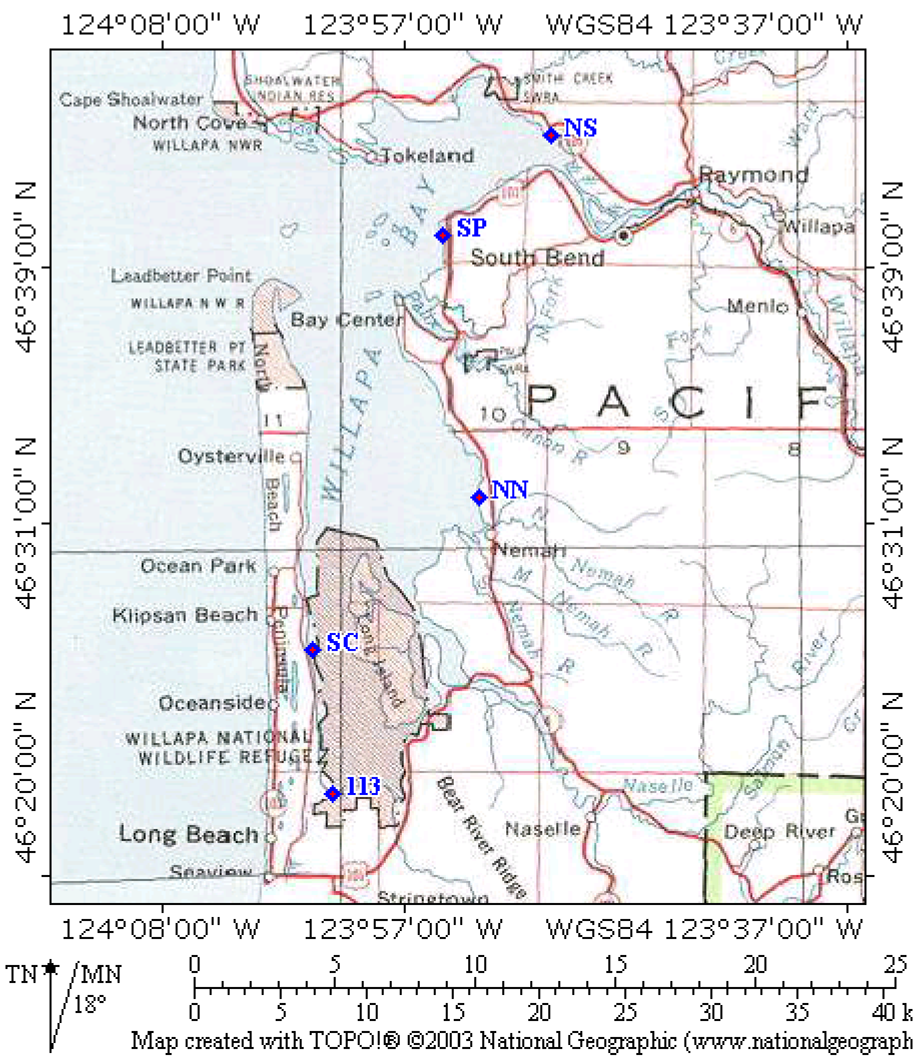

Figure 5. Locations of the five survey sites: S-Curves (SC), 113TH (113), North Nemah (NN), Stony Point (SP), and North Site (NS).

Five sites were chosen, two on the eastern shore of the peninsula, two on the eastern shore of the bay south of the Willapa River, and one on the northern shore of the bay just northwest of the mouth of the Willapa River (Figure 5). Site size varied due to shoreline shape and observation site lines, though an attempt was made to concentrate on bird activity within an approximate 1000 m semicircle surrounding the observation spot. All visible bird activity was noted when possible.

All the sites had *Spartina* clones and meadows to some degree, though cover was not identical (Figure 6). Three sites had been treated to some extent in 2002, but only one had been treated in 2001 (WSDA report 2001 and 2002). Though some of the sites had been treated in the previous two years, all but one site (S-curve site) had uninterrupted, solid expanses of *Spartina* present. The S-curve site was treated in 2002, and was chosen because it had several large clones in the intertidal and a band of mixed *Spartina* and arrowgrass along the lower intertidal upper marsh boundary. The goal was to survey the sites as the tide passed through the outer ‘clone fields’ first and then through the meadows (or visa versa) in order to see how the birds reacted to the grass. The amount of grass present and the proximity in time of its last treatment are surely factors in overall bird use, but this study was not designed to account for these variables. The study was only meant to document whether birds were using areas covered by varying amounts of *Spartina*.

All numbers of birds reported in this paper are count-estimates (Herman 1980). Whenever possible, actual counts of birds were made. However, many instances arose during the surveys that required quick estimation of total numbers. In these cases two methods of estimation were used. The first method resulted in concrete numbers. The

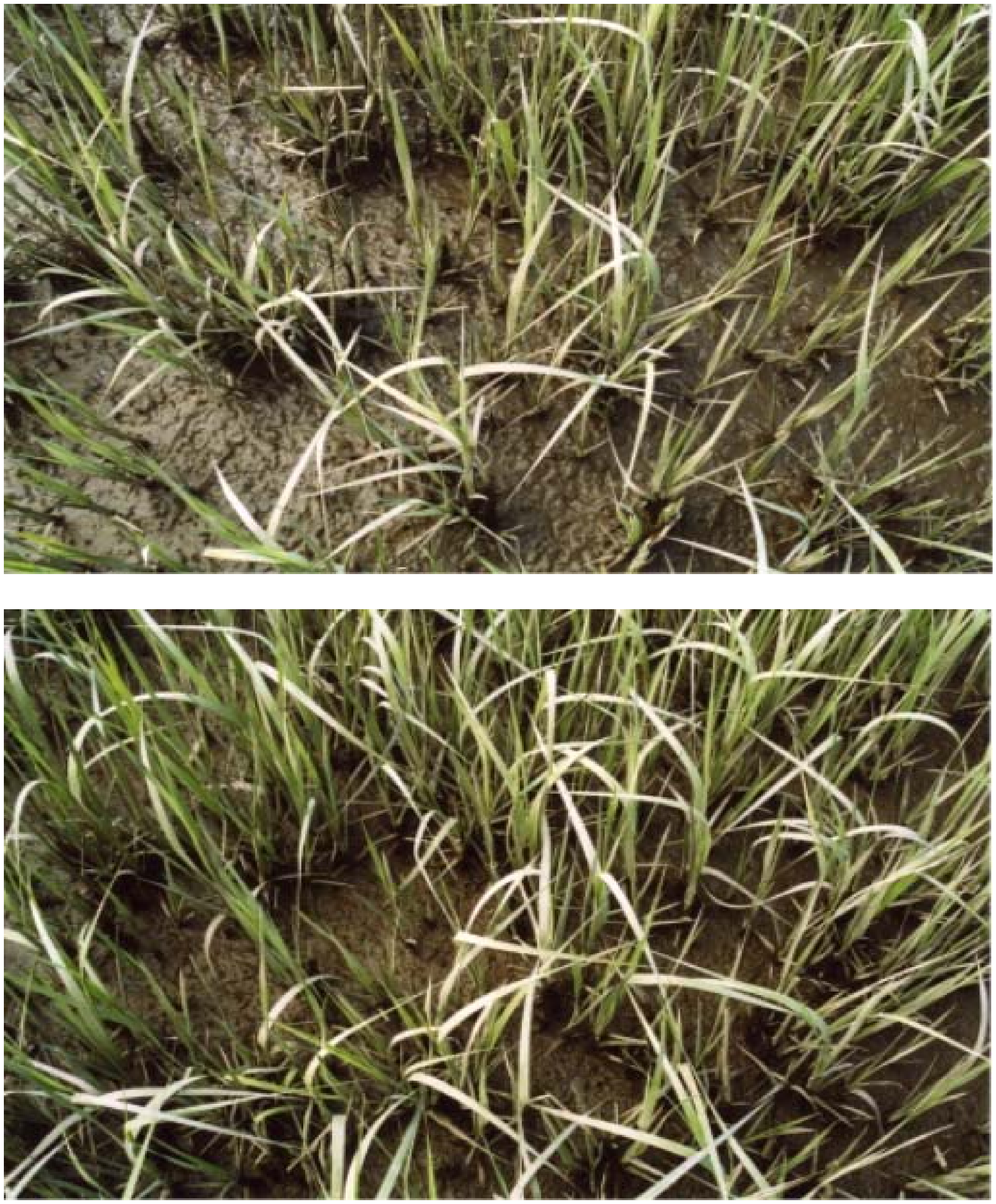

Figure 6. Differing stem densities of *Spartina***.** These two pictures show differing stem densities of *Spartina* plants at the same site (Stony Point). Not only was overall Spartina coverage of the sites different, but stem density was also different within and between sites.

second resulted in ranges. When compiling the data, the estimates were added to the concrete numbers resulting in total numbers for each site. If the results of the tabulations ended up being ranges, then the mean of the ranges were used to calculate and compare site numbers.

RESULTS

Shorebirds were documented utilizing areas of *Spartina* cover in all five sites surveyed. In all 10,825 individuals were observed in *Spartina* during the four weekends of study. Birds were seen feeding, roosting, and flying in and out of these areas. Often it was difficult to determine exactly what the birds were doing while in the cordgrass because the grass blocked the researchers' view. This became an increasing obstacle as the grass grew taller over the duration of the study. All instances of birds using *Spartina* were included in the general category of "birds in *Spartina*," even when instances of feeding, roosting, or other uses were determined by the observers. Seven species were documented utilizing cordgrass in the study sites, and one additional species was documented in cordgrass outside of the study areas (Table 1).

Dunlin (DUNL) was the species occurring in the greatest number in the grass with 4389 individuals recorded, and dowitcher (Long and Short-billed were lumped together, though Short-billed comprised >99% of the positively identified dowitchers [DOW spp]) was the second most numerous species positively identified with 2495 individuals recorded. Unidentified shorebirds (UID) were the second most numerous overall (3290). Western Sandpiper (WESA), Greater Yellowlegs (GRYL), Black-bellied Plover (BBPL), and Semipalmated Plover (SEPL) were also present in varying numbers. Four Least Sandpipers were identified in the grass on a trip to Leadbetter Point on April 26. It is a good possibility that Leasts were present in the study areas as well but were not separated from the other small sandpipers.

Table 1

Total birds in *Spartina* by species	
Dunlin	4389
Unidentified *	3290
Dowitcher spp. **	2495
Western Sandpiper ***	325
Greater Yellowlegs	250
Black-bellied Plover	51
Semipalmated Plover	25

* Unidentified consisted of unidentified "peeps" and mixed flocks with no % species make-up noted.
** Both Short-billed (99%) and Long-billed (1%) Dowitchers were identified in *Spartina* during the study.
*** 4 Least Sandpipers were observed in *Spartina* on Leadbetter Point on 4-26, but none were positively identified during the surveys.

The week of April 25- 27 marked the high point for total birds observed in the grass. Peak numbers of all but one species followed the pattern that Widrig determined for spring migration (Widrig 1979). Dunlin were present in large numbers in all of the first three weeks of the study, but peaked in the third week of the study, a full month past the peak migration for that species as determined by Widrig but near the time Buchanan (1997) found large concentrations in 1994. Total numbers of birds observed in *Spartina* grew steadily and peaked in the third week (5534 total birds) then dropped-off in the forth week (Tables 2 & 3). Large numbers of Western Sandpipers, normally expected near the last of April and the first of May, were never observed during the course of the study though there was a small increase observed over the time of the study. This could account for the drop in total numbers observed during the fourth week of the study.

Table 2

Total birds in *Spartina* by week and species

	DUNL	DOWI spp	WESA	GRYL	BBPL	SEPL	UID	TOTAL
Week 1 4/11-4/13	910	85	33	25	13	0	0	1066
Week 2 4/18-4/20	1117	725	75	105	37	0	300	2359
Week 3 4/25-4/27	2105	1185	100	45	1	8	2090	5534
Week 4 5/2-5/4	257	500	117	75	0	17	900	1866
TOTAL	4389	2495	325	250	51	25	3290	10,825

North Site, Stony Point, and North Nemah were respectively the top three sites in total numbers of birds seen in the grass (Tables 3 & 4). These were also the sites where the largest numbers of birds were observed in general during the survey period.

Table 3

Total birds in *Spartina* by site and week

f= falling tide r= rising tide

	NS	NN	SC	113	SP	TOTAL
Week 1 4/11-4/13	f 765	r 0	r 75	f 97	f 129	1066
Week 2 4/18-4/20	r 614	f 180	f 45	r 0	f 1520	2359
Week 3 4/25-4/27	f 5148	r 0	r 85	f 116	r 185	5534
Week 4 5/2-5/4	r 448	f 1225	f 174	r 19	f 0	1866
TOTAL	6975	1405	379	232	1834	10,825

Table 4

Total birds in *Spartina* by site and species

	NS	NN	SC	113	SP	TOTAL
DUNL	2812	215	167	45	1150	4389
DOWI spp.	1243	460	202	35	555	2495
WESA	100	105	5	40	75	325
GRYL	145	75	5	4	21	250
BBPL	7	0	0	11	33	51
SEPL	18	0	0	7	0	25
UID	2650	550	0	90	0	3290
TOTAL	6975	1405	379	232	1834	10,825

The S-curve site also had large concentrations of birds present, but the paucity of solid *Spartina* accounts for the diminished use of the grass by the birds. However, birds were observed feeding in the narrow band of arrowgrass at the upper marsh boundary on the last two weeks (with about 4000 present on April 26). The 113th site had the least number of birds both in the grass and at the site in general. Most of the birds observed from this site stayed well off to the east near Porter Point, the Bear River, and the southern end of Long Island, traditionally some of the best areas for shorebirds in the southern reaches of the bay.

Arguably the most interesting data collected during this study was related to bird use of *Spartina* during the tidal cycle. Across all sites birds overwhelmingly used the grass areas more on the falling tide than on the rising tide, with birds observed about 6.5 times more often on falling tides (Table 5). At the North Nemah site no birds were observed in *Spartina* on rising tides at all, and at both the 113th and Stony Point sites birds were not observed in the grass on one rising tide each. Observations for the individual species

Table 5

	Total birds in *Spartina* by site and tide					
	NS	**NN**	**SC**	**113**	**SP**	**TOTAL**
Rising	1062	0	160	19	185	1426
Falling	5913	1405	219	213	1649	9399

also followed the same pattern, except in the case of Semipalmated Plovers. Both total numbers and number of instances for every species (except Semipalmated Plover) found in *Spartina* were substantially higher on the falling tide (Table 6).

Table 6

	Total birds in *Spartina* by species and tide							
	DUNL	**DOWI spp**	**WESA**	**GRYL**	**BBPL**	**SEPL**	**UID**	**TOTAL**
Rising	182	458	17	95	7	17	650	1426
Falling	4207	2037	308	155	44	8	2640	9399

Generally, the birds began to arrive at the sites as the tide was passing through the band of *Spartina* on the falling tide. These birds were usually very active as they followed the ebbing tide through the grass; getting up, flying back and forth, and landing again at or near the tide line. Most of the birds arriving to feed at our sites did so before the tide reached the outer edge of the vegetated band. Often, birds were observed moving significant distances laterally along the shoreline, actively feeding in and at the edge of the *Spartina* band, even when open mud became available in front of the grass along the way. As the birds moved through the grass, they spread out more and more from their original, often tightly packed groups until they were finally beyond the grass.

The birds behaved very differently on the rising tide. If birds were observed using the grass on incoming tides, they normally did so in smaller numbers than the groups that were originally observed beyond the vegetation upon arrival. Generally, many more birds flew from the site when the majority of open mud at the edge of the *Spartina* had been covered than continued to move through the grass following the flooding tide line. Only twice, both at North Site, did we observe larger numbers of birds (>300) move through the entire band of vegetation with the rising tide (Figure 7). We never were able to document where the birds flew when they left early, but we surmise that they were moving to roost sites early, not to other places in the bay to continue foraging.

Figure 7. Shorebirds at North Site. This picture shows part of a mixed group of shorebirds (about 300 in all) that was witnessed following the tide line in with the rising tide at North Site. This group was observed foraging about equally in the openings between the grass and in the *Spartina* itself as it moved towards us.

In three instances we found large, mixed groups of shorebirds feeding and roosting in pastures near our sites when open mud was still available at other, nearby areas in the bay. A similar pattern was noted by Herman and Bulger (1981) during the spring in Grays

Harbor, Washington and by Brennan et al. (1985) with wintering Dunlin at various sites in Western Washington. Only a few birds were recorded moving into the upper marsh at our sites to roost on the rising tide, though birds were observed roosting at the sites at the beginning of falling tide. The difference could be due to a tidal magnitude effect or to bird movement during the high tide period.

We also observed one instance involving Peregrine Falcons that was of particular interest. On April 18th while at North Site, we witnessed two peregrines fly over a large group of shorebirds near the outer edge of the *Spartina* meadow. One bird flew inland towards us with an unidentified shorebird in its talons. The other bird circled higher before flying over us accompanied by two Bald Eagles. When the falcons were first spotted, we noticed that many groups of shorebirds flew up from in front of the meadow and landed in the grass, presumably seeking cover. This is of obvious interest because of the possibility that shorebirds can use *Spartina* as cover from predators.

DISCUSSION

Shorebirds may be adversely affected by invasive vegetation for three primary reasons. First, the birds could be excluded from the grass by physical characteristics, such as high stem density. Second, they could be psychologically predisposed to feeding only in open areas with undisturbed sight lines. Finally, they may be unable to fulfill their daily nutritional requirements due to a reduction of invertebrate prey bases within the grass. The first and second possibilities can be examined through direct observation of bird movements and use of colonized estuaries and through long-term population studies of birds in estuaries with differing amounts of exotic vegetation. The third requires both the examination of differences in available prey between vegetated and unvegetated areas as well as thorough investigations into the feeding behavior of the birds at each location in question.

Spartina and Shorebirds

It was expected that some use of areas covered by *Spartina* would be documented during the survey period. However, the variety and number of birds observed utilizing the grass was unexpected. Previous studies investigating the possible effects of the grass on shorebirds have implied a negative impact on overall numbers within and use of estuaries where *Spartina* is spreading.

Goss-Custard and Moser (1988) studied wintering Dunlin populations in different estuaries across Britain and found that numbers of shorebirds decreased significantly over the period between 1973-74 and 1985-86. The largest decreases were seen in estuaries where *Spartina anglica* had spread most significantly, though initial decreases in numbers

(1973-74 to 1977-78) were found to be independent of *Spartina* colonization while continued decreases (1977-78 to 1985-86) were correlated with its spread. The numbers of birds utilizing other estuaries where the grass was static or decreasing in density were not found to be increasing over the same period, thus giving the impression that the birds were not moving to alternate estuaries to winter. The belief is that both feeding area and time in which to feed during the winter months are being lost as the grass colonizes the higher intertidal areas, thus contributing to the observed decrease in wintering, British Dunlin. It was also noted that the grass had spread most in traditional high density feeding areas.

Davis and Moss (1982) studied the populations of four shorebird species as well as the spread of *Spartina anglica* in the Dyfi estuary in central Wales from 1969-1981. Though only a 10% increase in *Spartina* was noted, a significant decrease in three of the wader species was observed. As with the findings of Goss-Custard and Moser (1988), the grass spread most in traditional high-density shorebird areas. Numbers of Dunlin, Ringed Plover (C*haradrius hiaticula*), and Oystercatcher (*Haematopus ostralegus*) steadily decreased in all seasons after a peak in the early 1970's. Though a temporal correlation between an increase in *Spartina* and a decrease in waders was observed, no mechanical explanations were offered to explain the correlation.

Differences in shorebird feeding ecology and invertebrate communities were studied by Millard and Evans (1982) within *Spartina anglica* and on adjacent mudflats at Lindisfarne, England in the winter of 1973-74. Redshanks, *Tringa totanus*, were commonly observed feeding in *Spartina*, with up to 15% of the estuary's population feeding in the grass at all tidal levels, though it was found that they were mainly utilizing small areas of open mud within the meadows. Dunlins were observed avoiding the grass altogether. The researchers concluded that the difference in feeding ecology was probably due to flocking behavior as well as availability of desired prey.

Many species of shorebirds were found to be increasing in numbers in Langstone Harbour, England as the *Spartina anglica* meadows began to die back naturally during the 1970's (Haynes 1982). The increase in population was attributed to the increase in mudflat foraging areas and a beneficial change to the invertebrate community following the erosion of the *Spartina* meadows.

Evans (1986) observed similar results in Redshanks and other birds in the first two years after areas were treated with the herbicide 'Dalapon' in Lindisfarne, England. Again, it was concluded that changes in the invertebrate community following *Spartina* removal led to increased wader utilization. It was also suggested that desirable invertebrate species rebounded quickly in treated areas and that residual physical characteristics of the meadows led to greater prey availability and accessibility and, hence, greater bird use up to two years post treatment. However, continued growth of grass beyond two years resulted in decreasing use due to the supposed effects height (visibility) and shoot density (ability to land in and move through *Spartina*) have on waders. Contrary to these findings, the results of Goss-Custard and Moser's study (1988) suggest that die back of cordgrass in an estuary had no discernable effect on wader numbers even if the estuary had traditionally held larger numbers of birds before colonization by the grass. They hypothesized that the invertebrate community suffered from residual effects of the original impacts experienced during *Spartina* colonization, thus preventing birds from using these areas.

Nairn (1986) concluded that *Spartina* was a possible threat to Irish shorebirds based on a review of the English studies. No studies had been conducted in Ireland, so no firsthand evidence was used to reach this conclusion. The English studies are still the most detailed, in-depth research projects attempting to define the possible effects of *Spartina* on shorebird populations.

The most complete study conducted in the United States to determine the effects of invasive *Spartina* on shorebirds was conducted at the Willapa National Wildlife Refuge from 2000-2001 (Jaques 2002). The study is not as robust as those conducted in England, though results indicate that shorebird use of sparse to moderate density *Spartina* in Willapa Bay, Washington is less than use of open mud plots on flooding tides. The results, however, are limited; only five surveys were conducted from December 12, 2000 to March 23, 2001, none of which was during the period of greatest shorebird use of the bay -from mid-April to mid-May. Further, it was assumed that the birds did not use more dense stands of cordgrass, so such areas were not surveyed, and no consideration was made for possible tidal effects.

The field research contained in this paper is the only other study, found by the author, which attempts to examine the possible effects of *Spartina alterniflora* colonization on shorebird feeding behavior in Washington State.

Spartina and Invertebrate Communities

The effects that *Spartina* invasion has on native invertebrate communities have been studied in greater depth than the effects invasion has on shorebirds. Studies have mainly focused on the invasive *S. alterniflora* (Lana & Guiss 1991, Atkinson 1992, Zipperer 1996, Luiting et al. 1997) and *S. anglica* (Millard & Evans 1982, Jackson et al. 1985, Hedge and Kriwoken 2000). It is thought that changes in the physical nature of the habitat from unvegetated to vegetated may disrupt historic, invertebrate communities. These changes could, in turn, lead to disruptions in predator-prey relationships, energy flow, or other physical properties of the system. Examination of differences in invertebrate communities arising from colonization may help shed light on possible effects to birds, fish, crabs, and shellfish.

A preliminary study to quantify differences in invertebrate communities between plots colonized with *Spartina alterniflora* and adjacent mudflats was conducted in Willapa Bay, Washington in 1987 (Atkinson 1992). The study was limited in scope, though it did point to the conclusion that colonization had a negative effect on invertebrate life. Two subsequent studies, also in Willapa Bay, were conducted by students at the University of Washington (Zipperer 1996, Luiting et al. 1997). Both studies reached similar conclusions that differed from those of Atkinson. Both researchers found that the two communities were very similar on a coarse taxonomic scale. Density of organisms and species richness between vegetated and unvegetated plots was dependent on seasonal variations. The invertebrate community associated with *Spartina* was dominated by buried deposit feeders, suspension feeders, and predators where as the unvegetated community was dominated by surface feeders. *Corophium* spp., crustaceans, and mollusks were found in greater densities on the open mudflats, but the polychaete *Capitella capitata* and dipteran larvae were more common in the vegetated plots. The main factors affecting the communities were sediment grain size, shoot density, and below ground biomass.

A similar study was conducted in Paranagua Bay, Brazil, investigating invertebrate communities within native stands of *Spartina alterniflora* and adjacent mudflats (Lana & Guiss 1991). The researchers found both diversity and abundance of invertebrates to be significantly higher in the *Spartina alterniflora* plots than on the adjacent mudflats, though seasonal differences were documented. *Corophium* spp. were found more frequently on the mudflats while polychaetes were more common in the vegetation. Unlike the Zipperer and Luiting studies, however, Lana & Guiss found that suspension feeders were more common in the unvegetated plots. At all times the greatest invertebrate densities were correlated with the greatest detritus availability.

Studies to determine the differences in invertebrate communities inhabiting areas colonized by the invasive *Spartina anglica* and native mudflats in England and Tasmania have reached similar conclusions. Hedge and Kriwoken (2000) found significantly higher diversity and abundance of almost all invertebrate life in a Tasmanian *Spartina* marsh during the winter. However, seasonal variation in invertebrate communities has been documented in the USA (Zipperer 1996, Luiting et al. 1997), England (Jackson et al. 1985), and Brazil (Lana & Guiss 1991), so this study should be viewed in the narrow context of one season. In the UK Jackson et al. (1985) documented high densities of invertebrates, most notably the polychaete *Neries diversicolor,* within a *Spartina anglica* salt marsh, though Millard & Evans (1984) recorded mixed results elsewhere in the UK. The latter found that some *Spartina* plots had greater diversity and/or abundance than adjacent mudflats but some did not. *Corophium* spp., however, were always less abundant in the marsh.

Shorebird Feeding Ecology

Shorebirds in the Western Hemisphere rely on a diversity of prey in their diet (Skagen & Oman 1996). Many species of shorebirds utilize dual foraging strategies (visual and tactile) to increase the prey available to them (Hayman et al. 1986, Sutherland et al. 2000). They also show great variation in feeding patterns based on variations in tides, seasons, and moon stages (Dodd & Colwell 1998). Due to their migratory nature, they are required to utilize different prey sources as they move south and then back north during the course of a year. Skagen and Oman (1996) found that the most commonly cited prey for the ten most studied shorebird species were tellinid and venerid clams, gammarid and corophid amphipods, and nereid polychaete worms. Different species of these common prey resources can be found at most intertidal areas that waders utilize during their movements.

Many researchers have found that waders are opportunistic feeders that take advantage of the most abundant or most available prey resource at a given site (Goss-Custard et al. 1977(1), Goss-Custard 1977, Evans 1979, Brennan et al. 1990, Botton et al. 1994, Skagen & Knopf 1994, Smith & Nol 2000, Davis & Smith 2001). Thus, the highest density of foraging birds is expected to occur at sites with the highest densities of prey. It has also been noted that the birds may employ selective foraging techniques for more desired prey in addition to opportunistic foraging when multiple prey sources are abundant (Buchanan et al. 1985, Skagen & Oman 1996). Birds will utilize different prey at different sites within the same general region (Buchanan et al. 1985, Brennan et al. 1990) and different prey at different habitats within the same area (Smith & Nol 2000). Overall, however, high regional similarities in diet occur within the same species and between coexisting shorebirds of different species (Skagen and Oman 1996). Shorebirds have been documented moving to different sites when foraging conditions become unfavorable at preferred sites due to changes in habitat availability (Skagen & Knopf 1994, Warnock &

Takekawa 1995) or to changes in weather (Warnock et al 1995) though site fidelity has been reported as generally high both during migration (Herman & Bulger 1981) and on wintering grounds (Brennan et al. 1985, Warnock & Takekawa 1996). Shorebirds have also been recorded moving and/or changing prey bases when prey availability changes (Evans 1979), and moving from high-density bird and prey sites to lesser density sites to avoid competition (Botton et al. 1994).

There is little doubt that shorebirds are highly adaptable in their feeding ecology both during migration and on their wintering grounds. They are able to utilize the most abundant and/or available prey sources at any given location during most of the year. However, in certain situations shorebirds are forced to rely on a much narrower prey base. This often happens during the winter months when colder temperatures cause prey availability to be low (Evans 1979) and at migration staging areas that the birds are drawn to because of the abundance of one prey source, such as the Delaware Bay in the spring. Goss-Custard (1977) and Goss-Custard et al. (1977(2)) noted that shorebirds could be adversely affected by a loss of habitat on their English wintering grounds when prey availability is low, and Tsipoura and Burger (1999) hypothesized that a decline in horseshoe crab eggs, the main prey of spring, migrant shorebirds in the Delaware Bay, could have similar affects on shorebirds there. Thus, if prey resources are naturally limited, shorebirds may not be able to compensate for certain changes to their preferred foraging areas.

Studies documenting shorebird feeding ecology in Western Washington are limited. No studies were found from Willapa Bay. Brennan et al. (1990) described the diet of Dunlins during the winter of 1980-81 (December- March) in Puget Sound and Grays

Harbor.   Birds were found utilizing different prey resources at each of the four study sites. Polychaete and annelid worms were most common at one site, cumaceans at another, *Corophium* spp. at the third, and dipteran larvae at the forth. Buchanan et al. (1985) examined weight change in Dunlins as it relates to food habits and prey availability at the same four sites in Puget Sound and Grays Harbor and during the same winter as the Brennan study, and found that polychaete worms, the most abundant prey resource at all sites, were only consumed in proportion to its availability at one site. The study suggests that prey choice may involve a quality factor, and weight retention during the winter may be correlated with distance to available roosting sites. Both of these studies document that, though shorebirds in western Washington may not always choose prey based on availability, they employ a diversity of items in their diet throughout the region.

Wilson (1994) examined the impact that shorebirds have on the invertebrate community at Grays Harbor during spring migration and found polychaete worms and *Corophium* spp. to be the most commonly taken prey at his study site, implying that shorebirds feed opportunistically on multiple prey species during spring stopovers. He concluded that invertebrate populations were not significantly depleted by the very large number of birds present from late-April to mid-May. Other researchers have found that shorebirds significantly deplete prey at some sites over the course of a season (Goss-Custard 1977) or for a short period during and just after migration periods (Mercier & McNeil 1994). Wilson explains the differences in results as a function of length of stay rather than density of birds. Because stopover times of spring migratory shorebirds along the West Coast are typically less than 4 days (Iverson et al. 1996, Warnock and Bishop 1998), the birds are not able to significantly reduce their invertebrate prey.

CONCLUSION

Based on the research and literature review presented in this paper, it can not be considered a forgone conclusion that *Spartina alterniflora* colonization in Willapa Bay is a serious threat to the migrant shorebirds that utilize the bay's intertidal mudflats. It is also not a forgone conclusion that the colonies are benign in that regard. Some studies attempting to detect the possible effects invasive *Spartina* has had on shorebirds have concluded that the grass has a negative impact on the birds. However, these studies are generally limited in scope, and do not offer definitive proof that documented declines in shorebirds are caused by the invading grasses. Likewise, there is little information from Willapa Bay that would lead to this conclusion.

Documentation of shorebird use of native *Spartina* marshes is limited. Large numbers of shorebirds were reported moving between beach and salt-marsh habitats in Delaware Bay by Botton et al. (1994), though specific use of the marshes was not determined, and Burger et al. (1997) documented extensive use of Delaware Bay salt-marshes as foraging sites for shorebirds (7 species were found to be abundant, including: Dunlin, dowitcher, and Semipalmated Sandpiper). Tsipoura and Burger (1999) also found that marsh habitats were used frequently by foraging shorebirds in Delaware Bay, most notably by Semipalmated Sandpipers (*Calidris pusilla*). Thus, the current literature, though limited, suggests that shorebirds may rely on salt marshes as critical feeding areas within *Spartina alterniflora*'s native range. Why then would it be assumed that similar and, often, the same species would not utilize the grass where it is an exotic?

Many shorebird species have experienced population declines in North America and worldwide in the recent past (Howe et al. 1989, and Buchanan 2002). The causes of these declines are not fully understood, but many are the result of habitat loss. However, since populations are declining worldwide and *Spartina* invasion is not a worldwide phenomenon, there can be little certainty that the grass is the primary cause of decline in colonized estuaries. There are also problems associated with actually documenting shorebird use of the meadows due to the fact that the grass itself tends to obscure birds from sight. Survey methods not designed to account for visibility, tide stages and direction, time of year, as well as other variables may fail to gather reliable information on utilization of *Spartina* marshes by shorebirds. Thus, to assume that *Spartina* is the cause of shorebird population declines in colonized estuaries from the few studies conducted to date would be premature.

Shorebirds will make use of an area for foraging if an abundant food source is available. The *Spartina* colonized mudflats in Willapa Bay have been demonstrated to contain rich invertebrate communities comprised of many of the prey items that shorebirds commonly utilize such as polychaete worms and dipteran larva (Zipperer 1996, Luiting et al. 1997). Often these prey are more common within the *Spartina* than on the open mudflats. Hence, if the birds can use the area covered by grass, they will have access to an abundant food source.

The results of the fieldwork presented in this paper suggest that spring, migrant shorebirds in Willapa Bay may utilize *Spartina* covered areas to a significant extent, especially on the falling tide. More research is needed to refine and extend these results, and significant effort should be directed towards discovering the nature of the use. Care should be taken to account for variables such as season (with emphasis on spring and winter use by shorebirds), time of day, and tide stage, magnitude, and movement.

One might conclude based on the data presented in this paper that spring migrant shorebirds in Willapa Bay are able to meet their nutritional requirements. Why else would large numbers of birds forage in the meadows on the ebbing tide but not on the flooding tide even when open mud is available elsewhere in the bay? If the birds are not fully satiated by the time the flooding tide has reached areas covered by *Spartina*, one would assume that they would forage in the meadow as they do on the ebbing tide or move to areas free of vegetation to feed until all possible areas are covered by water. Individual birds will 'fill up' at different rates during the peak feeding time, and many observers have noted birds moving to roosting sites before all suitable foraging areas have been made inaccessible by the tide in areas free of vegetation (personal observations and personal communications). In these cases one would be forced to assume that the birds that leave are full and those that stay are not. This phenomenon may explain why the meadows are used less frequently on the flooding tide.

The use of pesticides in attempts to control or eradicate invasive species is a risky undertaking. Unintended impacts to non-target species are difficult to eliminate, especially in aquatic and coastal environments where wind and water can cause greater problems with chemical drift. In any situation where chemical application is considered as a management tool, there should be overwhelming evidence that irreparable harm will be caused by the unwanted organism before control is attempted. Though the *Spartina* colonization of Willapa Bay is a subject of concern, there is limited research available that demonstrates that the presence of the grass will cause a significant, negative impact to the native flora and fauna of the estuary. There is even less evidence to suggest that shorebirds using the bay as a migratory stopover or wintering ground have been or will be significantly impacted. Without further research documenting such impacts, current management practices with the aim of eradication may require reconsideration. Ultimately, *Spartina* occupation of Willapa Bay will impact shorebirds adversely only if their food supply is limited by the plant; the fact that shorebirds utilize patches of *Spartina* argues against that as an inevitable result of the colonization.

Works Cited

Aberle, Barbara L. 1993. The biology and control of introduced *Spartina* (cordgrass) worldwide and recommendations for its control in Washington. Master's Thesis, Evergreen State College. 176p.

Andrews, R.S. 1965. Modern sediments of Willapa Bay, Washington; a coastal plain survey. University of Washington, Department of Oceanography. Seattle, Washington. Technical Report #118.

Atkinson, James B. 1992. A preliminary investigation of benthic invertebrates associated with intertidal mudflats and intertidal mudflats infested with *Spartina* at one location in Willapa Bay, Washington. . Courtesy of Willapa NWR. Ilwaco, Washington.

Bertness, M.D. & A.M. Ellison. 1987. Determinants of pattern in a New England salt marsh plant community. Ecological Monographs **57**: 129-147.

-------. 1988. Peat accumulation and the success of marsh plants. Ecology **69**: 703-713.

-------. 1991. Zonation of *Spartina patens* and *Spartina alterniflora* in a New England salt marsh. Ecology **72**: 138-148.

Botton, Mark L., Loveland, Robert E., & Jacobsen, Timothy R. 1994. Site selection by migrating shorebirds in Delaware Bay, and its relationship to beach characteristics and abundance of horseshoe crab (*Limulus polyphemus*) eggs. The Auk **111**(3): 605-616.

Brennan, Leonard A., J.B. Buchanan, S.G. Herman, & T.M Johnson. 1985. Interhabitat movements of wintering dunlins in Western Washington. The Murrelet **66**: 11-16.

-------, Finger, Michael A., Buchanan, Joseph B., Schick, Charles T., & Herman, Steven G. 1990. Stomach contents of dunlins collected in Western Washington. Northwest Naturalist **71**: 99-102.

Buchanan, Joseph B., L.A. Brennan, C.T. Schick, M.A. Finger, T.M. Johnson, & S.G. Herman. 1985. Dunlin weight changes in relation to food habits and available prey. Journal of Field Ornithology **56**(3): 265-272.

------- & Joseph R. Evenson. 1997. Abundance of shorebirds at Willapa Bay, Washington. Western Birds **28**: 158-168.

-------. 2002. Shorebirds: plovers, oystercatchers, avocets and stilts, sandpipers, snipes, and phalaropes. In Volume IV: Birds. Washington Department of Fish and Wildlife. Found at http://www.wa.gov/wdfw/hab/phs/vol4/birdrecs.htm.

Burger, Joanna, Niles, Larry & Clark, Kathleen. 1997. Importance of beach, mudflat and marsh habitats to migrant shorebirds on Delaware Bay. Biological Conservation **79**: 283-292.

Chapman, V.J. 1960. Salt marshes and salt deserts of the world. Leonard Hill Ltd, London.

Chung, H.C. 1989. Ecological engineering of coastlines with salt marsh plantations. In Ecological Engineering: An Introduction to Ecotechnology, eds. W.J. Mitsch and S.E. Jorgensen (John Wiley and Sons, Inc., New York), pp. 255-289.

Colwell, Mark A. & Dodd, Sarah L. 1995. Waterbird communities and habitat relationships in coastal pastures of northern California. Conservation Biology **9**(4): 827-834.

------- & -------. 1997. Environmental and habitat correlates of pasture use by nonbreeding shorebirds. The Condor **99**: 337-344.

Daehler, Curtis C. & Strong, Donald R. 1996. Status, prediction and prevention of introduced cordgrass *Spartina* spp. invasions in Pacific Estuaries, USA. Biological Conservation **78**: 51-58.

Davis, Craig A. & Smith, Loren M. 2001. Foraging strategies and niche dynamics of coexisting shorebirds at stopover sites in the southern Great Plains. The Auk **118**(2): 484-495.

Davis, Peter & Moss, D. 1984. *Spartina* and waders—the Dyfi estuary. In: Spartina anglica *in Great Britain*. ed. Pat Doody. Nature Conservancy Council, Attingham Park, pp. 37-40.

Dodd, Sarah L. & Colwell, Mark A. 1998. Environmental correlates of diurnal and nocturnal foraging patterns of nonbreeding shorebirds. The Wilson Bulletin **110**(2): 182-189.

Evans, P.R. 1979. Adaptations shown by foraging shorebirds to cyclic variations in the activity and availability of their intertidal invertebrate prey. In Cyclic phenomena in marine plants and animals: proceedings of the 13th European marine biology symposium, eds. E. Naylor & R.G. Hartnoll (Pergamon Press Ltd., Oxford, England), pp. 357-366.

-------. 1986. Use of the herbicide 'Dalapon' for control of *Spartina* encroaching on intertidal mudflats: Beneficial effects on shorebirds. Colonial Waterbirds **9**(2): 171-175.

Frenkel, R.E. 1987. Introduction and spread of cordgrass (*Spartina*) into the Pacific Northwest. Northwest Environmental Journal **3**: 152-154.

Goss-Custard, J.D., R.E. Jones & P.E. Newbery. 1977(1). The ecology of the Wash I: distribution and diet of wading birds (*Charadrii*). Journal of Applied Ecology **14**: 681-700.

-------, R.A. Jenyon, R.E. Jones, P.E. Newbery & R. LE B. Williams. 1977(2). Ecology of the Wash II: seasonal variation in the feeding condition of wading birds (*Charadrii*). Journal of Applied Ecology **14**: 701-719.

-------. 1977. Ecology of the Wash III: density-related behavior and the possible effects of a loss of feeding grounds on wading birds (*Charadrii*). Journal of Applied Ecology **14**: 721-739.

------- & Moser, M. E. 1988. Rates of change in the numbers of Dunlin, *Calidris alpina*, wintering in British estuaries in relation to the spread of *Spartina anglica*. Journal of Applied Ecology **25**: 95-109.

Harrington, B. & E. Perry. 1995. Important shorebird staging sites meeting western hemisphere shorebird reserve network criteria in the United States. Unpublished Report produced for the USFWS.

Hayman, Peter, Marchant, J. & Prater, T. 1986. Shorebirds: An identification guide. Houghton Mifflin Company, Boston.

Haynes, F.N. 1982. *Spartina* in Langstone Harbour, Hampshire. In: Spartina anglica *in Great Britain*. ed. Pat Doody. Nature conservancy Council, Attingham Park. pp. 5-10.

Hedge, Paul & Kriwoken, Lorne K. 2000. Evidence for effects of *Spartina anglica* invasion on benthic macrofauna in Little Swanport estuary, Tasmania. Austral Ecology **25**: 150-159.

Herman, Steven G. 1980. The Naturalist's Field Journal. A manual of instruction based on a system established by Joseph Grinnell. Buteo Books, Vermillion SD. ISBN 0-931130-13-1 200pp.

Herman, Steven G. & Bulger, John B. 1981. The distribution and abundance of shorebirds during the 1981 spring migration at Grays Harbor, Washington. Contract # DACW67-81-M-0936. U.S. Army Corps of Engineers.

Howe, Marshall A., Giessler, Paul H., & Harrington, Brian A. 1989. Population trends of North American shorebirds based on the International Shorebird Survey. Biological Conservation **49**: 185-199.

Iverson, George C., Warnock, Sarah E., Butler, Robert W., Bishop, Marry Anne & Warnock, Nils. 1996. Spring migration of Western Sandpipers along the Pacific coast of North America: a telemetry study. The Condor **98**:10-21.

Jackson, D., Mason, C.F., & Long, S.P. 1985. Macro-invertebrate populations and production on a salt-marsh in east England dominated by *Spartina anglica*. Oecologia **65**: 406-411.

Jaques, Deborah. 2002. Shorebird status and effects of *Spartina alterniflora* at Willapa NWR. Courtesy of Willapa NWR. Ilwaco, Washington.

Lana, Paulo da Cunha & Guiss, Claudia. 1991. Influence of *Spartina alterniflora* on structure and temporal variability of macrobenthic associations in a tidal flat of Paranagua Bay (southeastern Brazil). Marine Ecology Progress Series **73**: 231-244.

Luiting, Victoria T., Cordell, Jeffrey R., Olson, Annette M., and Simenstad, Charles A. 1997. Does exotic *Spartina alterniflora* change benthic invertebrate assemblages. Proceedings of the Second International *Spartina* Conference. Olympia, Washington.

Mercier, Francine & McNeil, Raymond. 1994. Seasonal variations in intertidal density of invertebrate prey in a tropical lagoon and effects of shorebird predation. Canadian Journal of Zoology **72**: 1755-1763.

Millard, A. V. & Evans P.R. 1984. Colonization of mudflats by *Spartina anglica*; some effects on invertebrate and shore bird populations at Lindisfarne. In: Spartina anglica *in Great Britain*. ed. Pat Doody. Nature conservancy Council, Attingham Park. pp. 41-48.

Mobberly, D.G. 1956. Taxonomy and distribution of the genus *Spartina*. Iowa State College Journal of Science **30**: 47-574.

Nairn, R.G.W. 1986. *Spartina anglica* in Ireland and its potential impact on wildfowl and waders—a review. Irish Birds **3**: 215-228.

Partridge, T.R. 1987. *Spartina* in New Zealand. New Zealand Journal of Botany **25**: 567-575.

Ranwell, D.S. 1967. World resources of *Spartina townsendii* (sensulato) and economic use of *Spartina* marshlands. Journal of Applied Ecology **4**: 239-256.

Sayce, Kathleen 1988. Introduced cordgrass, *Spartina alterniflora* Loisel., in salt marshes and tidelands of Willapa Bay, Washington. U.S. Fish and Wildlife Service, Willapa Bay National Wildlife Refuge, Ilwaco, Washington. 70 p. FWSI-87058(TS).

Skagen, Susan K. & Knopf, Fritz L. 1994. Migrating shorebirds and habitat dynamics at a prairie wetland complex. Wilson Bulletin **106**(1): 91-105.

------- & Oman, Heather D. 1996. Dietary flexibility of shorebirds in the western hemisphere. Canadian Field-Naturalist **110**(3): 419-444.

Spicher, D. & M. Josselyn. 1985. *Spartina* (Gramineae) in Northern California: Distribution and taxonomic notes. Madrono 332: 158-209.

Smith, Adam S. & Nol, Erica. 2000. Winter foraging behavior and prey selection of the semipalmated plover in coastal Venezuela. The Wilson Bulletin **112**(4): 467-472.

Sutherland, T. F., Shepard, P. C. F. & Elner, R. W. 2000. Predation on meiofaunal and macrofaunal invertebrates by Western Sandpipers (*Calidris mauri*): evidence for dual foraging modes. Marine Biology **137**: 983-993.

Teal J.M. & J.W. Kanwisher. 1966. Gas transport in the marsh grass, ***Spartina alterniflora*.** Journal of Experimental Botany **17**: 355-361.

Tsipoura, Nellie & Burger, Joanna. 1999. Shorebird diet during spring migration stopover on Delaware Bay. The Condor **101**: 635-644.

Valiela, I., J.M. Teal, & W.G. Deuser. 1978. The nature and growth forms in the salt marsh grass, *Spartina alterniflora*. American Naturalist **112**: 461-470.

Warnock, Nils, Page, Gary W. & Stenzel, Lynne E. 1995. Non-migratory movements of dunlins on their California wintering grounds. The Wilson Bulletin **107**(1): 131-139.

------- & Bishop, Mary Anne. 1998. Spring stopover ecology of migrant Western Sandpipers. The Condor **100**(3): 456-467.

Warnock, Sarah & Takekawa, John Y. 1995. Habitat preferences of wintering shorebirds in a temporally changing environment: western sandpipers in the San Francisco Bay estuary. The Auk **112**(4): 920-930.

------- & -------. 1996. Wintering site fidelity and movement patterns of western sandpiper *Calidris mauri* in the San Francisco Bay estuary. Ibis **138**: 160-167.

Washington Department of Fish and Wildlife. 2002. Shorebirds: Plovers, oystercatchers, avocets and stilts, sandpipers, snipes, and phalaropes. Volume IV: Birds. Prepared by Joseph B. Buchanan. Found: www.wa.gov/wdfw/hab/phs/vol4/birdrecs.htm

Washington State 54th Legislature. 1995. Revised Code of Washington, Chapter 17.26.

Washington State Department of Agriculture. 1999. Report to the legislature: Progress of the *Spartina* and Purple Loosestrife eradication and control programs. Prepared by B. Reeves, Statewide *Spartina* Control Coordinator, Washington Department of Agriculture.

Washington State Department of Agriculture. 2001. Report to the legislature: Progress of the *Spartina* eradication and control program. Prepared by K.C. Murphy, Statewide *Spartina* Control Coordinator, Washington Department of Agriculture.

Washington State Department of Agriculture. 2002. Report to the legislature: Progress of the 2002 *Spartina* eradication program. Prepared by K.C. Murphy, Statewide *Spartina* Control Coordinator, Washington Department of Agriculture.

Washington State Department of Fish and Wildlife (Fish Program). 2001. Aquatic Nuisance Species Management Plan. Coordinated by Pamala Meacham of the Washington State Department of Fish and Wildlife for the Washington Aquatic Nuisance Species Committee.

Widrig, Ralph S. 1979. The shorebirds of Leadbetter Point: A twelve month census with notes on other records from Willapa Bay, Washington. Independent Publication.

Wilson, Herbert W. Jr. 1994. The effects of episodic predation by migratory shorebirds in Grays Harbor, Washington. The Journal of Experimental Marine Biology and Ecology **177**: 15-25.

Zipperer, Victoria T. 1996. Ecological effects of the introduced cordgrass, *Spartina alterniflora*, on the benthic community structure of Willapa Bay, Washington. Master's Thesis. University of Washington.

Appendix A

Tides, magnitudes, and survey times for each site by date.
F or R indicate whether surveys were done on the falling or rising tide.
Tide times and magnitudes are approximations from nearby tide tables.

	NORTH SITE (NS)			
	F	R	F	R
	4/11/2003	**4/18/2003**	**4/23/200**	**5/2/2003**
High Tide	9:00	15:50	9:30	15:20
Magnitude	8.0	9.2	7.5	7.9
Low Tide	16:00	9:20	16:00	8:50
Magnitude	0.9	-2.0	0.9	-0.7
Start	11:30	11:30	12:30	11:30
End	14:30	14:00	14:00	13:40

	S-CURVES (SC)			
	R	F	R	F
	4/13/2003	**4/19/2003**	**4/26/200**	**5/3/2003**
High Tide	11:50	3:50	11:10	3:10
Magnitude	8.6	10.5	7.4	9.0
Low Tide	6:20	11:10	5:40	10:30
Magnitude	2.7	-1.9	2.7	-0.8
Start	7:00	6:30	6:30	6:00
End	8:20	8:00	8:00	7:00

	STONY POINT (SP)			
	F	F	R	R
	4/13/2003	**4/20/2003**	**4/27/2003**	**5/4/2003**
High Tide	11:20	4:10	11:40	16:40
Magnitude	8.7	10.4	7.7	7.2
Low Tide	17:50	11:00	5:30	10:20
Magnitude	0.2	-1.7	2.0	-0.7
Start	12:00	6:45	6:40	12:30
End	15:30	8:30	8:50	14:00

Appendix A continued

	NORTH NEMAH (NN)			
	R	F	R	F
	4/11/2003	**4/18/2003**	**4/25/2003**	**5/2/2003**
High Tide	10:50	15:50	22:50	15:20
Magnitude	7.3	9.0	7.7	7.7
Low Tide	16:10	21:50	16:20	21:00
Magnitude	0.9	1.3	0.9	2.4
Start	16:00	17:20	17:00	17:00
End	19:30	20:00	19:15	19:40

	113TH (113)			
	F	R	F	R
	4/12/2003	**4/19/2003**	**4/26/2003**	**5/3/2003**
High Tide	10:40	17:10	11:10	16:30
Magnitude	8.1	8.6	7.4	7.6
Low Tide	18:00	11:10	18:00	10:30
Magnitude	0.5	-1.9	1.0	-0.8
Start	12:15	13:30	12:30	12:30
End	14:50	15:15	14:45	14:30