SITE-SPECIFIC PROJECTS

The Research Coordinators at the Reserves and Sanctuaries support a variety of research projects on NIS (**Appendix F**) and have expert knowledge about their protected areas. Therefore, we planned to capitalize on the local expertise and interests of these participants through site-specific projects in all the 5 Reserves and Monterey Bay and Olympic Coast Sanctuaries. Many of these projects will be expanded upon; they served as pilot studies that can be conducted at multiple protected areas in the future or at the same one over time.

List of Site-Specific Projects (alphabetical, by protected area)

- Elkhorn Slough NERR:
  - Habitat correlates of invasive green crabs; native to invasive crab ratios across sites
- Kachemak Bay NERR
  - Inter-annual variability of NIS recruitment at System Wide Monitoring stations
  - Effects of shipping policy change on NIS
  - Seasonal patterns of NIS recruitment
  - Educational programs for NIS on settling plates
- Monterey Bay NMS
  - Monitoring of NIS in more exposed, deeper areas; NIS impact to natural hard substrate
  - Identification of organisms attached to hard substrate in the harbor
- Olympic Coast NMS
  - Rapid assessment for invasive species in the southern third of the sanctuary (rest done)
- Padilla Bay NERR
  - Distribution, rate of spread, and impacts of NIS eelgrass, *Zostera japonica* in Padilla Bay
  - Patterns of barnacle larval dispersal
- South Slough NERR
  - NIS impacts along a salinity cline
  - NIS impacts in a Reserve versus an adjacent commercial bay
- Tijuana River NERR
  - Community composition of sessile invertebrates in artificially warmed water (power plant) versus cooler water nearby and in local marinas
  - Fouling organisms on natural hard substrate in TRNERR
  - Monitoring for Japanese Oyster, *Crassostrea gigas*
  - Effects of tamarisk, *Tamarix ramosissima*, invasion and eradication on salt marsh habitat

Site-Specific Project Reports

Elkhorn Slough NERR, Kerstin Wasson

Invasion Monitoring Report, June 2005

Prepared by R. Kvist Preisler

Invertebrate monitoring is among the many important monitoring programs in Elkhorn Slough. During the past 5 years of crab monitoring we have qualitatively noticed what seems to be an increasing abundance of the invasive European green crab in the slough. Traditionally, the crab monitoring has consisted of 10 days per year of sampling using minnow traps and settlement trays. To complement the monitoring by SERC and to compare whether there is a difference in green crab abundance and distribution among habitats we set out minnow traps and collapsible traps during two 4-day periods of low tides in June and July 2004 at 3 different locations: Kirby Park (KP), Whistlestop Lagoon (WL), North Marsh (NM). We set 6 traps (depending on the specific site) every day and checked the traps the following day. For each individual green crab caught we measured carapace width, claw size, and determined sex. In order to investigate whether green crabs exhibited depth or tidal flow rate preference, within each site (KP, WL, NM) we set traps at all of the following locations within each site: Tidal height: Intertidal, subtidal; Tidal flow: Full tidal flow, muted tidal flow. We found that green crab abundances were higher at sites with full, rather than with muted tidal flow ($p = 0.009$). We also found that green crab abundance was not related to depth: intertidal (0 ft) vs. subtidal (–2 ft) ($p = 0.53$).

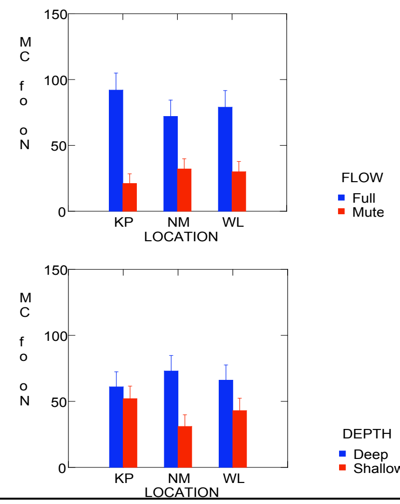


Figure 1. Above: Green crab abundances at full and muted flow within the same site. **Below:** Green crab abundances at 0 ft and – 2ft within the same site.

Because the European green crabs seem to have rapidly increased in abundance and distribution within Elkhorn Slough we wished to increase the effort of crab monitoring across many sites. In order to investigate whether there are certain trends in as to where green crabs are found we set 9 crab traps at 1 or 2 sites during two low tide series of 8 and 9 consecutive days during the month of April 2005 (**Fig ES-2**). We found that, in general European green crabs are found at the sites in the slough located along the main channel, rather than in smaller tidal creeks or diked areas with limited tidal flow. We detected large spatial and temporal variation in crab abundance. Quantifying this variation is useful as a basis for power analysis to inform the design of future long-term monitoring programs.

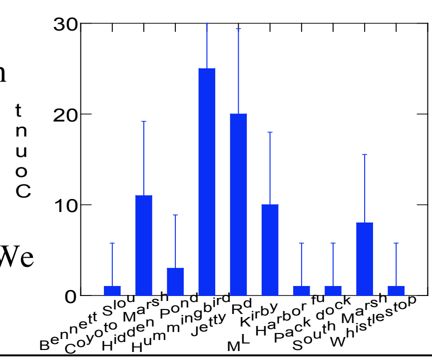


Figure 2. Number of green crabs found at 10 different sites

We also looked at whether ratios of native crabs to invasive crabs varied at different sites within Elkhorn Slough. We found that invasive crabs dominate more than half of the surveyed sites (**Fig ES-3**). These data were also obtained from the 17 days of sampling described above.

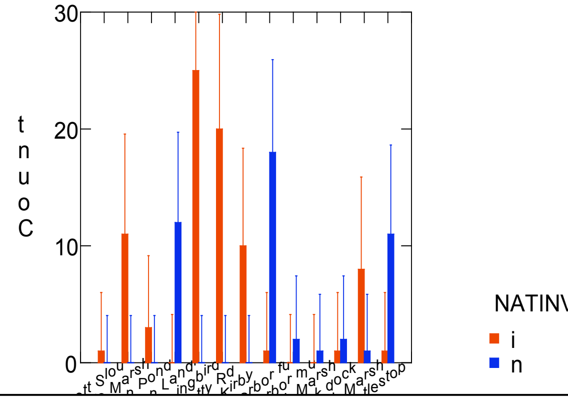


Figure 3. Number of green crabs relative to native crabs at 13 different sites

Furthermore, the traps we used also captured various fishes, i.e. sculpins, long jaw mudsuckers, sticklebacks and top smelt. The numbers of fishes that we caught are insufficient for any statistical analyses but identifying all fishes allows us to compile a species list for sites that have never before been sampled for fishes.

In addition to the work we originally proposed, we also seined for crabs and fish at each site sampled during the 17 days mentioned above. Again, we found that green crabs are found in the main channel of Elkhorn Slough, rather than in areas that are diked and/or have muted tidal flow. (The fish data from this work are part of a larger, unrelated study and are being presented elsewhere.)

To sum up, we found that green crabs appear to prefer full tidal flow over muted tidal flow, and are absent from sites with minimal tidal flow. We did not find any significant patterns with regard to depth (intertidal or subtidal). We did find significant differences among sites between ratios of native to invasive crabs.

Kachemak Bay Research Reserve, Scott Pegau

The KBNERR has been working with SERC to examine the interannual and seasonal variation in species on settling plates. Documenting patterns of temporal variation will help identify optimal timing of plate deployment and soak duration. In addition, we will use seasonal information to contrast recruitment times of different taxa in Alaska and to determine whether non-native species have different peak recruitment time from native ones. Interannual variation data will allow us to know how representative any year's data are. More importantly, multiple years of surveying will help identify what factors are correlated with peak recruitment of non-native and of native organisms.

Settling plates were placed on floating docks within the Homer harbor in 2003-2005. Between June 2004 and March 2005 we replaced the plates every three months. The last of these seasonal plates were pulled from the water at the end of June 2005. The plates from 2005 have not been analyzed yet.

A quick look at the plates showed relatively heavy loading for plates out from July 2004 to September 2004. The communities appeared to be different at each of the locations monitored.

There was no visible fouling of plates deployed from September 2004 to December 2004. One plate was checked on a monthly basis; it appears that organisms had settled by the end of October, but they were no longer present in December. We also found many larval organisms in the water column as late as November 2004. There were extremely few organisms present on plates deployed between December 2004 and March 2005. There were also relatively few organisms found on the plates deployed between March and June 2005. Interestingly, in June 2005 at a nearby site where we monitor temperature the probe had the heaviest biofouling of barnacles we had ever experienced. Yet there were very few barnacles present on the plates within the nearby harbor.

We are presently completing a set of protocols designed to allow school children to monitor for the presence of non-indigenous crabs. We expect that the education group will provide these protocols to schools in the surrounding villages. By working with the schools we can greatly expand our monitoring scope.

Monterey Bay NMS, Steve Lonhart & Andrew DeVogelaere

Prepared by Steve Lonhart

Invasive marine species are found in a wide variety of habitats, but harbors and ports are particularly invaded. This is in part due to vessel traffic that serves as an important vector, spreading invaders from one port to another. Monterey Harbor is a relatively small harbor, serving mostly recreational sailing vessels. However, even this small harbor is currently the home of at least a dozen marine invaders. Studies on invasive species within the harbor have been limited to one-time surveys or single-species projects. Long-term monitoring and extensive species identifications are lacking.

Our program involves two primary components. First, we will use a digital camera in an underwater housing to take photo quadrats. These images, covering a fixed area (a 10 by 10 cm square), will be taken at a variety of sites within the harbor. Our purpose is to collect high-resolution digital images of sessile invertebrates attached to the docks, pier pilings, and sea walls at fixed locations. These images can then be used to track changes through time at regular intervals (extending this work beyond the NFWF grant, but supported by MBNMS). In addition, taxonomic experts will use these images for identification.

The second component involves collecting specimens for identification by taxonomic experts. In conjunction with taking digital images, we will collect invertebrate specimens from selected locations. One group that is particularly hard to identify is the tunicates. We will collect all tunicate species, preserve them, and ship them to Dr. Gretchen Lambert for identification.

These in situ photographs and verified identifications will be placed on the Sanctuary Integrated Monitoring Network (SIMoN) website as part of our species database. This will be a vital reference tool for other agency and academic researchers working within the MBNMS. One key to effective management of invasive species is early detection. Having high-quality photos of these cryptic species is essential for distinguishing natives from invaders, tracking their spread, and rapidly responding to new invasions.

Olympic Coast National Marine Sanctuary, Mary Sue Brancato & Ed Bowlby

A Rapid Assessment Survey for Non-Indigenous Species in the Intertidal and Nearshore Area of Olympic Coast National Marine Sanctuary

Prepared by Mary Sue Brancato, Katie Brenkman, Helen Berry, John Chapman, Jeff Goddard Leslie Harris, Kathy Ann Miller, Claudia Mills, Brian Bingham, Betty Bookheim, Allen Fukuyama, Ben Miner, Bruno Pernet, Paul Scott, Dave Secord, and Melissa Wilson

Introduction

In 2001 and 2002, Olympic Coast National Marine Sanctuary (OCNMS) organized a team of invertebrate and algae taxonomists to conduct qualitative rapid assessment surveys for invasive species in the intertidal area of the sanctuary. The sanctuary chose to undertake this project due to concerns over the recent establishment of the European green crab *Carcinus maenas* to the south of the sanctuary in Willapa Bay and Grays Harbor. In addition, changes in ballast water exchange regulations and vessel traffic routing, changes in commercial fishing regulations, recent control mechanisms introduced for injurious invasive species outside of the Sanctuary, and the introduction of aquaculture activities in the area around the Sanctuary have been or soon will be implemented that could influence the opportunities for invasive species to establish in the Sanctuary.

The primary objective was to identify invasive species in different habitats along the 135 miles of shoreline within the sanctuary and Neah Bay, to establish baseline conditions for that point in time. To the best of our knowledge, no such open coast surveys have been conducted to date to determine the extent of introductions in an open coast area such as OCNMS.

A second objective was to compile an inventory of native species in the intertidal area of the sanctuary to contribute to the species inventory and voucher collection of invertebrate and algae species within the Sanctuary. A third objective was to compare the information from the outer coast to that available for Puget Sound (Cohen et al. 1998), Hoods Canal and Willapa Bay, a coastal estuary to the south of the sanctuary (Cohen et al. 2001).

Had injurious invasive species been found, another objective of the surveys was to provide insight and prioritization for future monitoring, prevention and control. It is our goal to conduct these surveys periodically in order to detect new invasions and should injurious species be found, to determine the effectiveness of any control measures undertaken. In addition, over the long term, the results of these surveys can be reviewed along with information obtained from the nearshore buoy array that OCNMS has established from April through October each year. The oceanographic information from these buoys can be used to determine if any trends exist and if the data correlate with any changes observed in invasive species introductions.

Due to tidal constraints, the two rapid assessment surveys conducted in 2001-2002 were insufficient to cover the geographic expanse of the sanctuary; therefore, an additional survey is planned for 2006 to fill in some of the geographic and habitat gaps. The funds with the from the National Fish and Wildlife Foundation have been used by OCNMS to both aid with the amphipod taxonomy from the 2001-2002 surveys and to support taxonomists involvement in the development and implementation of the 2006 rapid assessment to fill in the data gaps.

The qualitative rapid assessment survey methods complement the quantitative Smithsonian Environmental Research Center (SERC) panel studies conducted with OCNMS because some of the same areas were studied with each program providing somewhat different information. The rapid assessment surveys provide qualitative data on both mobile and sessile species and the occurrence of both native and non-native invertebrate and algal species along an expansive geographic range. Our first year of the SERC panels (2003) covered two of the sites (marinas) sampled during the rapid assessment, and the 2004 panels were co-located with our oceanographic moorings in the nearshore, providing information on larval recruitment and settlement of sessile invertebrate species.

Methods

The procedures for the rapid assessment surveys were adapted from those first used in the San Francisco Bay, using non-quantitative census methods.

Survey Schedule

Survey dates for intertidal sampling were selected based on the low tide schedule for the summer months and the availability of taxonomic expertise. Intertidal and marina dock surveys were conducted daily during six days in August 2001 (18-23 August) and seven days in August 2002 (6-12 August). In addition, since a key amphipod taxonomist, Dr. John Chapman, was unable to participate in the full duration of the 2001 assessment, he and a team from OCNMS surveyed the two sites he missed in 2001 during two days in July 2002 (23-24 July).

Nearshore samples were collected on 27 June 2002 from the OCNMS *RV Tatoosh* using a plankton net for surface tows and dip bucket for jellies. The intent of the sampling was to focus on jellies and copepods. The schedule for this sampling was not tide dependent but was based on the months when jellies were expected off the coast and the availability of the key taxonomist, Dr. Claudia Mills.

Survey Participants

The survey participants, their expertise and the dates they participated are provided in **Appendix OC-A**.

Site Access

Unlike other rapid assessment surveys conducted in Washington to date, the sites on the Olympic Coast could not be sampled by boat or by surveying dock fauna. Only two docks are located in the study area, both of which were sampled. The open coast and surf zone are also not conducive to sampling by boat, thus all intertidal sites were sampled by driving and then hiking to the location in time to be on site one hour before the low tide. In 2001 the sites selected could be accessed via day hike to the location. In 2002 the sites required backpacking into more remote sites and overnight stays.

<u>Site Selection</u>
The sites sampled and sampling logistics were arranged by Mary Sue Brancato (OCNMS). Each survey year the sites selected shared some of the following characteristics.

1. At least two of the areas selected included coastal tribal lands because subsistence harvest and protection of natives species is critical to the tribes,
2. All areas included sites that have been studied previously as part of the Olympic National Park/Washington coast monitoring program (initiated by Megan Dethier),
3. All areas included multiple habitat types, such as a cobble or rocky intertidal areas, adjacent to sand, or gravel beach habitats so that more than one location could be sampled within the tide window
4. All included areas with freshwater input

Because of the remote nature of the outer coast of Washington, sites were also selected based on 1) accessibility, 2) availability of floating docks, and 3) proximity to a site suitable for a field laboratory. Although Neah Bay is not located in the Sanctuary, the Makah Tribe expressed interest and OCNMS had considerable interest in sampling the site for several reasons: 1) its proximity to the sanctuary; 2) the only protected bay with saline water directly adjacent to the sanctuary; 3) the fact that as a marina environment the influence of boats (primarily commercial fishing and recreational) was apparent; 4) the presence of aquaculture in the area; 5) its proximity to the Strait of Juan de Fuca shipping channel; and 6) the historic use of Makah Bay, just outside of Neah Bay as a ship moorage location prior to entrance to the Strait.

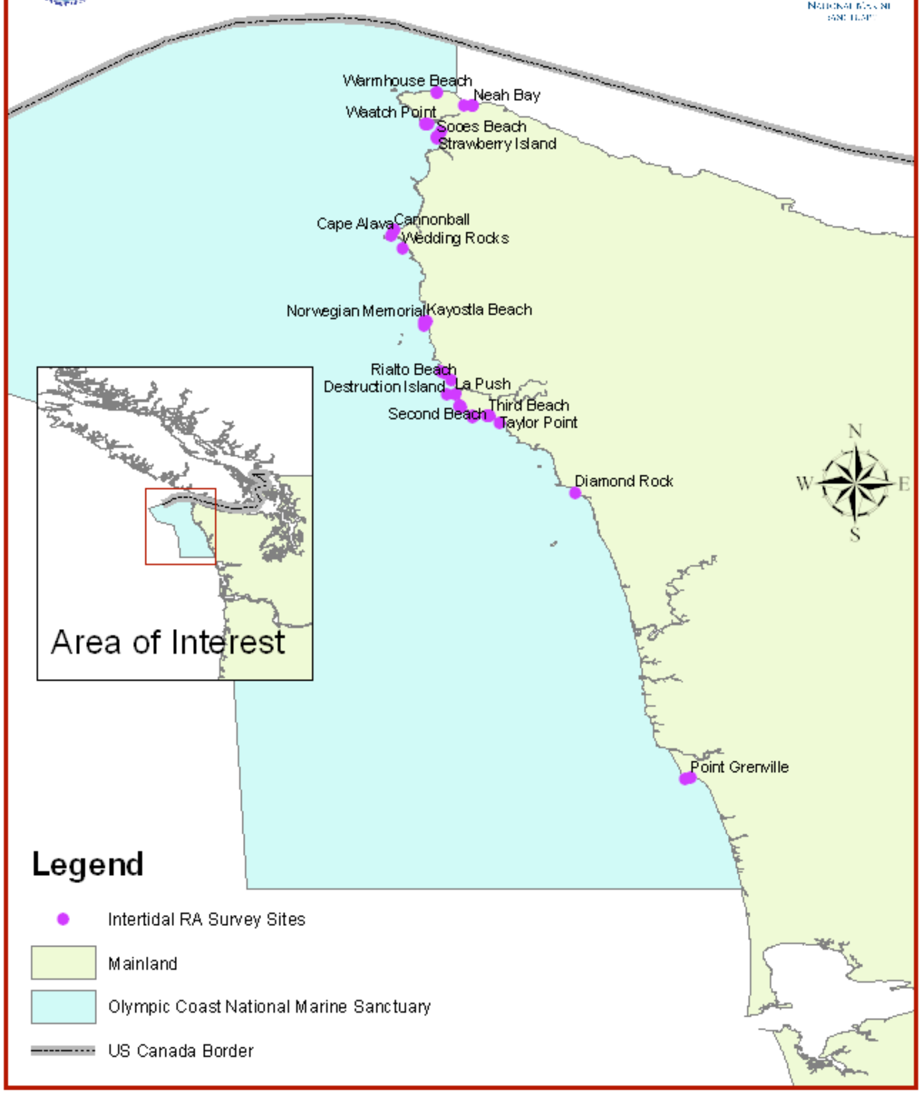
The intertidal sites selected, dates sampled and site characteristics are identified in **Table OC-1** and **Figure OC-1**. The latitude and longitude for the nearshore sampling sites are provided in **Appendix OC-B** and illustrated in **Figure OC-2**. The area that will be the focus for the 2006 sampling effort is identified in **Figure OC-3**.

<u>Survey Methods</u>

Intertidal sampling occurred for approximately one hour bracketing the low tide. Docks were also sampled for approximately one hour but sampling these was independent of tide. The focus of the sampling was on the low and mid tide zones; however, information was gathered from the high zone as well, as time permitted. Site sampling focused on the rocky intertidal habitat, moving to an adjacent sand habitat after surveying the rock habitat.

For each site, one person was designated to describe the site, another to take salinity and temperature readings, and the rest were paired so that each individual with taxonomic expertise was paired with a note taker, who recorded all the of the native and non-native species called out by the taxonomist. Samples were collected by all parties, particularly of those species that could not be identified in the field, needed confirmation in the laboratory, required further processing or were desired for vouchers.

Figure 1. Olympic Coast National Marine Sanctuary
Rapid Assessment of Invasive Species:
Intertidal Survey Sites 2001-2002



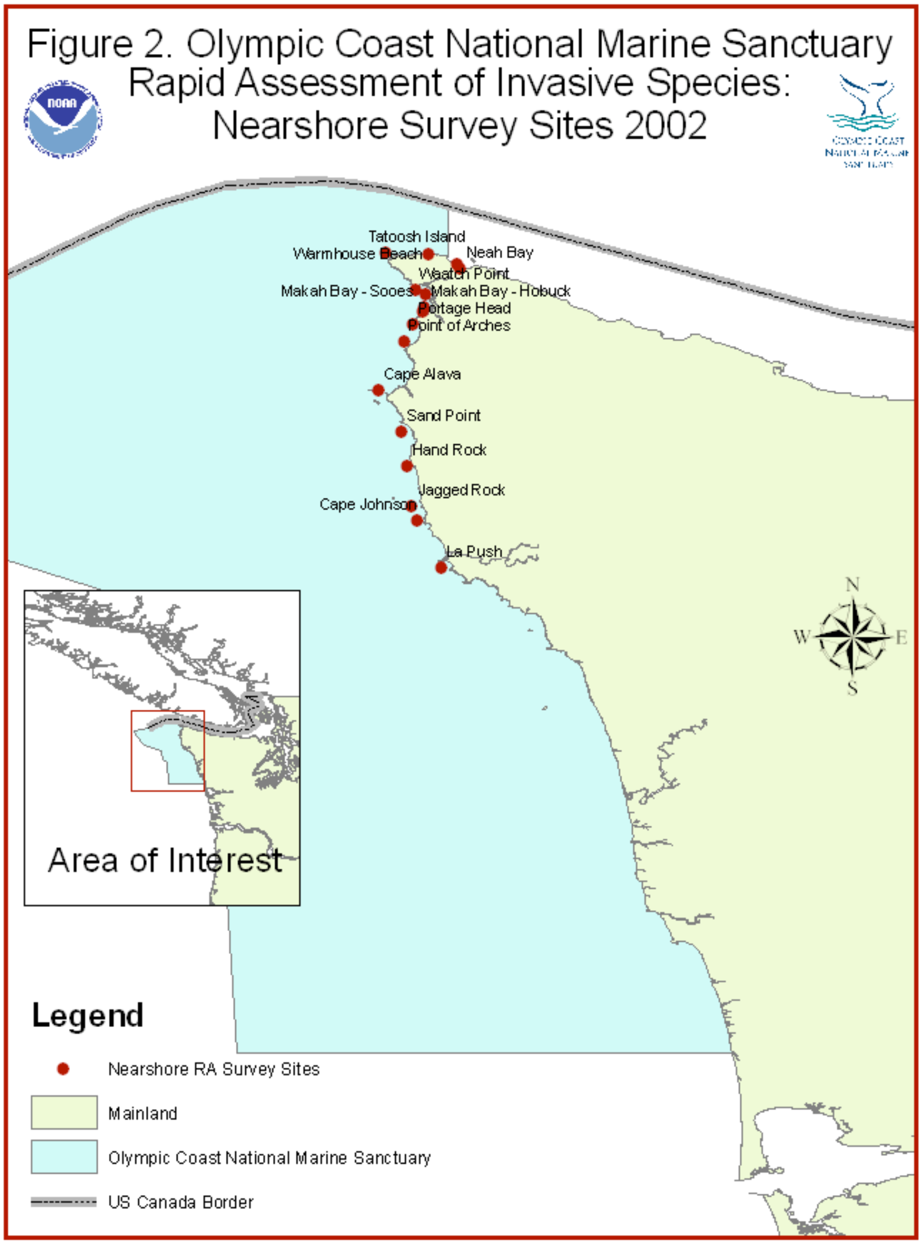


Figure 2. Olympic Coast National Marine Sanctuary
Rapid Assessment of Invasive Species:
Nearshore Survey Sites 2002
Tatoosh Island
Warmhouse Beach
Neah Bay
Waatch Point
Makah Bay - Sooes
Makah Bay - Hobuck
Portage Head
Point of Arches
Cape Alava
Sand Point
Hand Rock
Jagged Rock
Cape Johnson
La Push
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Area of Interest
Legend
Nearshore RA Survey Sites
Mainland
Olympic Coast National Marine Sanctuary
US Canada Border

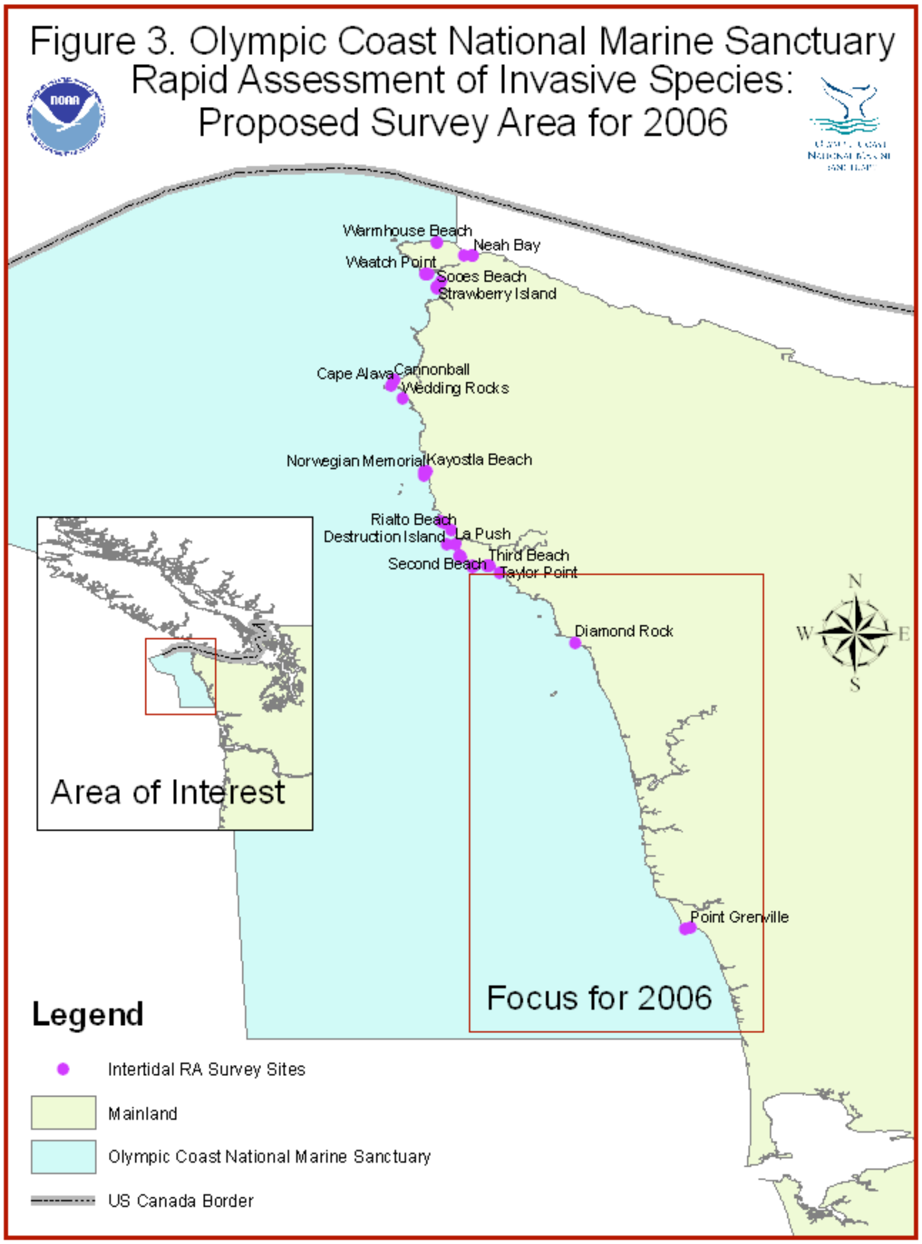

Figure 3. Olympic Coast National Marine Sanctuary Rapid Assessment of Invasive Species: Proposed Survey Area for 2006

<u>Species Identifications</u>

During both years, mobile field laboratories equipped with microscopes, fixatives and sample jars were used to identify organisms during the survey whenever possible. From the experience of previous rapid assessments, OCNMS tried to get as much of the identifications completed in the field or field laboratories. The tides were all morning tides; thus the afternoons were spent identifying organisms. Still, despite considerable field laboratory time, it was still necessary to send samples to taxonomists for additional identification work, which still continues today.

To date analyses are not yet complete for the nearshore samples (primarily copepods). The majority of the intertidal sample analyses have been completed except for the amphipod samples and a few miscellaneous taxa.

Both field and laboratory identifications were recorded along with the participants that made the identifications. Laboratory identifications were considered more accurate than field observations when selecting between the two.

Results/Conclusions

Thus far, 11 invasive and 13 cryptogenic species have been identified in the intertidal area of the sanctuary from the 2001-2002 survey efforts (**Tables OC-2** and **OC-3**, respectively). Taxonomists are still analyzing some of the samples collected from these surveys, in particular the amphipods, so the number may yet increase. The 11 nonindigenous species were distributed through six taxa; we found one alga, two polychaetes, one amphipod, one bryozoan, four bivalves and two ascidians. Likewise, the 13 cryptogenic species were also from several taxa, including eight polychaetes, one amphipod, one copepod, two isopods and one ascidian. Range expansion has been identified for three native species (**Table OC-4**). In addition, one never before described species of amphipod has been identified to date (J. Chapman draft report). In addition to the rapid assessment surveys, OCNMS has been conducting European green crab (*Carcinus maenas*) monitoring monthly from at least April through September of each year from 2001 to 2005, primarily in Neah Bay and occasionally near Waatch River near its entrance to Makah Bay. To date, no European green crab have been found in these traps.

Padilla Bay NERR, Doug Bulthuis

Distribution of the non-indigenous eelgrass, *Zostera japonica*, in Padilla Bay Washington in 2004
and
Establishment of a barnacle settlement monitoring program in Padilla Bay National Estuarine Research Reserve

Prepared by Douglas A. Bulthuis, Suzanne Shull, and Mary Anderson

Background

The Estuarine Reserves Division (NOAA/OCRM), SERC, five west coast National Estuarine Research Reserves (NERRS), and four west coast National Marine Sanctuaries cooperated in a joint National Fish and Wildlife Foundation project entitled "Broad-scale Non-indigenous Species Monitoring along the West Coast in National Marine Sanctuaries and National Estuarine Research Reserves". The project addressed the issue of non-indigenous species monitoring across the broad geographic range of protected sites along the west coast of the U.S. with two approaches (tiers). The first approach involved standardized and uniform methods at all sites based on organisms settling on fouling plates deployed for about three months during the summer. The second approach (tier) involved a variety of location-based methods and location-based non-indigenous species issues. SERC took primary responsibility for the first approach with some on-site assistance at each reserve or sanctuary. The reserves and sanctuaries took primary responsibility for the second approach and used a variety of techniques. Padilla Bay NERR submitted a proposal to SERC to provide planning and field support to SERC in implementing the first approach at Padilla Bay NERR (Task 1) and to support the second, site specific, approach at Padilla Bay NERR (Tasks 2-4). A summary of the four tasks in the proposal (titled *Monitoring for Non-indigenous Species in Padilla Bay NERR during 2003 and 2004 as part of the SERC Project: "Broad-scale Non-indigenous Species Monitoring along the West Coast in National Marine Sanctuaries and National Estuarine Research Reserves"*) is provided below:

Task 1: Provide support to SERC in implementing the first approach (tier) at Padilla Bay.
Task 2: Establish a barnacle settlement monitoring program in Padilla Bay NERR to indicate patterns of larval dispersal to Padilla Bay (and seasonal fluctuations) based on the barnacle settling plates used by Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO).
Task 3: Monitor the distribution of the non-indigenous eelgrass, *Zostera japonica* in Padilla Bay in 2004.
Task 4: Improve the capacity of Padilla Bay NERR to participate in non-indigenous species monitoring programs by the purchase of a suitable scope and compatible digital camera.

The present report is the final report for the proposal submitted by Padilla Bay National Estuarine Research Reserve, and divided into two parts: the first addressing Task 2, monitoring of barnacles; and the second addressing Task 3, distribution of *Zostera japonica*.

Establishment of a barnacle settlement monitoring program in Padilla Bay.

Monitoring of barnacle settlement at the water quality monitoring sites in Padilla Bay was established to indicate seasonal patterns of larval dispersal to the bay. Padilla Bay NERR maintains three sites as part of the NERRS System-wide Monitoring Program at which basic physical water quality parameters are measured every 30 minutes and at which dissolved inorganic nitrogen and phosphorus are measured semi-monthly. Two sites are located in Padilla Bay, one in the southern part of the bay (Bay View Channel), and the other site in the northern part of the bay (Ploeg Channel). The third site (Gong) is located east of Padilla Bay and the Ploeg Channel site in the strait between Samish and Guemes Islands. This area is a source of water to the northern part of Padilla Bay (**Fig PB-1**).

The settlement plates for barnacles were based on those used by Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO). Pieces of Safety Walk were cut to 2 x 2 inch squares and attached to rigid plastic plates. The plates were attached to a floating frame of PVC pipes with cable ties through pre-cut holes in the plates and pipes. The plates were installed with the safety walk facing down because preliminary trials indicated barnacles settled primarily on the underside of the plates. Four replicate plates are set out on each floating apparatus for each deployment.

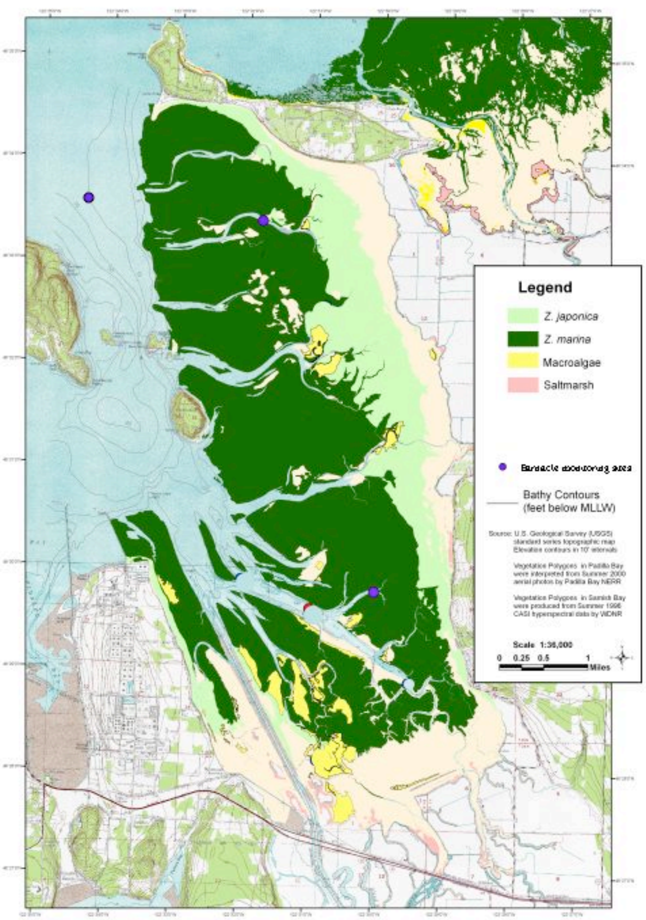

Figure PB-1. Location of water quality monitoring sites in Padilla Bay, Washington at which barnacle settlement is being monitored.

Frames and settlement plates were set out at the BayView Channel, Ploeg Channel, and Gong water quality sites in Padilla Bay (**Fig PB-1**). However, the Gong water quality site was out of commission for most of 2005 because of the loss of buoys, anchors, and datasondes. When a new apparatus is deployed at the Gong site during late summer of 2005, barnacle settlement plates will be deployed again at the Gong site.

Settlement plates are collected semi-monthly when water quality datasondes are exchanged. In the laboratory, each plate is examined and the total number of barnacles counted on each plate.

This barnacle settlement program has now been established at Padilla Bay NERR completing Task 2 of the Padilla Bay NERR proposal.

Distribution of non-indigenous *Zostera japonica* in Padilla Bay, Washington in 2004

Introduction

Zostera japonica (Japanese eelgrass) is a non-indigenous eelgrass to the west coast of North America (Den Hartog 1970, Harrison and Bigley 1982) Its native range on the Pacific coast of east Asia extends from the Kamchatka Peninsula, Russia, to Vietnam (Den Hartog 1970). *Z. japonica* was probably introduced to the west coast of North America, accidentally, with the introduction of the Pacific or Japanese oyster, *Crassostrea gigas*, for oyster culture for aquaculture production. *Z. japonica* is presently distributed from Vancouver Island, British Columbia to Humboldt Bay, California (Harrison and Bigley 1982, Phillips and Menez 1988, McBride 2002). *C. gigas* was introduced to Padilla Bay from Japan in the 1930's to establish oyster culture in the bay (Dinnel 2000). Oyster culture flourished briefly in Padilla Bay but growth of oysters in the bay were poor due to environmental conditions and pollution from pulp mills (Dinnel 2000). In 1932 *C. gigas* seed was imported from Japan and first planted in Padilla Bay. Presumably, *Z. japonica* was used as packing material and introduced accidentally to Padilla Bay and other commercial oyster growing areas at that time (Harrison and Bigely 1982, Dinnel 2000).

In Padilla Bay, *Z. japonica* generally occurs higher in the intertidal than the native eelgrass, *Zostera marina* L (Bulthuis 1991, 1995). *Z. japonica* generally seems to be occupying intertidal flats that had been devoid of macrophytes prior to the introduction of *Z. japonica*. Field and laboratory studies in Fraser River delta area (about 100 km north of Padilla Bay) indicated that *Z. marina* out competes *Z. japonica* when the two species overlap (Harrison 1982a, 1982b). However, anecdotal observations in Padilla Bay indicated that *Z. japonica* may be extending its range into areas that had been covered by *Z. marina* (Bulthuis, pers. obs.).

The distribution of eelgrasses and macroalgae in Padilla Bay has been mapped with a variety of methods, including satellite imagery, color and infra-red aerial photography, compact airborne spectral imagery, and videography (Webber et al. 1987, Bulthuis 1995, Shull 2000, Bulthuis and Shull 2002, Berry et al. 2003) In the satellite and aerial photography studies the boundary between *Z. marina* and *Z. japonica* has not always been clear. Sometimes intermixed areas of both species can be identified on the aerial photos. At other places in the bay, there is no clear demarcation although the vegetated "meadow" may begin with *Z. japonica* on the upper edge and be 100% cover of *Z. marina* in the lower intertidal areas of the meadow. The objectives of this study were to determine the boundary between *Z. marina* and *Z. japonica* in Padilla Bay in the summer of 2004 and to compare the distribution with previous attempts to map these two seagrasses in Padilla Bay.

Methods

The distribution of *Zostera marina* and *Z. japonica* in Padilla Bay (and the location of the interface between these two species where possible) were mapped with a combination of color aerial photography, ground truth investigations of percent cover, orthorectification of the aerial photographs, and photointerpretation and digitizing on screen with ArcGIS 9.0. See Shull and Bulthuis (2002) for a more detailed description of the steps involved in the delineation.

True color aerial photographs were obtained on June 3, 2004 at scales of 1:12,000 and 1:40,000 during a –3.9 ft low tide, the lowest tide of the year. The 1:12,000 scale aerial photos were scanned, orthorectified, and mosaicked into a single digital file and imported into ArcGIS 9.

Ground truth points were obtained during June, July, and August, 2004 at about 1300 locations. Ground truth teams often walked from the shoreline, out through the meadows of *Z. japonica*, and toward the lower intertidal, until the vegetation coverage was 100% *Z. marina*. Ground truth data collected at each point included: geographic coordinates; estimated percent cover of vegetation in an area of about 0.01 hectare (10m x 10m); and, within the vegetated area: the percent cover of three species of eelgrass, of green algae, of brown algae, and of red algae. (Frequently the genera of the most abundant algae were determined.) Herbarium specimens were collected for the eelgrass and algae at various ground truth sites. Digital photos of the vegetation were taken at most ground truth sites. The subtidal edge of the eelgrass was determined with vessel, depth sounder, and visual confirmation of the edge at more than 50 sites along the western border of the eelgrass beds in Padilla Bay. All of the ground truth data were entered in an Excel spreadsheet that was imported into ArcGIS database and then linked to the GPS data collected at each site. The digital photos were 'hot-linked' with point and click display to the ground truth GPS locations in ArcGIS to aid in interpretation.

Delineation of the vegetation was conducted on screen using ArcGIS 9. A geodatabase schema was used for the various vegetation categories. The vegetation boundaries and categories were delineated on the scanned orthorectified mosaic, with frequent reference and comparison to the color prints, ground truth database, and digital photos.

Results

The ground truth data indicated that *Z. japonica* is widely distributed close to the shoreline (**Fig PB-2**). *Z. japonica* also occurred in some areas in the central part of Padilla Bay (**Fig PB-2)**. Most of these areas were raised and slightly higher in elevation than the surrounding intertidal flats. *Z. japonica* was not distributed in the lower intertidal in Padilla Bay (apparently not below 0.0, chart datum).

Photointerpretation of the aerial photographs could clearly delineate vegetated intertidal flats from those lacking macrophytes. However, distinguishing *Z. japonica* from *Z. marina* was more difficult. Delineation between the species relied heavily on ground truth investigations. In some areas, with extensive ground truth data, the demarcation between the species could be seen on the aerial photos, especially where the boundary between the species coincided with a change in depth or type of substrate. In other areas, the ground truth data indicated changes between the species that could not be seen on the aerial photos. Thus, the aerial photos could not consistently be used to delineate *Z. japonica* from *Z. marina*.

Figure PB-2. True color aerial photomosaic of Padilla Bay, Washington June 3, 2004, with ground truth sites plotted. Sites marked in red are those at which *Zostera japonica* was the most common macrophyte. The northeast study area is outlined.

The northeastern study area of Padilla Bay was chosen as a selected area in which to compare results of mapping efforts from 2004 with previous mapping efforts in 1989 and 2000 (Bulthuis 1991, 1995; Bulthuis and Shull 2002, see area outlined in **Fig PB-2**). In 1989, much of the northeast study area had less than 10% cover of macrophytes (**Fig PB-3, Table PB-1**). In the summer of 2000 more than 100 hectares that had been bare in 1989, was mapped as *Z. japonica* or *Z. marina* with greater than 10% cover (**Fig PB-4, Table PB-1**). In 2004 the total area covered by vegetation was similar to 2000, but the mapped distribution of *Z. japonica* and *Z. marina* had changed (**Fig PB-5, Table PB-1**). The area covered by eelgrasses in the northeastern study area increased more than 100 hectares from 1989 to 2000 followed by little change from 2000 to 2004 (**Table PB-1**).

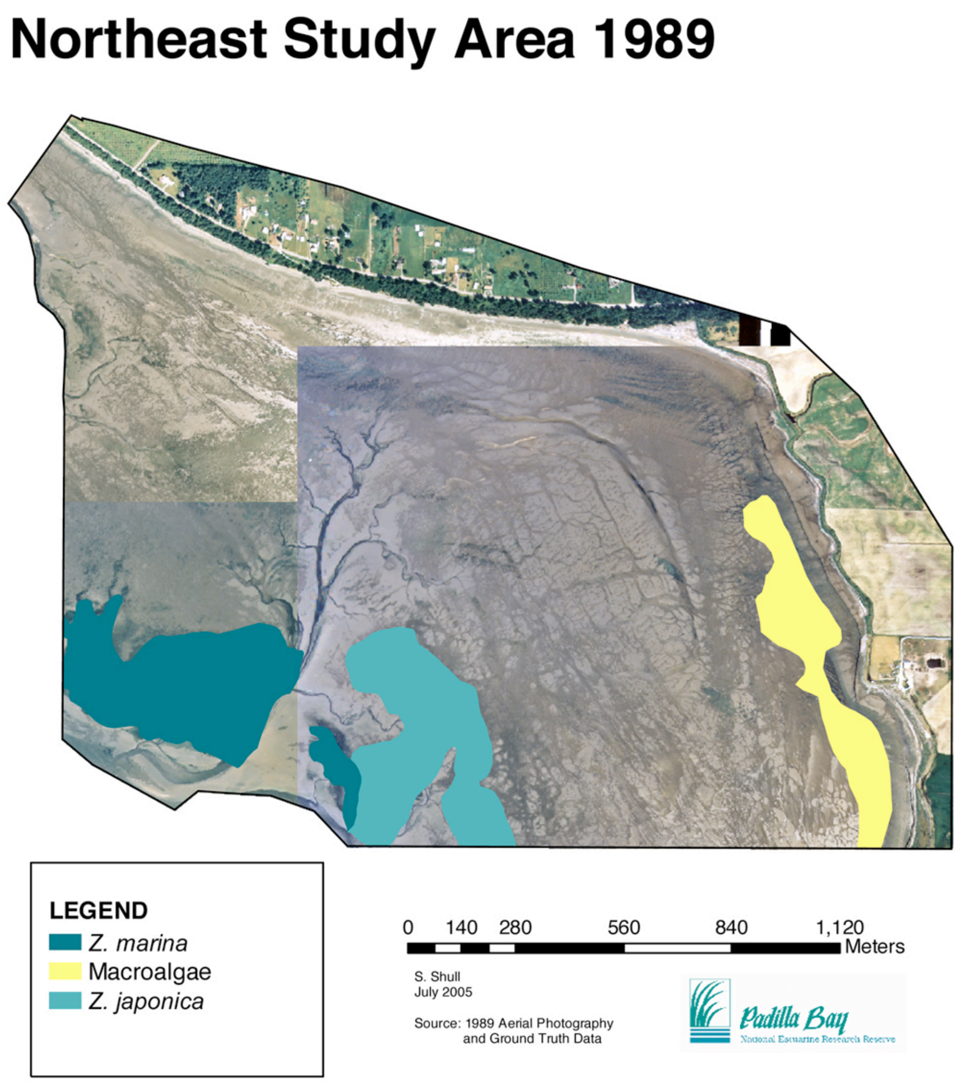

Figure PB-3. Distribution of macrophytes in 1989 in the northeast study area of Padilla Bay, Washington as mapped by Bulthuis 1991.

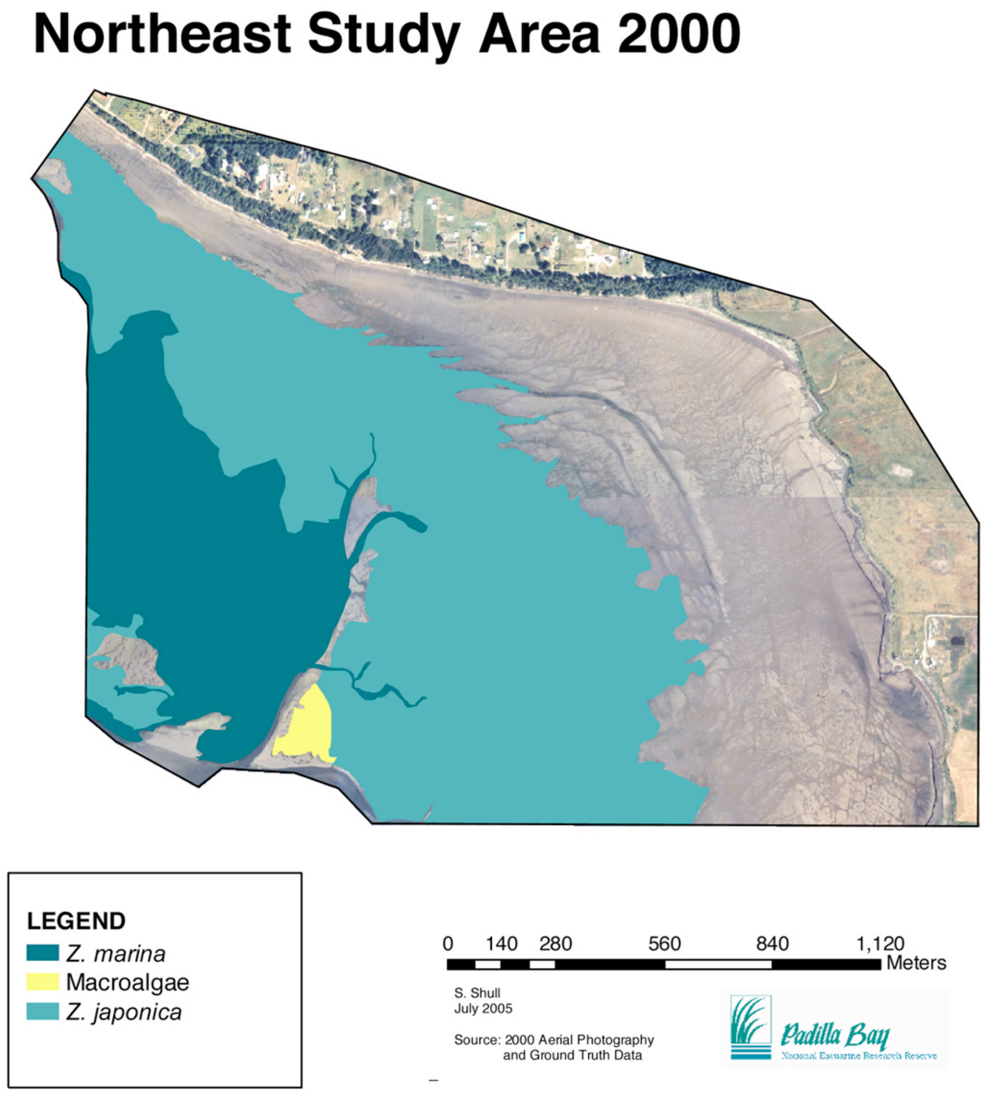

Figure PB-4. Distribution of macrophytes in 2000 in the northeast study area of Padilla Bay, Washington as mapped by Bulthuis and Shull 2002.

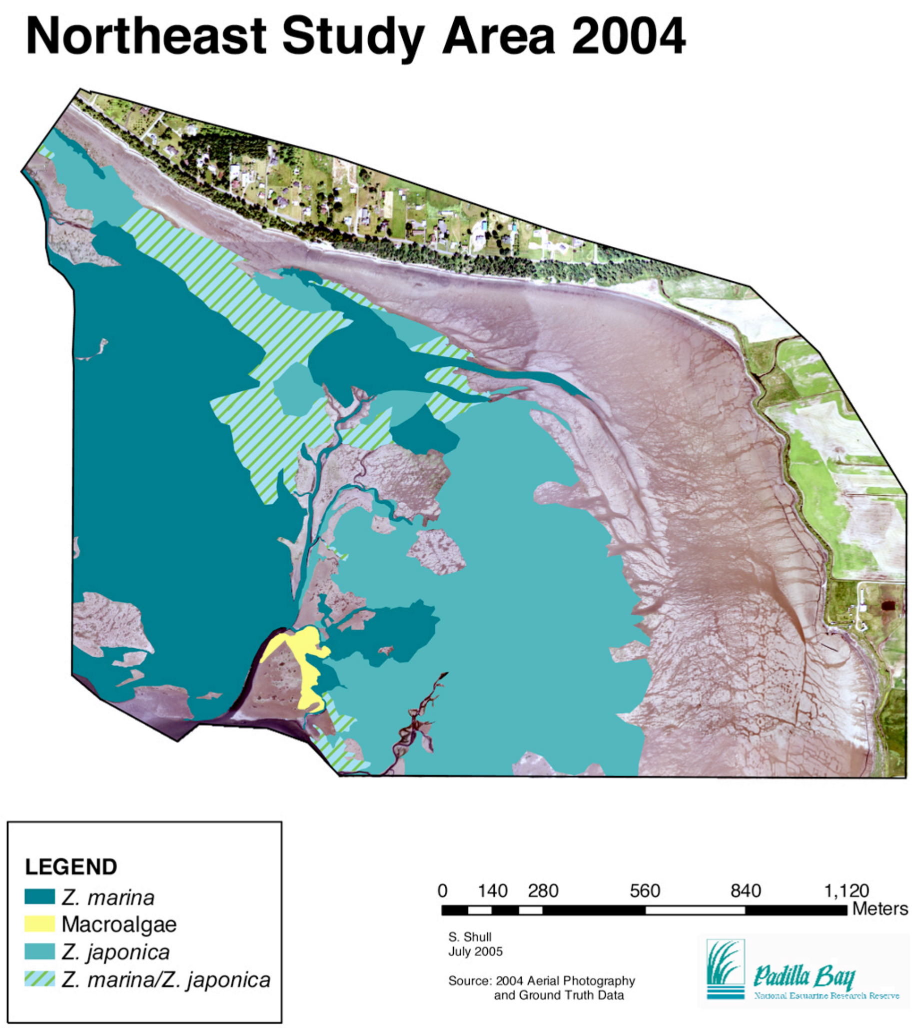

Figure PB-5. Distribution of macrophytes in 2004 in the northeast study area of Padilla Bay, Washington as mapped in the present study.

Table PB-1. Area of macrophytes (hectares) in northeast study area of Padilla Bay based on photointerpretation of true color aerial photographs and ground truth investigations.

	1989[1]	2000[2]	2004[3]
Z. japonica		119	68
Z. japonica and *Z. marina*	15		19
Z. marina	18	48	
Z. marina intertidal			69
Z. marina subtidal			4
Total eelgrass	**32**	**167**	**161**
macroalgal mats	10	2	2
saltmarsh	2	1	1
bare of macrophytes	247	122	128
Total in northeast study area	**291**	**292**	**292**

[1] Data from Bulthuis 1991
[2] Data from Bulthuis and Shull 2002
[3] Data from present study

Discussion

This study documents the widespread distribution of the non-indigenous eelgrass, *Zostera japonica* in Padilla Bay in 2004. *Z. japonica* is distributed both in large mono-specific meadows and in extensive areas in which *Zostera marina* and *Z. japonica* are intermixed. *Z. japonica* is generally distributed closer to the shore and higher in the intertidal than *Z. marina*. In the northeastern study area, the area covered by *Z. japonica* appeared to decrease from 2000 to 2004 (Table 1). However, in 2000 there were few ground truth sites in the part of the northeast study area which appears to have changed. The aerial photos do not indicate a clear difference among years. Therefore the apparent decrease in *Z. japonica* coverage and increase in *Z. marina* coverage in the northeast study area may be a result of misinterpretation of the aerial photos in 2000.

This study also demonstrated the need for extensive ground truth investigations in order to delineate between *Z. japonica* and *Z. marina*. The ground truth investigations were much more extensive in 2004 than in previous mapping efforts. Because of these differences in the extent of ground truth investigations among years, the 2004 study does not provide unequivocal evidence whether *Z. japonica* is extending its range in Padilla Bay into areas that had been covered by *Z. marina*, or whether *Z. japonica* distribution is decreasing in Padilla Bay.

Literature Cited

Berry, H. D., A. T. Sewall, S. Wyllie-Echeverria, B. R. Reeves, T. F. Mumford, J. R. Skalski, R. C. Zimmerman and J. Archer. 2003. *Puget Sound submerged vegetation monitoring project: 2000 - 2002 monitoring report*. Washington State Department of Natural Resources, Nearshore Habitat Program, Olympia, Washington. 60 pp plus appendices.

Bulthuis, D. A. 1991. *Distribution of habitats and summer standing crop of seagrasses and macroalgae in Padilla Bay, Washington, 1989.* Washington State Department of Ecology, Mount Vernon, Washington. 35 pp. Padilla Bay National Estuarine Research Reserve Technical Report No. 2.

Bulthuis, D. A. 1995. Distribution of seagrasses in a North Puget Sound Estuary: Padilla Bay, Washington, U.S.A. *Aquatic Botany* 50: 99-105.

Bulthuis, D. A. and S. Shull. 2002. *Accessible methodology for monitoring estuarine and coastal vegetation cover*. Washington State Department of Ecology, Padilla Bay National Estuarine Research Reserve, Mount Vernon, Washington. 14 pp plus figures. [Final report submitted to Cooperative Institute for Coastal and Estuarine Environmental Technology]

Den Hartog, C. 1970. *The sea-grasses of the world.* Amsterdam: North-Holland Publishing Co.

Dinnel, P. A. 2000. *Padilla Bay molluscs: a reveiw, with emphasis on the bivalves*. Washington State Department of Ecology, Padilla Bay National Estuarine Research Reserve, Mount Vernon, Washington. 40 pp. Ecology Publication No. 01-06-028, Padilla Bay National Estuarine Research Reserve Technical Report No. 24, Padilla Bay Estuarine Profile Contribution No. 1.

Harrison, P. G. 1982a. Comparative growth of *Zostera japonica* Aschers. & Graebn. and *Z. marina* L. under simulated intertidal and subtidal conditions. *Aquatic Botany* 14: 373-379.

Harrison, P. G. 1982b. Spatial and temporal patterns in abundance of two intertidal seagrasses, *Zostera americana* Den Hartog and *Zostera marina* L. *Aquatic Botany* 12: 305-320.

Harrison, P. G. and R. E. Bigley. 1982. The recent introduction of the seagrass *Zostera japonica* Aschers. and Graebn. to the Pacific Coast of North America. *Canadian Journal of Fisheries and Aquatic Sciences* 39: 1642-1648.

McBride, S. 2002. Zostera japonica *in Humboldt Bay - Biological information summary*. 3 pp. Fact Sheet published by California Sea Grant.

Phillips, R. C. and E. G. Menez. 1988. *Seagrasses*. Smithsonian Contributions to the Marine Sciences 34: 1-104.

Shull, S. 2000. *Mapping seagrass meadows of Padilla Bay, Washington, using a 1996 compact airborne spectrographic imager (CASI) dataset*. Masters Thesis, Western Washington University. 76 pp. Washington State Department of Ecology Publication No. 00-06-017, Padilla Bay National Estuarine Research Reserve Reprint Series No. 34.

Shull, S. and D. A. Bulthuis. 2002. *A methodology for mapping current and historical coverage of estuarine vegetation with aerial photography and ArcView*. Washington State Department of Ecology (Publication No. 03-06-020), Padilla Bay National Estuarine Research Reserve, Mount Vernon, Washington. 52 pp. Padilla Bay National Estuarine Research Reserve Technical Report No. 26.

Webber, H. H., T. F. ,. Mumford and J. Eby. 1987. *Remote sensing inventory of the seagrass meadow of the Padilla Bay National Estuarine Research Reserve: Areal extent and estimation of biomass*. Western Washington University, Huxley College of Environmental Studies, Bellingham, WA. 70 pp. Padilla Bay National Estuarine Research Reserve Reprint Series No. 6. [Final report to Marine & Estuarine Management Division, NOAA grant # NA86AA-D-CZ027]

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South Slough NERR, Steve Rumrill

Differences in Susceptibility to Invasion by Aquatic Non-indigenous Species along the Estuarine Gradients of the South Slough and Coos Bay, Oregon

Introduction: Biological invasions by aquatic non-indigenous species (NIS) pose a considerable threat to the ecological integrity of the South Slough and Coos estuary. The South Slough tidal basin, including the South Slough National Estuarine Research Reserve (NERR), is currently inhabited by over 50 species of aquatic non-indigenous organisms, and over 100 aquatic non-indigenous species have been identified within the adjacent waters of Coos Bay. Coos Bay and the South Slough are both susceptible to introductions of new aquatic non-indigenous species, and recent evidence suggests that release of ballast water associated with international shipping, interstate commerce of living marine organisms, inter-basin movements of commercial and recreational vessels, commercial shellfish mariculture, and recreational uses of the estuaries, are most likely the primary vectors that contribute to continued introductions and accelerated rates of invasion. As an integral sub-unit of the greater Coos estuary, the South Slough is directly linked to Coos Bay by the daily ebb and flood of the tides. This hydrodynamic process ensures the physical and biotic continuity between Coos Bay, where the incidence of aquatic NIS infestation is high, with the South Slough where the current levels of NIS are lower. The direct hydrodynamic link between these two tidal basins also suggests that South Slough is at considerable risk for colonization by new introductions on non-indigenous species.

Project Description: Staff members from the South Slough National Estuarine Research Reserve worked in collaboration with the Smithsonian Environmental Research Center (SERC) to investigate any similarities and/or differences in the spatial pattern of non-indigenous species along the estuarine gradients of the South Slough and Coos estuaries. This component of the project carried out along the southern Oregon coast focused on development of empirical data to understand differences in the susceptibility of estuarine habitats to invasion by aquatic non-indigenous species in relation to variability in physical water parameters (i.e., temperature, salinity, specific conductivity) and differences in habitat availability (i.e., location of docks, marinas, and pilings) along the shorelines of the South Slough and Coos Bay.

Field work was carried out during 2003 and 2004 to deploy, recover, and process a series of 140 replicated PVC fouling plates from a series of fourteen study sites (**Table SS-1**): (A) Coos Bay entrance / Coast Guard Beach, (B) Charleston Marina / Inner Boat Basin, (C) Charleston Marina / Outer Boat Basin, (D) Charleston Distant Water Fleet Dock, (E) Valino Island, (F) Long Island Peninsula / West, (G) Winchester Creek, (H) Empire Dock, (I) North Bend Airport Runway Extension, (J) North Bend Dock, (K) Port of Coos Bay / Citris Dock, (L) Coos Bay City Dock, (M) Shinglehouse Slough, and (N) Haynes Inlet. These study sites were selected to span a wide range of salinity conditions within the Coos Bay and South Slough estuaries, and representative sites were placed within the marine, marine-dominated, mesohaline, and riverine regions of the estuary (**Table SS-1**). A total of ten replicate plates were deployed at each study site, and the plates were either attached to masonry bricks that were hung from fixed or floating docks, attached to PVC pipe that was extended horizontally from vertical log piling, or suspended above the substratum affixed to a PVC frame. In all cases the PVC panels were oriented horizontally with regard to the substratum and water surface. All 140 fouling plates were recovered after a period of 100-110 days of immersion in the estuarine tidal channels. At the end of the deployment period, the panels were returned to the South Slough NERR / Estuarine and Coastal Science Laboratory, photographed, preserved, and then shipped to SERC for taxonomic identification of the epifouling invertebrates. Taxonomists from SERC are still working to analyze the fouling plate samples collected from the surveys conducted within South Slough and Coos Bay.

In another part of the project, baited crab traps were deployed to monitor the abundance and distribution of European Green Crab (*Carcinus maenas*) and several native crabs (*Cancer* *magister, C. productus, C. oregonensis*) at four study sites within the South Slough estuary. The South Slough NERR / SERC team also deployed and recovered a series of 10 shell rubble traps to gauge the abundance of non-indigenous Atlantic mud crabs (*Rhithropanopeus harrisii*) within riverine regions of the Coos estuary (Coos River and Catching Slough).

Table SS-1. Description of NIS assessment deployment sites and types within the South Slough and Coos estuary, Oregon

Study Site	Tidal Basin	Hydrodynamic Regime	No. Plates	Deployment Type
Coos Bay Entrance	Coos Bay	marine	10	vertical log piling
Charleston Marina - inner	South Slough	marine	10	floating dock
Charleston Marina - outer	South Slough	marine	10	floating dock
Distant Fleet Facility	South Slough	marine dominated	10	floating dock
Valino Island	South Slough	marine dominated	10	vertical log piling
Long Island Peninsula	South Slough	mesohaline	10	PVC frame
Winchester Creek	South Slough	riverine	10	vertical log piling
Empire Dock	Coos Bay	marine dominated	10	fixed dock
North Bend Airport	Coos Bay	marine dominated	10	PVC frame
North Bend Dock	Coos Bay	mesohaline	10	fixed dock
Citris Dock	Coos Bay	mesohaline	10	fixed dock
Coos Bay City Dock	Coos Bay	mesohaline	10	floating dock
Shinglehouse Slough	Coos Bay	riverine	10	PVC frame
Haynes Inlet	Coos Bay	mesohaline	10	PVC frame

Results from this investigation are timely and important because Oregon's shallow estuaries and protected embayments are particularly susceptible to invasion by aquatic non-indigenous species. Long-term commercial oyster mariculture operations have resulted in numerous deliberate and inadvertent introductions of exotic species into the tidal channels and tideflat communities of South Slough and Coos Bay. Moreover, intensive human settlement and industrial shoreline development in Coos Bay has been coupled with a long legacy of commercial deep-draft ship traffic and chronic introductions of non-native species via ballast water. The increased frequency of non-native introductions associated with oyster mariculture and ballast water transport has created many opportunities for exotic species to invade new ecological niches, including the relatively undisturbed habitats located within the protected administrative boundaries of the South Slough NERR.

Tijuana River National Estuarine Research Reserve, Jeff Crooks

The funding provided by the National Fish and Wildlife Foundation have facilitated coast-wide collaborative efforts and site-based projects aimed at better understanding patterns of marine invasion. At the Tijuana River National Estuarine Research Reserve, a portion of these resources have been used for travel to a meeting (sponsored by the California State Lands Commission) that addressed managing invasions via ship fouling. In addition, the funds were used to support interns that have helped with the regional monitoring effort as well as our local projects. The latter include a number of continuing studies, including invasion assessment in a power plant effluent, documenting the distribution of the Pacific oyster in San Diego County, and augmenting ongoing work on the impact of salt cedar invasion (*Tamarisk* sp.) in Tijuana Estuary salt marshes.

<u>Invasions in a warm-water effluent in San Diego Bay</u>

San Diego Bay, immediately north of the Tijuana River National Estuarine Research Reserve, is marked by heavy commercial, military, and recreational uses. In the south bay, one of the principal factors driving environmental signatures is the warm water discharged from a power plant. These warm water effluents have some well-known effects, such as facilitating resident populations of green sea turtles and sea horses. Much less is known about impacts to fouling communities or how this warm water might change invasion patterns. The potential effect of the warm water on invasions is particularly relevant given that the Port of San Diego has recently begun an effort to increase commercial use of the harbor. To this end, Dole Fruits has now made San Diego its home port, and its ships, which often come from warm climates, now frequently call on San Diego.

To address this issue, we are building off the coast-wide project and have deployed fouling panels at three sites in the bay. These include the power plant's discharge channel, the plant's intake channel (where water is much cooler), and an adjacent marina. The latter was one of the sites sampled as part of the larger project last summer. The plates were deployed on 21 January 2005, with six plates at each site. The panels will be retrieved in the late summer, after seven months (some of the sites are adjacent to endangered species breeding habitat and access is prohibited for much of the spring and summer).

Upon retrieval, plates will be photographed and processed in a manner consistent with our other plate protocols. We will generate species lists for the different sites, as well as assess community information such as percent cover and diversity patterns.

The Pacific oyster in San Diego County

The oyster *Crassostrea gigas*, which is native to Asia, is an interesting invader on the west coast of the United States. In the decades proceeding and following turn of the last century, much effort was expended in trying to get this commercially important species to establish itself in North America. "Success" was met with in some locales, such as in the Pacific Northwest, where the oyster can now be found in the wild. In many other places, such as San Francisco Bay, however, the oyster failed to establish despite many attempts (although many "tag-along" species did invade). In other locations, such as southern California, there were only limited attempts at oyster introduction, as the water was thought to be too warm to allow for establishment of self-sustaining populations. There are grow-out facilities for sterile adults, however, such as in Tomales Bay, California, and San Quintin, Baja California, Mexico.

In San Diego County, there have been occasional reports of the oyster over the years, but there have been no reports of established populations. Recently, however, a colleague (C. Gramlich, San Diego State University) had reported populations in Mission Bay, San Diego. Those populations, which occur in the northeast portion of the bay, have since been confirmed. Our subsequent field work has also identified populations in the south part of Mission Bay. Additional searching in other county lagoons has revealed populations in the Tijuana River Estuary and Oceanside Harbor. There are also recent accounts of the mussel in Agua Hedionda Lagoon.

This project will continue by additional searches to determine presence in other county bays and estuaries. In addition, we will assess size structure of populations to determine if recruitment events appear rare or common. We are also collecting samples for detailed taxonomic (and perhaps genetic) analysis. When completed, this study will offer a better picture of the invasion of this unexpected species in southern California.

The impacts of Tamarisk on high marsh communities in the Tijuana River Estuary

Until recently, it has appeared that the salt marshes of southern California have been relatively free from plant invaders. This contrasts with the situation in estuaries in northern California and the Pacific Northwest, which have been plagued with invasion of exotic cordgrass. Unfortunately, our reprieve is now over. In the Tijuana River Estuary, there are now large stands of salt cedar (*Tamarisk* spp.) growing in the high intertidal salt marsh. Although the plant is a well-known and often-cursed invader of freshwater and terrestrial systems, its presence in marine systems has not raised much concern. At the TR NERR, however, many acres of formerly low-lying succulent (pickleweed) marsh have been converted to tamarisk forests. The impacts of the tree invasion, as well as recovery of the system after tamarisk removal, are the focus of a large research project funded by California Sea Grant.

The NFWF funding has allowed us to expand the scope of this work and address some additional problems not originally part of the larger project. In particular, we are focusing on the effects of the marsh conversion to forest for terrestrial invertebrates, such as insects and spiders (marine invertebrates are being sampled as part of the Sea Grant project). We have developed methodologies to assess insect communities in the invaded and uninvaded habitats, and preliminary analysis suggests major differences in the arthropod assemblages in the tamarisk and pickleweed zones. We are also performing follow-up analysis to assess the degree to which such responses are due to food resources or to the dramatic structural change in the system. When placed in the larger context of our studies, we will have key information on shifts in biotic assemblages due to the tree invasion.

Future work

As most of the work described above is ongoing, we will continue with our sampling and analysis plans. This information, coupled with coast-wide study and other invasions work, will give much-needed information on the extent, impact, and implications of coastal invasions in San Diego. We are currently developing a database of local invaders, which will interface with the larger database being developed as part of this project. In addition, our core mission relates to translating science into education and outreach. As such, we are actively working with our education staff to incorporate invasion-related themes into our K-12 program, and are planning workshops for local resource managers and decision-makers about the prevention and control of invaders.