Washington State Exotics Expedition 2000:
A Rapid Survey of Exotic Species in the Shallow Waters of Elliott Bay, Totten and Eld Inlets, and Willapa Bay

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Executive Summary

In recent decades, the world has witnessed an array of harmful invasions by exotic marine and freshwater organisms. In 1998, the Washington State Department of Natural Resources organized a rapid survey of exotic organisms in Puget Sound in order to provide the public and policymakers with information on the status of exotic species in Washington waters (Cohen *et al*. 1998). The 1998 Puget Sound Expedition collected and identified 39 non-indigenous species in six days of sampling. Ten of these were new records for Puget Sound.

We report here on a second survey of exotic organisms in Washington State waters, conducted May 17-23, 2000. The 2000 Expedition was the sixth in a series of Rapid Assessment surveys for exotic marine organisms on the Pacific Coast. As in past surveys, our primary objective was to assess the status of exotic invasions within defined regions and habitat types through non-quantitative census methods. Secondary objectives were to obtain data for comparisons between habitats and regions, and for comparisons with past surveys; to obtain baseline data for future assessments of changes in invasion status and the effectiveness of prevention or control efforts; to detect new invasions and document significant range extensions; and to identify new species.

While the 1998 Puget Sound Expedition focused on floating dock habitats in Puget Sound, the 2000 Expedition selected sampling sites to obtain broad coverage in shallow water habitat types in terms of substrate, salinity, water temperature and spatial distribution. We sampled intertidal mudflats, cobble beaches, oyster reefs, dock fouling, saltmarshes and consolidated clay substrates. Three regions in Washington State were sampled to capture a range of oceanographic conditions and patterns of human use:

- Elliott Bay and the Duwamish River estuary are located in the Central Basin of Puget Sound, near the City of Seattle. This is an area of intensive urban development and the site of a major international port, the Port of Seattle.

- Totten and Eld Inlets are relatively protected bays in the Southern Basin of Puget Sound. Aquaculture and residential land uses predominate in these inlets. The Port of Olympia, a small international port, is in adjacent Budd Inlet.

- Willapa Bay is Washington’s largest outer coast estuary. It is the state’s largest aquaculture center. Much of its shoreline is undeveloped. There is currently no commercial shipping in the bay.

The collection and field identification of specimens was followed by the examination of live samples in the laboratory by the expedition's team of taxonomic experts. Considerable taxonomic work remains in order to complete the analysis of the samples. The information in this report is a preliminary assessment of the available data.

As of October 2001, 40 exotic species have been identified from the 2000 Expedition. Most of these are native to the North Atlantic or the Northwestern Pacific region, and most were introduced to the Northeastern Pacific with oysters imported for aquaculture, as ship fouling organisms or in ballast water.

The 2000 Expedition collected four exotic species in Willapa Bay that were not previously known from that bay. One of these, the spionid worm *Pseudopolydora bassarginensis,* is a new record for North America. A phyllodocid worm in the genus *Nereiphylla* may be either a new species or a previously unreported introduction. The collection of the native nudibranch, *Emarcusia morroensis*, in Elliott Bay substantially extended its documented range on the Pacific Coast. In addition to these, the terebellid worm *Neoamphitrite figulus*, which was collected in Willapa Bay during a reconnaissance trip in March 2000, is a new record for the Pacific Coast of North America.

Among the three regions, 15 exotic species were collected in each of the Elliott Bay and Totten/Eld Inlet regions, and 34 were collected in Willapa Bay. The apparent ecological dominance by exotics was slightly greater in Totten/Eld Inlets than in Elliott Bay, and much greater in Willapa Bay:

> <u>Elliott Bay:</u> Fifteen exotic species were collected and identified from Elliott Bay. Seven are native to the North Atlantic, six to the Northwest Pacific, one to the Black and Caspian seas, and one is of unknown origin. The 2000 Expedition identified eight exotic species in the Elliott Bay region that were not found by the

previous 1998 Puget Sound Expedition, with a total of 21 exotic species identified in the region by the two expeditions. At none of the sampled sites were exotic species dominant or common, except for the European freshwater or brackish water hydroid *Cordylophora caspia* found in moderate abundance at a marina near the Duwamish River Turning Basin.

Totten and Eld Inlets: Fifteen exotic species were collected and identified from Totten and Eld Inlets. Six are native to the North Atlantic, eight to the Northwest Pacific, and one is of unknown origin. The 2000 Expedition identified eight exotic species in the south Puget Sound region that were not found by the previous 1998 Puget Sound Expedition, with a total of 24 exotic species identified in south Puget Sound by the two expeditions. Known exotic species were more obviously common or dominant here than in Elliott Bay. At Kennedy Creek and Mud Bay, large numbers of the Atlantic worm *Neanthes succinea* lay on the mud surface; the Japanese seaweed *Sargassum muticum* and the Atlantic bryozoan *Schizoporella unicornis* were common at Steamboat Island; the Asian fouling tunicate *Botrylloides violaceous* was common on the Taylor Shellfish Rafts; the Manila clam *Venerupis philippinarum* was common along with various native clams on the beach at Kamilche Point; and the anemone *Diadumene lineata* and the cumacean *Nippoleucon hinumensis*, both from Japan, were abundant at Mud Bay. In addition, the Mediterranean mussel *Mytilus galloprovincialis* and the Japanese oyster *Crassostrea gigas* were present in culture at some of the sites.

Willapa Bay: Thirty-four exotic species were collected and identified from Willapa Bay. Twenty are native to the North Atlantic, 12 to the Northwest Pacific, one to the Black and Caspian seas, and one is of unknown origin. The 1998 Puget Sound Expedition did not collect samples in Willapa Bay. Of the three regions sampled by the 2000 Expedition, Willapa Bay yielded the largest number of exotic species and was the most visually dominated by exotics.

Among the three regions, Elliott Bay has experienced the most extensive physical alteration, and Willapa Bay the least. However, the apparent dominance by exotics was slightly greater in Totten/Eld Inlets than in Elliott Bay, and much greater in Willapa Bay. Thus the greatest number and extent of invasions was found in the least physically altered system. This pattern appears to contradict the hypothesis that more disturbed habitats are more vulnerable to invasions (e.g. Elton 1958; Lozon & MacIssac 1997). However, it is important to note that while Willapa Bay is relatively undeveloped, it is far from pristine. Habitats and natural processes in the bay have been extensively altered by practices such as diking, agriculture, aquaculture, dredging and deforestation of the watershed. Dominant invaders (Atlantic cordgrass and Japanese oysters) have also altered the physical environment.

Elliott Bay is an important international and coastal shipping center, which Totten/Eld Inlets and Willapa Bay are not. The latter two regions, however, are major historic and current sites for aquaculture. Since these regions appear to be as invaded as (or more invaded than) Elliott Bay, this suggests that aquaculture activities may historically have been as effective as (or more effective than) ship-associated mechanisms in moving organisms across and between oceans, and between bays. We note that aquaculture activities have historically been efficient vectors for moving pests and parasites of shellfish. The shipment and planting of oysters for commercial aquaculture is considered to be a possible mechanism responsible for introducing onto the Pacific Coast 35 of the 40 exotic species collected by the Expedition. In contrast, ballast water is considered a possible transport mechanism for 13 of the species, and all ship-associated mechanisms together (ship-fouling, solid ballast and ballast water) for 28 of the species. All of these mechanisms would also be effective at moving organisms between bays on the Pacific Coast.

Much more work is needed to inventory and monitor exotic species in the region. The greatest necessity is for the tools, funding, institutional framework and mandate to support the taxonomic activities needed to recognize and identify new exotic species. Such actions would directly support monitoring for exotic species, they would also benefit marine taxonomic work generally, and contribute immeasurably to our understanding of Washington's marine ecosystems and the impacts of human activities upon them.

Report of the Washington State Exotics Expedition 2000

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Introduction

In recent decades, the world has witnessed an array of harmful invasions by exotic marine and freshwater organisms. These include:

- The Atlantic comb jelly *Mnemiopsis leidyi* was introduced into the Black Sea and the Sea of Azov in the early 1980s. It became phenomenally abundant and consumed much of the seas' crustacean zooplankton, contributing to the decline of the region's anchovy and sprat fisheries and of the fishing fleets of six nations that depended on them (Travis 1993). *Mnemiopsis* subsequently declined dramatically.

- The European zebra mussel *Dreissena polymorpha* appeared in the Great Lakes in the late 1980s. Within a few years, the mussels spread across much of North America, from Canada to New Orleans and from the Hudson River to Oklahoma (Nalepa and Schloesser 1993). Zebra mussels have become a massive nuisance, causing millions of dollars of damage primarily by blocking the water intake systems of cities, factories and power plants. In addition to economic damage, zebra mussels could cause ecological damage, such as threatening native unionid mussels through competition.

- Toxic red and brown tides have appeared in many parts of the world. Some cases were shown to be caused by dinoflagellates introduced in ballast water or shellfish imports for aquaculture (Hallegraeff *et al.* 1989; Hallegraeff and Bolch 1991). Human neurotoxins produced by the dinoflagellates accumulate in clams or mussels, sickening and occasionally killing people that eat them. During a red tide outbreak in New Zealand, people walking along the shore became ill from airborne toxins (O'Hara 1993).

- In 1991, the South American epidemic strain of cholera-causing bacterium *Vibrio cholerae* was discovered in oysters and fish in Mobile Bay, Alabama. The U.S. Food and Drug Administration sampled ships arriving from South America and found the same strain of cholera in the ballast water of a third of them (*U.S. Federal Register* 1991; McCarthy and Khambaty 1994). Some medical researchers believe that ballast water discharges were responsible for initially introducing the cholera strain into South America (Ditchfield 1993; Epstein *et al.* 1993), triggering an epidemic that resulted in at least a million cases and ten thousand deaths (Tauxe 1995).

These and other well-publicized aquatic invasions, including the introduction to the Pacific Coast of the European green crab *Carcinus maenas* (Cohen *et al.* 1995) and the Chinese mitten crab *Eriocheir sinensis* (Cohen and Carlton 1997), have led to increasing public concern about the status and impacts of non-native species.

To provide the public and policymakers with better information on the status of exotic species in Washington waters, the Washington State Department of Natural Resources organized a survey of exotic organisms in Puget Sound in 1998 (Cohen *et al*. 1998). The1998 Puget Sound Expedition collected and identified 39 non-indigenous species in six days of sampling. Ten of the non-indigenous species collected by the expedition are new records for Puget Sound.[i]

We report here on a second survey of exotic organisms in Washington State waters, conducted May 17-23, 2000. We sampled in three regions: Elliott Bay and the Duwamish River estuary near Seattle in Puget Sound; Totten and Eld Inlets near Olympia, also in Puget Sound; and Willapa Bay, on Washington's outer coast. This survey was the sixth in a series of Rapid Assessment surveys for exotic marine organisms on the Pacific Coast. Four surveys were conducted in San Francisco Bay in 1993, 1994, 1996 and 1997, and the fifth was the 1998 survey in Puget Sound. The primary goal of each survey was to provide general information on the extent of biological invasions within a region in terms of the number and distribution of non-native species that are present. To this end, multi-institutional teams of taxonomic experts were assembled to quickly sample and identify a broad suite of organisms at a number of sites within the region. Participants in the current study included staff or faculty from the Washington Department of Natural Resources, Washington Department of Ecology, Washington Department of Fish and Wildlife, King County Environmental Laboratory, University of Washington (Seattle and Tacoma campuses and Friday Harbor Laboratories), Evergreen State College, Western Washington University, Oregon State University, San Francisco Estuary Institute, Los Angeles County Museum of Natural History and Institute of Marine Biology/Far East Branch of Russian Academy of Science; and students from the University of Washington.

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i The original report listed eleven new records, which we amended to ten new records when we discovered earlier reports of the entoproct *Barentsia benedeni* in Puget Sound.

Methods

As in past surveys, our primary objective was to conduct a rapid assessment of the status of exotic invasions within defined regions and habitat types through non-quantitative census methods. Secondary objectives were to obtain data for comparisons between habitats and regions, and for comparisons with past surveys; to obtain baseline data for future assessments of changes in invasion status and the effectiveness of prevention or control efforts; to detect new invasions and document significant range extensions; and to identify new species.

Three regions in Washington State were sampled to capture a range of oceanographic conditions and patterns of human use (Figure 1). Elliott Bay and the Duwamish River estuary are located in the Central Basin of Puget Sound, near the City of Seattle, with large areas of intensive urban development, and the Port of Seattle, a major international port. Totten and Eld Inlets are relatively protected bays in the Southern Basin of Puget Sound. Aquaculture and residential land uses predominate in these inlets, and the Port of Olympia, a small international port, is in adjacent Budd Inlet. Willapa Bay is Washington's largest outer coast estuary. It is the state's largest aquaculture center, much of its shoreline is undeveloped, and there is currently no commercial shipping in the bay.

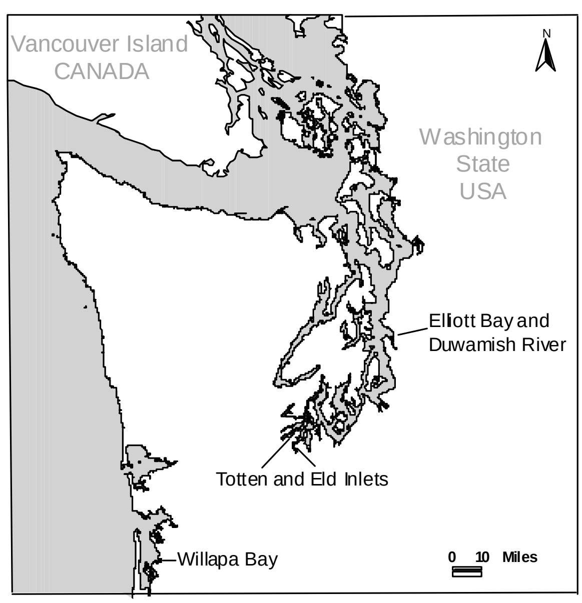

Figure 1. Map of Sampling Regions in Washington State

Within each region, sampling sites were selected to obtain broad coverage in habitat types in terms of substrate, salinity, water temperature and spatial distribution (see Figures 2-4 and Tables 1-3). We mainly sampled intertidal mudflats, cobble beaches, oyster reefs, dock fouling (organisms growing on the sides and undersides of floating docks and associated floats, bumpers, tires, ropes, etc.), saltmarshes and consolidated clay substrates. When present, we sampled associated structures and substrates such as concrete pilings, bridge supports, wooden pilings and drift logs. Sampling sites were selected by Helen Berry, David Milne, Brett Dumbauld, Jeff Cordell, Alan Kohn, Tom Mumford, Betty Bookheim, Liz Carr, David Secord, Claudia Mills and Andrew Cohen.

Near surface (0-0.3 m) salinity and water temperature were measured at most sites using two refractometers and thermometers. We also measured salinity and water temperature with a YSI (Yellow Springs Instruments) conductivity/temperature meter for comparison, since we obtained variable readings from similar electronic meters in previous expeditions. Salinity measurements are presented in this report in Practical Salinity Units (psu), which are comparable to parts per thousand (ppt).

Organisms were sampled by a variety of manual techniques. Tools included shovels, hand scrapers, a long-handled scraper with a steel mesh net, and sieves. A custom-made cylindrical benthic sampler fitted with 1 mm stainless steel mesh walls was thrown out on a line and retrieved by dragging along the bottom, working like a small benthic sled to collect larger infauna. Vertical plankton hauls were taken with a 0.5 m, 102 micron mesh net with a 211 micron mesh cod end. Medusae and ctenophores were caught with a cup mounted on a long handled pole. Benthic (bottom) samples were taken with an Ekman grab, sieve-washed and sorted on site. Unsieved bottom samples were retained for later examination for foraminifera and other microfauna.

Field identification of specimens was followed by examination of live samples in the laboratory by the expedition's team of taxonomic experts. A one-liter representative voucher collection was obtained from each main sampling site, plus additional samples of material of interest. The samples were kept on ice in insulated coolers until examination in the laboratory. Laboratory work was conducted at the University of Washington at Tacoma; at the Evergreen State College; and in a temporary laboratory set up in Ocean Park near Willapa Bay, with equipment on loan from UW-Tacoma, the Los Angeles County Museum of Natural History, and the Washington Department of

Natural Resources. Expedition members identified organisms, and some individuals retained material for further study at their home institutions. After examination was completed, samples were fixed in 10% formalin, with most of the material to be later transferred to 70% ethanol. The voucher collections are currently held by Washington DNR, and will be deposited in an appropriate curated facility. Other material, including sponge, hydroid, nudibranch and kamptozoan specimens, were shipped to specialists for additional work. Specimens of selected gastropods and bryozoans were preserved in 95% ethanol for DNA analysis at the Institut de la Mer et du Littoral in La Rochelle, France and the American Museum of Natural History in New York.

Additional information on participants, schedule and equipment is provided in Appendices 1-3.

Regions and Sites Sampled

Elliott Bay and the Duwamish Waterway
by Marjorie Wonham and Kevin Britton-Simmons

Elliott Bay and the Duwamish river estuary have been inhabited for thousands of years. With the arrival of white settlers 150 years ago this region was fundamentally altered by human activities. The following description of historical changes is summarized from Blomberg (1995). Prior to development, the Duwamish estuary consisted of three main distributary channels meandering over approximately 1,619 ha (4,000 acres) of intertidal mud and sand flats and vegetated marsh. The estuary received freshwater input from the 424,760 ha (1,640 mi^2) watershed drainages of lakes Sammamish and Washington and the Cedar, Black, Green and White rivers.

From 1900-1920, the Duwamish estuary was physically modified in three major ways. First, the meandering estuarine channels were excavated and dredged to create the Duwamish Waterway, a single large, straight navigation channel. Second, the dredged material was used to fill in adjacent wetland areas for industrial shoreline development. Third, the White River was diverted to provide water for the City of Tacoma, and the Lake Washington Ship Canal was built, eliminating the Black River and diverting the Cedar River.

The Elliott Bay and Duwamish region now contains almost 2.104 ha (5,200 acres) of industrial land, all of which is former estuarine habitat. Less than 2% of the original intertidal habitat and only 30% of the original watershed areas remain. The channels have been reduced from 28.2 linear km (17.5 mi) of riparian habitat to 16.1 km (10 mi) of predominantly bulkheads, riprap and docks.

Local restoration and mitigation efforts include projects by the Port of Seattle and a multi-agency effort initiated by the federal Coastal America program. Since the mid-1980's the Port of Seattle has constructed 1.45 ha (3.6 acres) of intertidal habitat at 5 sites and 5.0 ha (12.4 acres) of artificial subtidal reefs, as mitigation for new development projects. Three Coastal America restoration sites have been established, including a *Carex lyngbyei* and *Scirpus maritimus* revegetation project at the Duwamish Turning Basin (see site descriptions below).

The Duwamish River and Elliott Bay remain heavily polluted with polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs) and heavy metals released through historical activities, surface runoff, combined sewer overflow drains and industrial spills. Currently, commercial harvest of shellfish is prohibited and recreational harvest is not recommended in Elliott Bay, due to high fecal coliform bacteria levels.

The major pathway of exotic organisms to the Elliott Bay/Duwamish region is commercial shipping. Maritime trade in this region began in the 1850s and by 1890 as many as 11 ships departed Seattle daily carrying timber, coal, salted salmon and wheat to destinations such as California, China and Europe. The Port of Seattle was established in 1911 and by 1960 Seattle was the fifth most active container port in the United States, a ranking it retains today. During the last decade the Port of Seattle handled an annual average of 14.4 million metric tons of cargo, over 94% of which (by value) is trade with Pacific Asia. Approximately 3 million metric tons of ballast water is discharged into Seattle waters annually (Carlton *et al.* 1995).

In addition to shipping, two important vectors transporting exotic species into Elliott Bay and the Duwamish waterway are recreational boating and aquaculture. Recreational boats arrive daily from locations worldwide and are a potential vector of fouling organisms. Although no commercial aquaculture is conducted here, species introduced elsewhere in Puget Sound via aquaculture may spread into this region. Finally, the importation of live seafood and biological specimens may be potential vectors for exotic species.

We sampled 4 sites in Elliott Bay and 3 sites along the Duwamish River (Figure 2 and Table 1). These sites varied in the salinity, water temperature and substratum sampled. At three sites (Bell Harbor Marina, Magnolia Park and Duwamish River Turning Basin), C.E. Mills sampled for macrozooplankton at a later tide or from nearby docks.

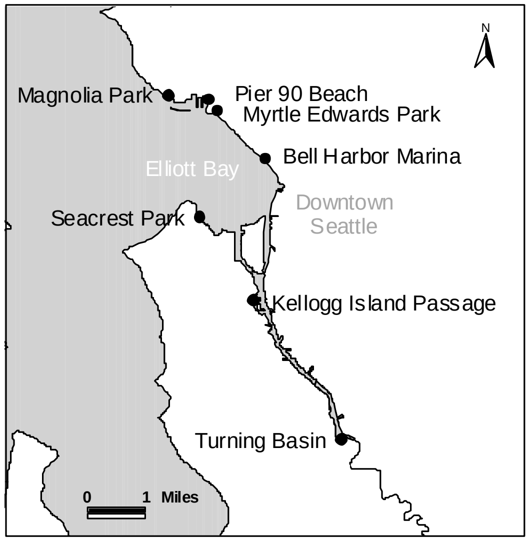

Figure 2. Map of Sampling Sites in Elliott Bay

Table 1. Elliott Bay and Duwamish River Site Descriptions

1. Bell Harbor Marina, Elliott Bay — 8:30-9:30 am, 17 May 2000
   47° 36’ 36.698” N; 122° 20’ 48.790” W — Salinity 26 psu Water temperature 12°C

Site description: Port of Seattle marina in downtown Seattle that receives international yacht traffic and is adjacent to a new cruise ship facility. The marina is composed of concrete floats and steel pilings; we sampled both and observed macroplankton from the floats. C.E. Mills returned at high tide at 5:00-6:00 pm to sample the macroplankton when it was much denser. The bottom substrate around the periphery of the marina is composed of mixed coarse rock. We took a benthic grab from muddy bottom near the center of the marina about 8 m below the water surface.

Biotic community: Float community dominated by kelps (especially *Desmarestia* and *Laminaria*) and mussels with small barnacles. Pilings covered with barnacles above the water line (*Balanus glandula* and *Chthamalus*), with mussels and *Metridium* common below the water line. Plankton with abundant small hydromedusae, especially *Clytia gregarium*, *Eutonina indicans*, *Aequorea victoria* and *Leuckartiara* sp.

2. Myrtle Edwards Park, Elliott Bay — 10:30-11:10 am, 17 May 2000
   47° 37’ 35.897” N; 122° 22’ 20.031” W — Salinity 27 psu Water temperature 12°C

Site description: Seattle City Park in front of Elliott Bay Fishing Pier. Shoreline composed of large boulder riprap throughout the intertidal and dropping steeply to below the water line. Adjacent to a grain terminal where a ship from Panama was in port.

Biotic community: Boulder community dominated by mixed algae in the low intertidal including *Enteromorpha*, *Ulva*, *Mastocarpus*, *Iridaea*, *Polysiphonia*, *Cryptosiphonia* and other species; small numbers of mixed invertebrates on the undersides of rocks. High intertidal dominated by barnacles, periwinkles and limpets.

Table 1. Elliott Bay and Duwamish River Site Descriptions (Continued)

3. Pier 90 Beach, Elliott Bay — 10:50-11:50 am, 17 May 2000
47° 37’ 51.840” N; 122° 22’ 40.261” W — Salinity 27 psu Water temperature 14°C

Site description: Sandy north-facing beach in protected cove south of Pier 90. Upper intertidal riprapped. Low and mid-intertidal substrate of sand with a few pebbles, cobbles and boulders.

Biotic community: Sand flats dominated by *Macoma nasuta*, with *Tellina modesta* and *Macoma balthica*. Muddy sand in low intertidal with abundant capitellids, nephtyids and glycerid/glycinid worms. Abundant juvenile English Sole in the shallow subtidal.

4. Magnolia Park, Elliott Bay — 12:30-1:25 pm, 17 May 2000
47° 37’ 56.463” N; 122° 23’ 54.932” W — Salinity 27 psu Water temperature 16°C

Site description: Seattle City Park beach in Elliott Bay. Small backshore beach with logs. Outfall pipe empties onto riprap in upper intertidal. Low intertidal with pebble-cobble veneer over coarse sandy pockets, with a few boulders. The nearby Elliott Bay Marina was also sampled later in the day for macrozooplankton, primarily off the west side of Pier A, adjacent to the sea wall.

Biotic community: Low intertidal cobbles coated with barnacles and ulvoid green algae, with some *Anthopleura elegantissima* on the undersides. *Calliopea* amphipods abundant in the surf, *Nereocystis* bed offshore. Common worms include nephtyids, capitellids and glycerids/goniatids. *Idotea wosnesinskii* was abundant under high rocks. The Elliott Bay Marina had abundant hydromedusae alongside the dock, especially *Clytia gregaria*, with large numbers also of *Eutonina indicans, Proboscidactyla flavicirrata, Aequorea victoria* and *Mitrocoma cellularia*; ctenophores and young scyphomedusae present, but scarce.

5. Kellogg Island Passage, Duwamish River — 9:30-10:40 am, 18 May 2000
47° 33’ 33.256” N; 122° 21’ 04.845” W — Salinity 10 psu Water temperature 13°C

Site description: We sampled at a public access point located on the western channel of the Duwamish River across from Kellogg Island, the last remaining natural meander of the lower Duwamish River. Upper intertidal fairly sandy with brick debris from defunct brick factory. Low intertidal composed of soft mud with some brick and wood pieces and a few large logs.

Biotic community: Upper intertidal with *Balanus*, *Fucus*, *Enteromorpha* and occasional *Hemigrapsus oregonensis*. Low intertidal dominated by *Gnorimosphaeroma*, *Corophium salmonis* and a few clams. Logs with lots of shipworm bores, barnacles and *Mytilus*.

6. Seacrest Park, Elliott Bay — 10:50-11:50 am, 18 May 2000
47° 35’ 20.417” N; 122° 22’ 49.255” W — Salinity 26 psu Water temperature 13°C

Site description: Seattle City Park near Duwamish Head. Pebble-cobble pocket beach with areas of steep boulder-cobble riprap extending to below the waterline, fishing pier on pilings and public float.

Biotic community: High intertidal riprap dominated by *Fucus*. Low intertidal with diverse algae (especially reds) and invertebrates. Benthic grabs yielded abundant worms and amphipods. Hydromedusae and young scyphomedusae were common in the plankton.

Table 1. Elliott Bay and Duwamish River Site Descriptions (Continued)

7. Turning Basin, Duwamish River — 12:40-1:20 pm, 18 May 2000
47° 30’ 38.590” N; 122° 18’ 11.484” W — Salinity 2 psu Water temperature 15°C

Site description: Site of multi-agency *Carex*-marsh restoration project and public access at about 103rd Street, off West Marginal Place S. Upper mudflat gravelly. Lower intertidal soft mudflat with small tidal feeder-creeks. The mud is anoxic beginning about 1 cm below the surface. The nearby Duwamish Yacht Club marina, a private marina at 1801 S. 93rd Street with floating concrete docks, was sampled for macrozooplankton.

Biotic community: Mudflat with a surface coat of fine filamentous green algae and *Enteromorpha*, and perforated with small polychaete and amphipod tube-holes. Barnacles present on concrete debris. The Duwamish Yacht Club floats were heavily fouled with green filamentous algal slime; *Corophium spinicorne* and small colonies of *Cordylophora caspia* were present on the submerged rungs of ladders, and barnacles were common on the pilings.

Totten and Eld Inlets

By Helen Berry and David Milne

Totten and Eld inlets are located at the southernmost end of Puget Sound. These narrow inlets are each approximately 15 km long and less than 2 km wide. The inlets gradually shoal from approximately 30 m depth at the mouth to intertidal mudflats and salt marshes at the head. Salinity is relatively high in the inlets (29-31 psu at the time of sampling), with relatively fresh areas near creek mouths (0.5 psu measured during sampling.) The inlets have relatively low wave exposure due to limited fetch. Tidal amplitude in this region is up to 6 m, the greatest in Washington.

The shoreline habitats in the two inlets are similar. Backshore areas are generally composed of glacial till. The shorelines at the mouths of the inlets are predominantly composed of mixed coarse substrate. Cobbles and pebbles in the upper and middle intertidal zones grade to sand and mud in the lower intertidal and subtidal zones. The beaches gradually decrease in slope and sediment size from the mouth to the head of the inlets.

Middens and other archaeological remains show that, prior to European settlement, the inlets were used extensively by Native Americans, who lived in the area and harvested the Olympia oyster, *Ostrea conchaphila*, and a variety of clam species.

In the mid-1800s, Europeans began to settle in the area. They used the inlets extensively for transportation. Rail lines brought timber from southern forests to boats at Kamilche Point in Totten Inlet and to Mud Bay in Eld Inlet. European settlers also harvested native oysters and clams for personal and commercial use. Early aquaculture involved extensive buildup of horizontal beds behind low dikes for retention of water at low tide.

As native oyster stocks became depleted, oyster growers began importing and planting other species. By the 1950s, growers had abandoned farming Olympia oysters in favor of the more resilient and faster-growing Pacific oysters *Crassostrea gigas*. A variety of aquaculture species are currently produced. *Crassostrea gigas* and *Ostrea conchaphila* are grown on floats and on beaches. Mussels are grown on rafts in Totten Inlet: the exotic Mediterranean mussel *Mytilus galloprovincialis* is “seeded”, and the native bay mussel *Mytilus trossulus* may settle naturally on the rafts. The introduced Manila clam *Venerupis philippinarum* and the native clam *Protothaca staminea* are grown intertidally in Totten and Eld Inlets.

Currently, waterfront land on Totten and Eld Inlets is occupied primary by low density, single family residences and by The Evergreen State College. Approximately one-third of the upper intertidal shoreline has been modified by bulkheads or seawalls (Nearshore Habitat Program 2000). Shellfish production takes place in much of the intertidal zone, commercial shellfish growers own the lands or lease them from the state or private owners. Water quality is generally good, and the shellfish beds are rarely closed to harvest. Small boats are common in the inlets for recreation and for aquaculture work. There are some private docks in the inlets, but no commercial marinas. The Port of Olympia in nearby Budd Inlet receives limited international shipping traffic. Major pathways for introducing exotic species into the inlets include aquaculture, boats, and natural dispersal from other areas.

We sampled six sites in Totten and Eld inlets (Figure 3). At the Taylor Shellfish site, we sampled at the shore near the boat ramp and on the shellfish-growing rafts.

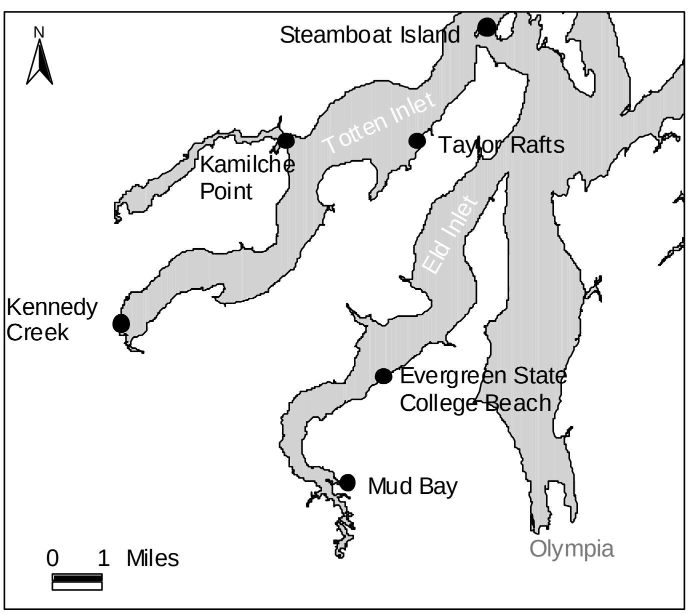

Figure 3. Map of Sampling Sites in Totten and Eld Inlets

Table 2. Totten and Eld Inlet Site Descriptions

8. Taylor Shellfish Rafts, Gallagher Cove, Totten Inlet — 10:00-11:10 am, 19 May 2000
47° 09’ 10.043” N; 122° 57’ 51.991” W — Salinity 30 psu Water temperature 14°C

Site description: Three wooden floating rafts supported by plastic-galvanized drums, with 10’-long, hanging lines coated with cultured mussels and fouling invertebrates. The mussels are grown here for 12 to 16 months prior to harvest. Rafts were previously used to culture *Crassostrea virginica* and *Ostrea edulis*. We also sampled the adjacent beach and boat ramp belonging to Taylor Shellfish. The low-angle beach has mixed gravel-pebble-cobble veneer overlying clay-silt hardpan. Upper intertidal composed of narrow pebble and shellhash band and concrete bulkhead. Some oyster bags lying on the low intertidal beach.

Biotic community: Hanging lines dominated by the seeded mussel *Mytilus galloprovincialis* densely covered with sponges, botryllid tunicates, *Metridium* and diatoms, as well as many other invertebrates. *Pleurobrachia bachei* was the most abundant macrozooplankter. On the adjacent beach and boat ramp, barnacles were common on pebbles and cobbles. Patchy ulvoids growing on hardpan.

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9. Kamilche Point, Totten Inlet — 12:30-1:40 pm, 19 May 2000
47° 09’ 07.253” N; 123° 01’ 06.195” W — Salinity 30 psu Water temperature 15°C

Site description: Private beach belonging to Judy Taylor at the junction of Little Skookum and Totten Inlets. Backshore composed of a concrete bulkhead. Moderately steep beach of sand with pebble veneer, with patches of hardpan in the middle and high intertidal. Commercial plantings of clams in the mid-intertidal and oysters in the low intertidal.

Biotic community: Dense clams found in the intertidal zone including *Venerupis, Tresus* and *Saxidomus*. Nearly solid *Crassostrea gigas* oysters coated with ulvoids and miscellaneous red algae in the low intertidal, bounded at the upper end by an old dike.

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10. Kennedy Creek, Totten Inlet — 2:25-3:15 pm, 19 May 2000
47° 05’ 56.949” N; 123° 05’ 10.404” W — Salinity 0.5 psu Water temperature 14°C

Site description: Protected river delta at the head of Totten Inlet, accessed from Highway 101 pull-off. Extensive saltmarsh with a 0.5 m vertical bank that drops to gravelly intertidal mudflats.

Biotic community: Saltmarsh characterized by two species of *Juncus*, and with a patch of about 20 chocolate lilies, *Fritillaria lanceolata*. Mudflats with sparse green algae, small barnacles on pebbles, branches and other debris. Mud dominated by *Neanthes succinea*; gravelly mud with abundant *Corophium salmonis*, and cumaceans in fine sediments at the waterline.

Table 2. Totten and Eld Inlet Site Descriptions (Continued)

11. The Evergreen State College Beach, Eld Inlet — 12:20-1:00 pm, 20 May 2000
47° 05' 11.682" N; 122° 58' 31.869" W — Salinity 29 psu Water temperature 15°C

Site description: Protected, moderately-sloping beach with backshore glacial feeder-bluff. Upper intertidal pebble and cobble beach with a few boulders. Middle and lower intertidal zone composed of mixed fine muddy sand with pebbles, cobbles and abundant shell hash.

Biotic community: Abundant bivalve and polychaete infauna. Common clams included *Protothaca staminea*, *Macoma nasuta* and *M. inquinata*, *Clinocardium nuttallii* and *Saxidomus giganteus*. Common worms included *Hemipodus borealis*, *Nereis vexillosa*, *Harmithoe imbricata* and *Ophiodromus pugettensis*. Barnacles abundant on pebbles, cobbles and boulders.

12. Steamboat Island, junction of Totten Inlet and Eld Inlet — 1:45-3:00 pm, 20 May 2000
47° 11' 05.687" N; 122° 56' 22.366" W — Salinity 31 psu Water temperature 13°C

Site description: Beach accessed by gated ramp, with the sampling site about one hundred yards to the left. Primary sampling location was a lower intertidal hardpan bench with sheer drop-off on the water side, with about 1 m of the vertical face exposed. Samples were also collected along the adjacent beach with pebble, cobble and sand veneer, backed by concrete bulkheads, and on a beached wooden float in the lower intertidal.

Biotic community: Numerous, densely-packed pholid bivalves *Zirphaea pilsbryi* boring into the mudstone at upper elevations in the bench. Abundant *Schizoporella unicornis* in lower intertidal and otherwise diverse invertebrate community including starfish, limpets and gastropods. Prominent band of *Laminaria saccharina* with mixed red algae and a band of *Sargassum muticum* in the shallow subtidal. Hardpan bench with a dense mat of ulvoid green algae, and dense red and brown algae at lower levels. *Ulva* and *Porphyra* growing on lower intertidal beach areas.

13. Mud Bay, Eld Inlet — 4:55-5:25 pm, 20 May 2000
47° 03' 20.778" N; 122° 59' 19.758" W — Salinity 2 psu Water temperature 15°C

Site description: Protected river delta at the head of Eld Inlet, accessed from Ralph and Karen Munro's property. Extensive backshore saltmarsh with 0.5 m vertical bank that drops to mudflats.

Biotic community: Saltmarsh characterized by *Juncus* and *Potentilla,* with *Salicornia* in lower elevation areas. Mudflats dominated by *Neanthes succinea*, abundant *Nippoleucon hinumensis* at the waterline, and barnacles, littorines and *Diadumene lineata* on pebbles in the mud. *Mya arenaria* present, but not common.

Willapa Bay
By David Secord and Andrew Cohen

Willapa Bay is a large estuary on Washington's outer coast. At high tide the water covers approximately 88,000 acres (more than 100 square miles), but nearly half the water drains out at low tide, revealing extensive mudflats, native saltmarsh, and marsh dominated by the Atlantic cordgrass *Spartina alterniflora*. There is currently no commercial shipping in the bay, and most of its shoreline is undeveloped.

The bay has supported a large commercial oyster industry nearly continuously from the early 1850s to the present. Initially, extensive reefs of the native Olympia oyster, *Ostrea conchaphila*, were harvested to meet market demand in San Francisco. The native oyster went into serious decline by the 1880s, and early in the 20th century it was commercially replaced by *Crassostrea virginica* from the eastern United States. This species declined after World War I, and by 1936 the Pacific oyster *Crassostrea gigas*, from Japan, had become the dominant oyster in Willapa Bay. Of the more than one million cases of oysters shipped from Japan to Washington between 1948 and 1983, the Washington Department of Fish and Wildlife estimates that over half went to Willapa Bay (letter from Robert Sizemore, WDFW, to Lisa Veneroso, 11 April 1994). The import of each of the oyster species for commercial exploitation brought associated exotic assemblages of organisms from the Atlantic and Western Pacific Oceans.

The major habitat types in Willapa Bay are vast intertidal mudflats and emergent saltmarsh. In both of these habitats, the visually dominant organisms are exotic: the Atlantic cordgrass *Spartina alterniflora* spreading both vegetatively and by seed despite extensive mechanical and chemical control efforts; extensive beds of the Japanese oyster *Crassostrea gigas*; and the Japanese eelgrass *Zostera japonica* covering large areas of mudflats. Willapa Bay is classically estuarine, with many rivers and streams flowing into it, but also with substantial oceanic flushing. Its salinities are generally lower than those in Puget Sound but higher than those in San Francisco Bay. It may be the most highly invaded large estuary in the Pacific Northwest, and introduced organisms such as the oysters and cordgrass may be providing habitat for additional invaders. For example, clusters of Japanese oysters provide firm substrate for exotic organisms such as the Japanese nestling clam *Neotrapezium liratum*, the Japanese anemone *Diadumene lineata*, and the Atlantic sponge *Clathria prolifera*, while the Atlantic cordgrass may provide habitat for the juvenile European green crab *Carcinus maenas*. Further research will be needed to characterize these parallel webs of ecological interactions (e.g. competition, predation and positive interactions *among* invaders) which are creating new and shifting ecological communities alongside the remaining native flora and fauna of Willapa Bay.

We sampled 14 sites in Willapa Bay (Figure 4). Due to the size of Willapa Bay and related logistical considerations, no sites were selected in the northern portion of the bay. Overall, approximately twice as many sites were sampled in Willapa Bay than in the other regions. Sites were selected by considering habitat type, suspected populations of exotic organisms, and logistics.

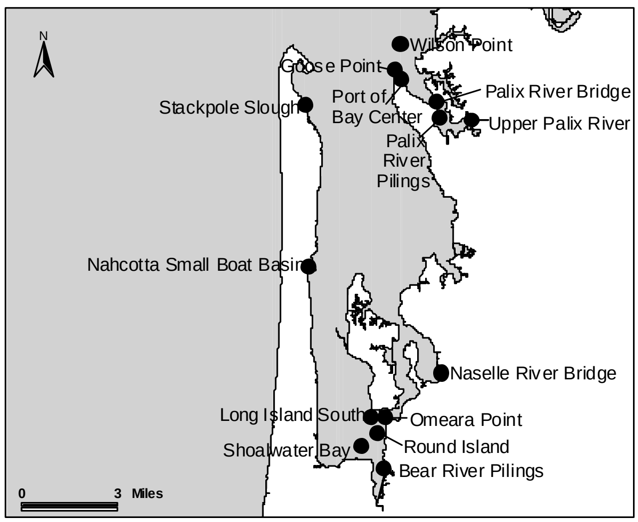

Figure 4. Map of Sampling Sites in Willapa Bay

Table 3. Willapa Bay Site Descriptions

14. Naselle River Bridge, Willapa Bay — 9:15-10:00 am, 21 May 2000
46° 26'.05 " N; 123° 54' 08.350 " W — Salinity 9 psu Water temperature 16°C

Site description: We sampled saltmarsh, mudflat and concrete bridge supports in the Naselle River channel on the south side of the Highway 101 bridge. Water samples were also collected from the bridge. The backshore along this shoreline is composed of riprap.

Biotic community: Marsh with *Carex, Triglochin* and *Spartina*. *Fucus* on high rocks, with *Neotrapezium liratum* bivalves under the rocks. Mudflat with *Zostera japonica* cover, abundant *Ilyanassa obsoleta*, and some clams and polychaetes. *Crassostrea gigas* oysters on and mounded around concrete bridge supports, with associated *Odostomia* snails and *Neotrapezium*.

Table 3. Willapa Bay Site Descriptions (Continued)

15. Goose Point, Willapa Bay — 10:45am-12:30 pm, 21 May 2000
46° 37’ 57.466 ” N; 123° 57’ 21.486 ” W — No water accessible at low tide

Site description: Extensive mudflat with a few *Spartina* clones; wave-cut bluffs with a fossil layer of primarily native oysters and ghost-shrimp burrows. High intertidal hard clay-mud; middle intertidal sandy-firm mud with pools and shallow channels.

Biotic community: Extensive *Spartina* wrack near high water line. High intertidal with some *Spartina* clones grading into sand with *Abarenicola* lugworm castings. Mid-intertidal covered with *Zostera japonica*, with many *Neotrypaea* and *Upogebia* holes, and amphipod *Eohaustorius* abundant, but patchy. *Zostera marina* in tidepools.

16. Port of Bay Center, Willapa Bay — 1:10-1:45 pm, 21 May 2000
46° 37’ 42.572’’ N; 123° 57’ 09.040 ” W — Salinity 17 psu Water temperature 17°C

Site description: Small boat harbor with fishing boats, surrounded by commercial oyster-processing facilities. Wooden floats supported by uncoated orange styrofoam, with creosote wood pilings along slough channel; silt and mud bottom. Large mounds of oyster shells along shoreline. Oily sheen on water surface throughout marina.

Biotic community: Floats dominated by heavily-silted; filamentous diatoms growing on all surfaces, and *Enteromorpha* growing at the waterline. Abundant invertebrates included yellow sponge, *Crassostrea gigas*, *Metridium* and ubiquitous *Diadumene lineata* anemones, and *Obelia* hydroids. Oysters dominated the pilings, with some barnacles higher up.

17. Upper Palix River, Willapa Bay — 9:55-10:35 am, 21 May 2000
46° 36’ 06.236” N; 123° 52’ 58.946” W — Salinity 0 psu Water temperature 14°C

Site description: Narrow river channel (about 8 m wide) with fresh water at low tide. Exposed fine-mud river banks with moderate slope up to *Caryx lyngbii* meadow with yarrow. Logs and branches in river bed.

Biotic community: Logs and emergent branches with barnacles, green algae, *Corophium* and the hydroid *Cordylophora caspia*. Mud with abundant polychaetes.

18. Palix River Pilings, Willapa Bay — 10:50-11:05 am, 21 May 2000
46° 36’ 10.700” N; 123° 54’ 47.270” W — Salinity 6 psu Water temperature 16°C

Site description: Four upright pilings and one fallen piling in mid-river.

Biotic community: The exposed fauna and flora on pilings from uppermost to lowest were: barnacles, *Ulva/Porphyra* algae, mussels and oysters, and hydroids, some of which were coated with *Conopeum.* A plankton tow yielded no medusae.

Table 3. Willapa Bay Site Descriptions (Continued)

19. Wilson Point, Willapa Bay — 11:20-11:40 am, 21 May 2000
46° 38’ 57.879” N; 123° 57’ 09.608” W — Salinity 22 psu Water temperature 22°C

Site description: Southern edge of oyster flat belonging to David Nisbet, near the entrance to the Palix River. Flat composed of uniformly fine sand/mud, with *Zostera marina* growing just below the tideline.

Biotic community: Oysters with abundant botryllid tunicates of various colors, *Polysiphonia*, and *Ulva*. Mud with thin *Zostera japonica* cover and infauna with abundant capitellids, nephthids and hemichordates.

20. Palix River Bridge, Willapa Bay — 12:00-12:20 pm, 21 May 2000
46° 36’ 46.551” N; 123° 54’ 56.389” W — Salinity 18 psu Water temperature 24°C

Site description: Site of intensive *Spartina* control through use of herbicides. Flats of sandy mud, with hydrogen sulfide very near the surface. We also scraped samples from the concrete pilings under the Palix River bridge on Highway 101, several hundred meters upriver.

Biotic community: Upper tidal flat dominated by dead *Spartina* stems, with a few live *Spartina* shoots, and *Triglochin* and *Salicornia* becoming established. Lower intertidal with cover of *Zostera japonica* grading into *Zostera marina* at the water line, with *Nippoleucon hinumensis, Grandidierella japonica* and *Corophium acherusicum* abundant. Concrete pilings with green filamentous algae high up, and barnacles, oysters and mussels below, with *Diadumene lineata* anemones on the oysters.

21. Stackpole Slough, Willapa Bay — 10:45-12:00 noon, 22 May 2000
46° 36’ 21.345” N; 124° 02’ 35.516” W — Salinity 19 psu Water temperature 17°C

Site description: Slough accessed from short trail in Leadbetter Point State Park. Extensive high intertidal *Spartina* stand penetrated by intertidal creek with sandy bottom; mid-intertidal sandy-mudflat sloping down to slough, with oyster flats on the other side of the slough. Salinity and water temperature in the intertidal creek differed from that in the slough (Salinity in creek was 7 psu, water temperature was 22°C).

Biotic community: *Spartina alterniflora* with dense mats of blue green algae over sandy-mud substrate, grading downward into dense *Zostera japonica* with some blue-green algae on mid-intertidal slope; and some *Z. japonica* intermixing with dense *Z. marina* in slough. Old, broken *Spartina* stems coated with barnacles; *Z. japonica* zone with abundant infauna of *Abarenicola*, capitellids and nephthids, grading into small clams and polychaetes in the sandy slough bottom. Creek with abundant *Venerupis philippinarum* at the level of the *Spartina* stand. Both species of *Zostera* with abundant reproductive shoots. Large heap of Japanese oyster drills, *Ocinebrellus inornatus*, left by growers to die at beach-end of trail.

Table 3. Willapa Bay Site Descriptions (Continued)

22. Nahcotta Small Boat Basin, Willapa Bay
46° 30' 02.348" N; 124° 01' 50.635" W
1:40-2:30 pm, 22 May 2000
Salinity 22 psu Water temperature 17°C

Site description: Small boat harbor next to oyster-processing facilities and the commercial marina for the Port of Peninsula. Wooden floats supported by uncoated blue styrofoam, with creosoted wood pilings. Large mounds of oyster shells along shoreline. Oily sheen on water surface throughout the marina.

Biotic community: Floats characterized by *Enteromorpha* at the waterline, and a dense cover consisting mostly of filamentous diatoms and obelioid hydroids, mixed with other invertebrates including abundant yellow sponge (*Halichondria*?), some *Clathria prolifera* sponge, *Botrylloides violaceus* and *Botryllus schlosseri*, and many polynoid polychaetes. Pilings dominated by barnacles, with oysters beginning at the mid-intertidal level.

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23. Omeara Point, Willapa Bay
46° 24' 10.914" N; 123° 57' 12.399" W
9:45-11:00 am, 22 May 2000
Salinity 20 psu Water temperature 18°C

Site description: Mudflat east of Omeara Point.

Biotic community: Mudflats with a moderate density of *Zostera japonica,* abundant *Ilyanassa obsoleta*, sparse *Crassostrea gigas*, abundant *Crangon, Grandidierella japonica, Notomastus* and *Nippoleucon hinumensis*. We also sampled a raised oyster mound about 30 by 20 feet in area, composed of heavily silted *Crassostrea gigas*, surrounding two grounded drift logs. *Neotrapezium liratum* were abundant in and under oysters (Estimated 500-600 per square meter from one sample). *Diadumene lineata, Fucus* on drift logs, *Mya arenaria, Crangon, Nippoleucon hinumensis, Venerupis philippinarum*; *Limnoria* and *Bankia setacea* found boring into logs. Ten 0.11-m^2 areas on mud at periphery of oyster mound censused for *Ilyanassa obsoleta*. These contained 2-12 individuals each, with a mean density of 52/m^2.

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24. Round Island, Willapa Bay
46° 23' 42.536" N; 123° 57' 32.749" W
11:20-11:50 am, 22 May 2000
No water accessible at low tide

Site description: Upper intertidal marsh fringe on cobble, pebbles and sand. Middle to high intertidal beach composed of angular cobbles and pebbles on sand/mud matrix. Middle to low intertidal mudflat. Thick layer of *Crassostrea gigas* providing substrate throughout middle and low intertidal.

Biotic community: *Glaux maritima, Jaumea carnosa* and *Potentilla* in marsh. In cobble/mixed coarse substrate and in oyster clumps, abundant *Idotea wosnesinskii, Neotrapezium liratum, Veneruperis philippinarum* in very high densities, few barnacles and little *Fucus.* Thick band of *Crassostrea gigas* in low intertidal. Medium density of *Zostera japonica* on mudflat with *Ilyanassa obsoleta* and *Z. marina* in swales. *Ilyanassa obsoleta*, censused in 3 one-m^2 quadrats along periphery of mud island, had a mean density of 45/ m^2 (.)

Table 3. Willapa Bay Site Descriptions (Continued)

25. Bear River Pilings, Willapa Bay — 12:00-12:30 pm, 22 May 2000
46° 22' 11.559" N; 123° 57' 04.895" W — Salinity 1 psu Water temperature 13°C

Site description: Bend in the Bear River next to highway 101, near saltmarsh above river channel. Sampled old pilings in intertidal mudflat.

Biotic community: Barnacles, algae and *Cordylophora caspia* on old pilings.

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26. Shoalwater Bay, Willapa Bay — 1:00-1:15 pm, 22 May 2000
46° 23' 04.358" N; 123° 58' 29.670" W — No water accessible at low tide

Site description: Extensive mudflat with pooling water at the southernmost extent of the bay. We sampled on the mudflat, not in the marsh.

Biotic community: In the high intertidal, dense *Spartina* spreading onto the mudflat. On the mudflat, *Spartina* seedlings, high density *Zostera japonica*, green algae and the snail *Ilyanassa obsoleta*. Many infaunal holes.

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27. Long Island South, Willapa Bay — 1:20-1:45 pm, 22 May 2000
46° 24' 17.338" N; 123° 57' 51.365" W — Salinity 16 psu Water temperature 21°C

Site description: Muddy sand flat off the southwest tip of Long Island, with a higher energy shore with open fetch to NW and W. We sampled along the main channel.

Biotic community: *Zostera japonica* and *Z. marina* in channels, *Ilyanassa obsoleta* abundant, some green algae, many *Sacoglossus* castings and infaunal holes.

Results and Discussion

The information in this section is a preliminary assessment of the available data. As noted below, considerable taxonomic work remains in order to complete analysis of the samples. The information given here should thus be considered provisional and subject to refinement as analysis proceeds.

The expedition sampled at a total of 27 sites in the three regions, with some sites composed of multiple, separately-sampled habitats. For example, sampling at Site #8, Taylor Shellfish Raft, was primarily conducted on Taylor Shellfish Company mussel- and oyster-growing rafts in Gallagher Cove, but expedition participants also sampled at the adjacent beach. The specimens and data for these two habitats were collected separately, but are combined in this report and presented as one site.

The Expedition collected and identified 40 exotic organisms in the three regions (Tables 4-7). Most of these organisms are native to the North Atlantic or the Northwestern Pacific region, and most were introduced to the Northeastern Pacific with oysters imported for aquaculture, in ship fouling or in ballast water (Table 8). A few appear to represent new or unpublished records for the region, for the state, or for the Pacific Coast of North America (Table 9). As discussed below, the status of several organisms collected by the Expedition will likely be clarified by further taxonomic analysis, and may produce additional records of exotic species. One polychaete worm collected by the Expedition represents either a new species or a previously unreported introduction, and one native nudibranch collected provides a substantial extension in its documented Pacific Coast range. A few of the species have undergone name changes in recent years, these are listed in Appendix 4.

Exotic Species Collected in Elliott Bay and Duwamish Waterway

Seven sites were sampled in the Elliott Bay and Duwamish River Estuary region May 17-18, including among them two floating dock habitats (Bell Harbor Marina and Seacrest Park) and intertidal mud, sand, cobble and riprap (boulder) substrates, plus two adjacent dock sites that were sampled for macroplankton (cnidaria and ctenophora). The five sites in Elliott Bay had salinities of 26-27 psu, and the two Duwamish River sites had salinities of 2 and 10 psu. (Both here and in the other regions, the intertidal sites were sampled at low tide, so that the measured salinities may be lower than the mean salinity at those sites on those days.) Water temperatures ranged from 12 to 16 °C for the seven sites.

Fifteen exotic species were collected and identified from this region (Table 4). Seven are native to the North Atlantic, six to the Northwest Pacific, one to the Black and Caspian seas, and one is of unknown origin (see Table 8). The 1998 Puget Sound Expedition sampled at floating docks within the Elliott Bay and Harbor Island marinas, collecting and identifying 13 exotic species (Cohen *et al.* 1998, Appendix 5). Of these, seven were collected by the 2000 Expedition, five were not, and one species requires additional taxonomic work. The 2000 Expedition has thus identified eight exotic species in the Elliott Bay region that were not found by the previous expedition, for a total of 21 exotic species identified in the region by the two expeditions.

Table 4. Exotic Species Collected in Elliott Bay

General Taxon	Species	Sites Collected (site number)
Protoctista: Algae: Phaeophyta	*Sargassum muticum*	Myrtle Edwards Park (2), Pier 90 Beach (3), Magnolia Park (4), Seacrest Park (6)
Cnidaria: Hydrozoa	*Cordylophora caspia*	Turning Basin (7)
Annelida: Polychaeta	*Hobsonia floridana*	Kellogg Island Passage (5), Turning Basin (7)
Annelida: Polychaeta	*Pseudopolydora kempi japonica*	Kellogg Island Passage (5)
Mollusca: Bivalvia	*Mya arenaria*	Magnolia Park (4), shells at Kellogg Island Passage (5)
Mollusca: Bivalvia	*Venerupis philippinarum*	shells at Kellogg Island Passage (5)
Arthropoda: Crustacea: Cumacea	*Nippoleucon hinumensis*	Elliott Bay Magnolia Park (4), Kellogg Island Passage (5), Seacrest Park (6)
Arthropoda: Crustacea: Tanaidacea	*?Sinelobus stanfordi*	Turning Basin (7)
Arthropoda: Crustacea: Amphipoda	*Corophium acherusicum*	Pier 90 Beach (3)
Arthropoda: Crustacea: Amphipoda	*Corophium insidiosum*	Bell Harbor Marina (1), Pier 90 Beach (3), Kellogg Island Passage (5)
Arthropoda: Crustacea: Amphipoda	*Grandidierella japonica*	Kellogg Island Passage (5)
Bryozoa: Cheilostomata	*Cryptosula pallasiana*	Bell Harbor Marina (1), Myrtle Edwards Park (2)
Bryozoa: Cheilostomata	*Schizoporella unicornis*	Bell Harbor Marina (1), Myrtle Edwards Park (2), Seacrest Park (6)
Urochordata: Ascidiacea	*Botrylloides violaceus*	Myrtle Edwards Park (2)
Urochordata: Ascidiacea	*Botryllus schlosseri*	Bell Harbor Marina (1)

At none of the sampled sites were exotic species found to be dominant or common, except for the European freshwater hydroid *Cordylophora caspia* which was present in moderate abundance at a marina near the Duwamish River Turning Basin (site 7). Various cryptogenic taxa (*Enteromorpha* spp., *Ulva* spp., *Mytilus trossulus* or *galloprovincialis*, *Macoma balthica* or *petalum*) were common at some of the sites.

Exotic Species Collected in Totten and Eld Inlets

Six sites were sampled in Totten and Eld Inlets May 19-20, comprising a variety of habitats including floating rafts and intertidal mud, sand and cobble beaches, with areas of hard clay or mudstone. Five sites had salinities of 29-31 psu, and two, at Kennedy Creek and Mud Bay (at the head of Eld Inlet), had salinities of 0.5 and 2 psu. Water temperatures ranged from 13 to 15 °C for the six sites.

Fifteen exotic species were collected and identified from Totten and Eld Inlets (Table 5). Six are native to the North Atlantic, eight to the Northwest Pacific, and one is of unknown origin (see Table 8). The 1998 Puget Sound Expedition sampled in south Puget Sound at floating docks in the Boston Harbor Marina and Shelton Yacht Club, collecting and identifying 17 exotic species (Cohen *et al.* 1998, Appendix 5). Of these, eight were collected by the 2000 Expedition, eight were not, and one species requires additional taxonomic work. Thus, the 2000 Expedition has identified seven exotic species in the south Puget Sound region that were not found by the previous expedition, for a total of 24 exotic species identified in south Puget Sound by the two expeditions.

Known exotic species were more obviously common or dominant here than in Elliott Bay. At Kennedy Creek and Mud Bay, large numbers of the Atlantic worm *Neanthes succinea* lay on the mud surface; the Japanese seaweed *Sargassum muticum* and the Atlantic bryozoan *Schizoporella unicornis* were common at Steamboat Island; the Asian fouling tunicate *Botrylloides violaceous* was common on the Taylor Shellfish Rafts; the Manila clam *Venerupis philippinarum* was common along with various native clams on the beach at Kamilche Point; and the anemone *Diadumene lineata* and the cumacean *Nippoleucon hinumensis*, both from Japan, were abundant at Mud Bay. In addition, the Mediterranean mussel *Mytilus galloprovincialis* and the Japanese oyster *Crassostrea gigas* were present in culture at some of the sites.

Table 5. Exotic Species Collected in Totten and Eld Inlets

General Taxon	Species	Sites Collected (Site number)
Protoctista: Algae: Phaeophyta	*Sargassum muticum*	Steamboat Island (12)
Cnidaria: Anthozoa	*Diadumene lineata*	Mud Bay (13)
Annelida: Polychaeta	*Neanthes succinea*	Kennedy Creek (10), Steamboat Island (12), Mud Bay (13)
Mollusca: Prosobranchia	*Batillaria attramentaria*	Taylor Rafts (8)
Mollusca: Prosobranchia	*Crepidula fornicata*	Taylor Rafts (8), Evergreen State College Beach (11)
Mollusca: Bivalvia	*Crassostrea gigas*	Taylor Rafts (8), Kamilche Point (9), Evergreen State College Beach (11)
Mollusca: Bivalvia	*Mya arenaria*	Kamilche Point (9), Kennedy Creek (10), Evergreen State College Beach (11), Mud Bay (13)
Mollusca: Bivalvia	*Venerupis philippinarum*	Taylor Rafts (8), Kamilche Point (9), Evergreen State College Beach (11)
Arthropoda: Crustacea: Cumacea	*Nippoleucon hinumensis*	Mud Bay (13)
Arthropoda: Crustacea: Isopoda	*Limnoria tripunctata*	Mud Bay (13)
Arthropoda: Crustacea: Amphipoda	*Caprella mutica*	Taylor Rafts (8), Steamboat Island (12)
Arthropoda: Crustacea: Amphipoda	*Corophium acherusicum*	Taylor Rafts (8), Steamboat Island (12)
Arthropoda: Crustacea: Amphipoda	*Jassa marmorata*	Taylor Rafts (8), Steamboat Island (12)
Bryozoa: Cheilostomata	*Schizoporella unicornis*	Taylor Rafts (8)
Urochordata: Ascidiacea	*Botrylloides violaceus*	Taylor Rafts (8)

Exotic Species Collected in Willapa Bay

In Willapa Bay the Expedition participants split into two groups May 21-22, one group sampling nine sites by airboat, the other group sampling five sites from land. Sites sampled by airboat included intertidal sites in the Palix and Bear rivers and in the southern end of Willapa Bay. Sites sampled from land included some intertidal sites plus the floating docks at Bay Center and Nahcotta. The intertidal sites included mud, sand and cobble substrates, hard clay, oyster reefs, some *Spartina* marsh, a *Spartina* control site, and scrapings from pilings in low salinity water in the rivers. Salinities at the river sites ranged from 0 to 18 psu, and in the bay from 16 to 22 psu. Water temperatures ranged from 13 to 24 °C in the rivers, and 17 to 22 °C in the bay.

Thirty-four exotic species were collected and identified from Willapa Bay (Table 6). Twenty are native to the North Atlantic, 12 to the Northwest Pacific, one to the Black and Caspian seas, and one is of unknown origin (see Table 8). In addition to these, the terebellid worm *Neoamphitrite* *figulus*, which was collected in Willapa Bay during a reconnaissance trip in March 2000 but not during the expedition itself,[ii] is a new record for the Pacific Coast of North America. It has previously been reported from both sides of the North Atlantic, from the Northwestern Pacific and from Arctic seas.

Table 6. Exotic Species Collected in Willapa Bay

General Taxon	Species	Sites Collected (site number)
Protoctista: Algae: Phaeophyta	*Sargassum muticum*	Stackpole Slough (21)
Plantae	*Spartina alterniflora*	Naselle River Bridge (14), Goose Point (15), Palix River Bridge (20), Stackpole Slough (21), Shoalwater Bay (26)
Plantae	*Zostera japonica*	Naselle River Bridge (14), Goose Point (15), Palix River Pilings (18), Palix River Bridge (20), Stackpole Slough (21), Omeara Point (23), Round Island (24), Shoalwater Bay (26), Long Island South (27)
Porifera	*Clathria prolifera*	Stackpole Slough (21), Nahcotta Small Boat Basin (22), Round Island (24)
Cnidaria: Hydrozoa	*Cordylophora caspia*	Upper Palix River (17), Bear River Pilings (25)
Cnidaria: Anthozoa	*Diadumene lineata*	Goose Point (15), Port of Bay Center (16), Palix River Bridge (20), Stackpole Slough (21), Omeara Point (23)
Annelida: Polychaeta	*Hobsonia floridana*	Upper Palix River (17)
Annelida: Polychaeta	*Polydora cornuta*	Stackpole Slough (21)
Annelida: Polychaeta	*Pseudopolydora bassarginensis*	Stackpole Slough (21)
Annelida: Polychaeta	*Pseudopolydora kempi japonica*	Naselle River Bridge (14), Palix River Bridge (20), Stackpole Slough (21), Round Island (24)
Annelida: Polychaeta	*Streblospio benedicti*	Upper Palix River (17), Palix River Bridge (20), Round Island (24)
Mollusca: Prosobranchia	*Crepidula fornicata*	Stackpole Slough (21)
Mollusca: Prosobranchia	*Ilyanassa obsoleta*	Naselle River Bridge (14), Omeara Point (23), Round Island (24), Shoalwater Bay (26), Long Island South (27)
Mollusca: Prosobranchia	*Ocinebrellus inornatus*	Stackpole Slough (21)
Mollusca: Prosobranchia	*Urosalpinx cinerea*	Omeara Point (23)
Mollusca: Bivalvia	*Crassostrea gigas*	Naselle River Bridge (14), Port of Bay Center (16), Palix River Pilings (18), Wilson Point (19), Palix River Bridge (20), Stackpole Slough (21), Nahcotta Small Boat Basin (22), Omeara Point (23), Round Island (24)
Mollusca: Bivalvia	*Mya arenaria*	Naselle River Bridge (14), Upper Palix River (17), Palix River Bridge (20), Stackpole Slough (21), Omeara Point (23)
Mollusca: Bivalvia	*Neotrapezium liratum*	Naselle River Bridge (14), Omeara Point (23), Round Island (24), Bear River Pilings (25)
Mollusca: Bivalvia	*Petricolaria pholadiformis*	Goose Point (15)
Mollusca: Bivalvia	*Venerupis philippinarum*	Goose Point (15), Stackpole Slough (21), Omeara Point (23), Round Island (24)

ii Collected by A.N. Cohen and H.D. Berry at the Nahcotta Small Boat Basin on Marsh 24, 2000, and identified by L.H. Harris.

Table 6. Exotic Species Collected in Willapa Bay (Continued)

General Taxon	Species	Sites Collected (site number)
Anthropoda: Crustacea: Ostracoda	*Eusarsiella zostericola*	Round Island (24)
Arthropoda: Crustacea: Cirripedia	*Balanus improvisus*	Upper Palix River (17), Bear River Pilings (25)
Arthropoda: Crustacea: Cumacea	*Nippoleucon hinumensis*	Naselle River Bridge (14), Palix River Bridge (20), Round Island (24)
Arthropoda: Crustacea: Isopoda	*Limnoria tripunctata*	Goose Point (15)
Arthropoda: Crustacea: Amphipoda	*Ampithoe valida*	Naselle River Bridge (14), Port of Bay Center (16), Stackpole Slough (21), Nahcotta Small Boat Basin (22)
Arthropoda: Crustacea: Amphipoda	*Corophium acherusicum*	Naselle River Bridge (14), Stackpole Slough (21)
Arthropoda: Crustacea: Amphipoda	*Corophium insidiosum*	Port of Bay Center (16), Stackpole Slough (21), Nahcotta Small Boat Basin (22), Round Island (24)
Arthropoda: Crustacea: Amphipoda	*Grandidierella japonica*	Palix River Bridge (20), Stackpole Slough (21), Round Island (24)
Arthropoda: Crustacea: Amphipoda	*Jassa marmorata*	Naselle River Bridge (14)
Arthropoda: Crustacea: Amphipoda	*Melita nitida*	Palix River Pilings (18)
Bryozoa: Ctenostomata	*Bowerbankia gracilis*	Port of Bay Center (16), Nahcotta Small Boat Basin (22)
Urochordata: Ascidiacea	*Botrylloides violaceus*	Wilson Point (19), Stackpole Slough (21), Nahcotta Small Boat Basin (22)
Urochordata: Ascidiacea	*Botryllus schlosseri*	Stackpole Slough (21)
Urochordata: Ascidiacea	*Molgula manhattensis*	Port of Bay Center (16), Stackpole Slough (21), Round Island (24)

Of the three regions sampled by the expedition, Willapa Bay yielded the largest number of exotic species and was the most obviously dominated by exotics. At some sites in the southern part of the bay, the Atlantic cordgrass *Spartina alterniflora* and the Japanese eelgrass *Zostera japonica* extended as green growths over the mudflats as far as the eye could see. Artifically seeded beds and naturally settled reefs of Japanese oysters *Crassostrea gigas* provided the dominant hard substrate. Living on and among the oysters were large numbers of the Japanese nestling clam *Neotrapezium liratum* and the Japanese anemone *Diadumene lineata*, along with occasional clumps of the Atlantic sponge *Clathria prolifera*. The numbers of *Neotrapezium* were especially impressive, estimated at 500-600 per square meter in one oyster reef, and between the valves of a single dead oyster we found eight *Neotrapezium* from 1 to 4 cm long. Around the edges of the reefs, great numbers of the Atlantic mudsnail *Ilyanassa obsoleta* grazed the mud surface, their egg capsules covering the shells of the outermost oysters. Many of these organisms were also common at other sites in the bay, along with several exotic amphipods, the Japanese cumacean *Nippoleucon hinumensis* and Manila clams *Venerupis philippinarum* at some mudflat sites. Two species of exotic botryllid tunicates were common on the docks at the Nahcotta Small Boat Basin, and at low salinity sites in the rivers the Black and Caspian Sea hydroid *Cordylophora caspia* and the Atlantic barnacle *Balanus improvisus* coated the pilings.

The Expedition did not collect any European green crabs, *Carcinus maenas*, in Willapa Bay, although the Washington Department of Fish and Wildlife trapped several near the Expedition's sampling sites on the same days. Since the discovery of the species in Willapa Bay in June of 1998, only a few hundred green crabs have been caught there, despite significant efforts (Brett Dumbauld, pers. comm.). Two other shellfish pests, the Atlantic and Japanese oyster drills, are reportedly common-to-abundant at various locations in the bay (Brett Dumbauld, pers. comm.), but were only collected during the Expedition at two sites: Omeara Point (a single specimen of the Atlantic drill *Urosalpinx cinerea*, plus a few egg cases on a Japanese oyster) and Stackpole Slough (the Japanese drill *Ocinebrellus inornatus* common on Japanese oysters). At the latter site there was also a large pile of dead Japanese drills on the beach, presumably collected by oyster growers and dumped there.

Other Possible Exotic Species

In addition to the exotic organisms identified by the Expedition and discussed above, other exotic species may have been collected but not identified here as exotic for a variety of reasons. For example, the intended taxonomic work on some groups of organisms has not been completed; some of the organisms require molecular genetic analysis or other taxonomic assessment beyond the scope of the Expedition in order to establish their identity; and for some organisms with a wide reported range, their native range is at present unknown, so that they might be either native or exotic in the sampled region (these organisms are called "cryptogenic" [Carlton 1996]). Several examples of possible exotics in different taxonomic groups are given here.

<u>Protists</u> The Expedition collected mud samples that will be examined by appropriate experts for the presence of the Japanese foraminifer *Trochaminna hadai*, known to occur at many sites on the Pacific Coast (McGann *et al.* 2000). Other than the foraminifera, little effort was made or is planned to identify the protists collected by the Expedition or determine their exotic/native status.

Algae Green algae, commonly referred to as ulvoids, were collected by the Expedition. Ulvoids are good examples of cryptogenic taxa. Those collected may be native or exotic species in several genera, such as *Ulva, Enteromorpha, Ulvaria* and *Monostroma.* These genera are common ship-fouling and oyster-fouling organisms, are widespread throughout the world, and are taxonomically difficult, so that sorting out the native distributions of these species will be challenging. Another example is *Bryopsis "hypnoides"*, collected at the Nahcotta docks in Willapa Bay. A type locality in the French Mediterranean suggests that this is an exotic, but due to unresolved questions about the number, identity and Pacific Coast distribution of species in this morphologically variable and taxonomically difficult genus (e.g. see Silva 1979), we continue to list it as cryptogenic.

Porifera Sponges were collected at a number of sites that appear similar to *Halichondria bowerbanki* and *Haliclona loosanoffi*, exotic species known from San Francisco Bay and a few other Pacific Coast bays (Cohen and Carlton 1995.) The samples will be sent along with other sponges to appropriate experts for identification.

Hydrozoa Hydroids in the genera *Obelia* and *Gonothyraea* were collected at various sites. Some authors have reported that certain species in these genera on the Pacific Coast are exotic (e.g. Cohen and Carlton 1995), but the taxonomy of these genera is difficult and the exotic status of species present on the Pacific Coast has been questioned (Mills 1998). Accordingly, in the 1998 Puget Sound Expedition report and the present report we do not list any species in these genera as exotic. Specimens collected by the 2000 Expedition will be sent to appropriate experts for examination, which may help to resolve this question.

Polychaeta Many of the polychaete worms collected by the Expedition have initially been identified only to genus. Further taxonomic work may reveal additional records of exotic species; for example, the specimens identified as *Eusyllis "habei"* and *Spio* sp. A may turn out to be exotic.

Bivalvia Two genera of bivalves on the Pacific Coast require molecular genetic analysis to distinguish native from exotic. Among Pacific Coast bay mussels in the species *Mytilus*, the native *M. trossulus* predominates in the north and the exotic Mediterranean mussel *M. galloprovincialis* predominates in the south, with a zone of extensive mixing and hybridization in central California around San Francisco Bay (Sarver and Foltz 1993). The Mediterranean mussel is used in aquaculture in Washington State, where its presence has been reported outside of culture facilities at some sites. *Macoma balthica* is a small clam native to the Pacific Coast, but molecular analysis revealed that the apparent San Francisco Bay population of this clam is in fact exotic, being genetically similar to an Atlantic population (Meehan *et al.* 1989) which is thought by some to represent a distinct species, *Macoma petalum* (Cohen and Carlton 1995). Mussels and clams of these types, which may include exotic species or exotic-native hybrids, were common at many sites.

<u>Crustacea</u> Questions about the exotic/native status of several peracarid crustaceans collected by the Expedition are yet unresolved:

- A *Dynamella*-like isopod was collected at a few sites, with work still underway to determine if it is an exotic.
- Tanaids in the genus *Sinelobus* were collected from at least one site, and may be present in collections from other sites. This genus is exotic to the Pacific Coast, with only one species reported in the genus, *S. stanfordi*. However, the genus is recorded from an extraordinarily wide range of habitats and probably harbors more than one species, and the specimens collected on the Pacific Coast consistently differ in a few characteristics from the description of *S. stanfordi* given by Sieg and Winn (1981). In this report, specimens in this genus are reported as *?Sinelobus stanfordi*.
- The amphipod *Hyale plumulosa* was collected from five sites. It is reported from both coasts of North America, and may in part be exotic on the Pacific Coast.

<u>Kamptozoa</u> The Expedition collected a kamptozoan (entoproct) that keys out to the exotic species *Barentsia benedeni* in Pacific Coast keys (Mariscal 1975; Kozloff 1987). However, recent monographic work has revised this genus (Wasson 1997), and further work is needed to determine whether the collected specimens are exotic.

<u>Bryozoa</u> A bryozoan in the genus *Conopeum* was collected which closely resembles in form and habitat the exotic *Conopeum tenuissimum* identified from San Francisco Bay (Cohen and Carlton 1995). However, the genus is taxonomically difficult and further work will be needed to positively identify the collected specimens to species.

Overall Results

In all, 40 exotic species have been identified from the 2000 Expedition's collections, with 15 each in the Elliott Bay and Totten/Eld Inlet regions, and 34 in Willapa Bay (Table 7). As described above, the apparent dominance by exotics was slightly greater in Totten/Eld Inlets than in Elliott Bay, and much greater in Willapa Bay.

Among the three regions, Elliott Bay has experienced the greatest amount of physical alteration associated with urbanization (dredging, channel straightening, hardening of shoreline, filling of wetlands, diversion of freshwater inflows, industrial development of the shoreline), and Willapa Bay the least. For example, 98% of upper intertidal shoreline along Elliott Bay and the Duwamish River has been modified, compared to 31% in Totten/Eld and 23% in Willapa Bay (Nearshore Habitat Program 2000). Thus the greatest number and extent of invasions was found in the least physically altered system. This pattern appears to contradict the hypothesis that more disturbed habitats are more vulnerable to invasions (e.g. Elton 1958; Lozon & MacIssac 1997; etc.). It is also possible that physical and biological disturbance in Willapa Bay is less visibly apparent. While Willapa Bay is relatively undeveloped, it is far from pristine. Habitats and natural processes in the bay have been extensively altered by practices such as diking, aquaculture, agriculture, dredging and deforestation of the watershed. Additionally, dominant intertidal invaders have altered the physical environment; for example, the spread of exotic Atlantic Cordgrass marshes has changed habitat characteristics, and large populations of cultured Japanese Oysters have changed water column characteristics through filter feeding.

Elliott Bay is an important international and coastal shipping center, which Totten/Eld Inlets and Willapa Bay are not. These latter two regions, however, are major historic and current sites for aquaculture. Since these regions appear to be invaded as (or more invaded than) than Elliott Bay, this suggests that aquaculture activities may historically have been as effective as (or more effective than) ship-associated mechanisms (such as the transport of ship-fouling organisms, solid ballast and ballast water) in moving organisms across and between oceans, and between bays on the Pacific Coast. We note also that aquaculture activities have historically been notoriously efficient vectors for moving pests and parasites of shellfish (e.g. Farley 1992; Mo 1994); and that despite substantial improvements in the inspection and handling of aquaculture shipments, such transport of pests and parasites has continued to occur in recent decades (e.g. the South African sabellid worm *Terebrasabella heterouncinata*, a devastating parasite of abalone and other marine gastropods, was imported into California and released into California waters by abalone aquaculture facilities in the 1980s-1990s, though a subsequent control effort may have eradicated it from the wild in the one site where it was recognized; the Japanese fouling mussel *Musculista senhousia* was transported into Willapa Bay with shipments of Manila clams in the 1990s, but did not become established in the bay). The shipment and planting of oysters for commercial aquaculture is considered to be a possible mechanism responsible for introducing onto the Pacific Coast 35 of the 40 exotic species collected by the Expedition (Table 8). In contrast, ballast water is considered a possible transport mechanism for 13 of the species, and all ship-associated mechanisms together (ship-fouling, solid ballast and ballast water) for 28 of the species (Table 8). All of these mechanisms would also be effective at moving organisms between bays on the Pacific Coast.

The Expedition collected four exotic species in Willapa Bay that were not previously known from those regions (Table 9). One of these, the spionid worm, *Pseudopolydora bassarginensis*, is a new record for North America. The Expedition also collected at Steamboat Island at Totten/Eld Inlets a phyllodocid worm in the genus *Nereiphylla* that may be either a new species or a new record of an exotic species on the coast, and collected at Seacrest Park in Elliott Bay a native nudibranch, *Emarcusia morroensis*, that was previously reported only as far north as Marin County in California (Behrens 1991). In addition to these, a reconnaissance trip to Willapa Bay two months before the Expedition collected a terebellid worm, *Neoamphitrite figulus*, which is a new record for the Pacific Coast of North America.

Table 7. Summary of Exotic Species Collected

	Elliott Bay	Totten/Eld Inlets	Willapa Bay
Phaeophyceae			
Sargassum muticum	X	X	X
Anthophyta			
Spartina alterniflora	–	–	X
Zostera japonica	–	–	X
Porifera			
Clathria prolifera	–	–	X
Cnidaria			
Cordylophora caspia	X	–	X
Diadumene lineata	–	X	X
Annelida: Polychaeta			
Hobsonia florida	X	–	X
Neanthes succinea	–	X	–
Polydora cornuta	–	–	X
Pseudopolydora bassarginensis	–	–	X
Pseudopolydora kempi japonica	X	–	X
Streblospio benedicti	–	–	X
Mollusca: Gastropoda			
Batillaria attramentaria	–	X	–
Crepidula fornicata	–	X	X
Ilyanassa obsoleta	–	–	X
Ocinebrellus inornatus	–	–	X
Urosalpinx cinerea	–	–	X
Mollusca: Bivalvia			
Crassostrea gigas	–	X	X
Mya arenaria	X	X	X
Neotrapezium liratum	–	–	X
Petricolaria pholadiformis	–	–	X
Venerupis philippinarum	X	X	X
Arthropoda: Crustacea: Ostracoda			
Eusarsiella zostericola	–	–	X
Arthropoda: Crustacea: Cirripedia			
Balanus improvisus	–	–	X
Arthropoda: Crustacea: Cumacea			
Nippoleucon hinumensis	X	X	X
Arthropoda: Crustacea: Isopoda			
Limnoria tripunctata	–	X	X
Arthropoda: Crustacea: Tanaidacea			
?Sinelobus stanfordi	X	–	–
Arthropoda: Crustacea: Amphipoda			
Ampithoe valida	–	–	X
Caprella mutica	–	X	–
Corophium acherusicum	X	X	X
Corophium insidiosum	X	–	X
Grandidierella japonica	X	–	X
Jassa marmorata	–	X	X
Melita nitida	–	–	X
Bryozoa			
Bowerbankia gracilis	–	–	X
Cryptosula pallasiana	X	–	–
Schizoporella unicornis	X	X	–
Urochordata			
Botrylloides violaceus	X	X	X
Botryllus schlosseri	X	–	X
Molgula manhattensis	–	–	X
Total Species	**15**	**15**	**34**

Table 8. Origins, Earliest Records and Mechanisms of Introduction of Exotic Species Collected

Native ranges, dates of earliest record (planting, collection or report) on the Pacific Coast of North America and in Washington State, and possible initial mechanisms of introduction to the Pacific Coast are given. Much of this information is expanded and revised from Carlton (1979), Cohen and Carlton (1995), Cohen *et al*. (1998) and Mills *et al*. (2000). Earliest records consisting of written accounts that do not state the date of planting, collection or observation are preceded by the symbol "=". Mechanisms given in parentheses indicate less likely mechanisms. Mechanisms are listed as:

- SF **-** in ships' hull fouling or boring
- SB **-** in solid ballast
- BW **-** in ships' ballast water or seawater systems
- PM **-** as packing material for shipped goods
- OA **-** with shipments of Atlanticoysters
- OJ **-** with shipments of Japanese oysters
- PL **-** with shipments of aquatic plants

	Native Range	**1st Pacific Coast Record**	**1st Washington State Record**	**Mechanism of Introduction**
Phaeophyceae				
Sargassum muticum	NW Pacific	1944	1948	OJ
Anthophyta				
Spartina alterniflora	NW Atlantic	ca. 1938	ca. 1938	OA,SB,PM
Zostera japonica	W Pacific	1957	1957	OJ
Porifera				
Clathria prolifera	NW Atlantic	1945-49	=1967	OA,SF
Cnidaria				
Cordylophora caspia	Black/Caspian Seas	ca. 1920	ca. 1920	BW,SF
Diadumene lineata	NW Pacific	1906	=1939	OA,SF
Annelida: Polychaeta				
Hobsonia florida	NW Atlantic	1940	1940	OA,SF,PL
Neanthes succinea	N Atlantic	1896	˜1995	OA,SF
Polydora cornuta	N Atlantic	1932	1937	OA,SF,(BW)
Pseudopolydora bassarginensis	NW Pacific	2000	2000	OJ,SF,BW
Pseudopolydora kempi japonica	NW Pacific	1951	1968	OJ,SF,BW
Streblospio benedicti	N Atlantic	1932	=1971	BW,OA,(SF)
Mollusca: Gastropoda				
Batillaria attramentaria	NW Pacific	1924	1924	OJ
Crepidula fornicata	NW Atlantic	1905	1905	OA
Ilyanassa obsoleta	NW Atlantic	1907	=1945	OA
Ocinebrellus inornatus	NW Pacific	1924	1924	OJ
Urosalpinx cinerea	NW Atlantic	1890	=1929	OA
Mollusca: Bivalvia				
Crassostrea gigas	NW Pacific	1875	1875	OJ
Mya arenaria	NW Atlantic	1874	1884	OA
Neotrapezium liratum	NW Pacific	1924	1924	OJ
Petricolaria pholadiformis	NW Atlantic	1927	=1943	OA
Venerupis philippinarum	NW Pacific	1924	1924	OJ
Arthropoda: Crustacea: Ostracoda				
Eusarsiella zostericola	NW Atlantic	1953	1998	OA,SF,(BW)
Arthropoda: Crustacea: Cirripedia				
Balanus improvisus	N Atlantic	1853	1955	OA,SF

Table 8. Origins, Earliest Records and Mechanisms of Introduction of Exotic Species Collected (Continued)

	Native Range	1st Pacific Coast Record	1st Washington State Record	Mechanism of Introduction
Arthropoda: Crustacea: Cumacea				
Nippoleucon hinumensis	NW Pacific	1979	1980	BW
Arthropoda: Crustacea: Isopoda				
Limnoria tripunctata	not known	1871 or 1875	1962	SF
Arthropoda: Crustacea: Tanaidacea				
?Sinelobus stanfordi	not known	1943	=1996	SF,BW
Arthropoda: Crustacea: Amphipoda				
Ampithoe valida	NW Atlantic	1941	1966	OA,SF,BW
Caprella mutica	NW Pacific	1973-77	1998	OJ,BW
Corophium acherusicum	N Atlantic	1905	1915	OA,SF
Corophium insidiosum	N Atlantic	1915	1915	OA,SF
Grandidierella japonica	NW Pacific	1966	1977	OJ,SF,BW
Jassa marmorata	NW Atlantic	1938	=1995	SF,BW
Melita nitida	NW Atlantic	1938	1966	OA,SF,SB,BW
Bryozoa				
Bowerbankia gracilis	NW Atlantic?	=1923	=1953	OA,SF
Cryptosula pallasiana	N Atlantic	1943-44	1998	OA,SF
Schizoporella unicornis	NW Pacific	1927	1927	OJ,SF
Urochordata				
Botrylloides violaceus	NW Pacific	1973	1977	OJ,SF
Botryllus schlosseri	NE Atlantic	1944-47	late 1960s-1970s	OA,SF
Molgula manhattensis	NW Atlantic	1949	1998	OA,SF,BW

Table 9. New Records of Exotic Species

NR New record for the region
PR Previous record exists for the region
X Not recorded in the region

Region:	Puget Sound	Willapa Bay	Washington State	Pacific Coast
Cordylophora caspia	PR	**NR**	PR	PR
Pseudopolydora bassarginensis	X	**NR**	**NR**	**NR**
Melita nitida	PR	**NR**	PR	PR
Bowerbankia gracilis	PR	**NR**	PR	PR
New records for region:	0	4	1	1

Research and Research/Monitoring Needs

As noted above, the information provided in this report is provisional, pending additional taxonomic work and analysis. While we hope that some part of this additional work will be done, there is no funding allocated for it. We expect that, as in past expeditions, the work will remain incomplete and the full potential value of the Expedition will not be realized. As in the 1998 Puget Sound Expedition, most of the Expedition members participated without being paid for their time, out of an interest in the phenomenon of biological invasions and the ecology of the region. While we hope that they will pursue the remaining laboratory and analytical work, we understand that funded work will take precedence.

Various agencies have expressed a need for a regular monitoring program for exotic species in Washington waters. While sampling directed to this purpose would be an important component, the greatest necessity is for the tools, funding, institutional framework and mandate to support the taxonomic activities needed to recognize and identify new exotic species in the region. The types of tools and framework needed have been outlined for San Francisco Bay (Cohen 1999), most of which would also be applicable to Washington State. While such actions would directly support monitoring for exotic species, they would also benefit marine taxonomic work generally, and contribute immeasurably to our understanding of Washington's marine ecosystems and the impacts of human activities upon them.

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APPENDIX 2
Puget Sound Expedition Schedule and GPS Site Locations

DAY	TIME
May 16 (Tuesday) ASSEMBLE THE TEAM IN SEATTLE	
May 17 (Wednesday) ELLIOTT BAY	
Low tide -0.5 ' at 1125 (Seattle prediction).	
1. Bell Harbor Marina, Pier 66	8:30-9:30 am
47° 36' 36.698" N; 122° 20' 48.790" W	
2. Myrtle Edwards Park, in front of Elliott Bay Fishing Pier	10:30-11:10 am
47° 37' 35.897" N; 122° 22' 20.031" W	
3a. Sandy north-facing beach south of Pier 90	10:50-11:50 am
47° 37' 51.840" N; 122° 22' 40.261" W	
3b. Smith Cove (north of Pier 91)	11:45 am
(no GPS)	
4a. Magnolia Park beach, north Elliott Bay	12:30-1:25 pm
47° 37' 56.463" N; 122° 23' 54.932" W	
4b. Elliott Bay Marina, north Elliott Bay	3:40-5:00 pm
(no GPS, but about 200 m east of Magnolia Park beach)	
May 18 (Thursday) ELLIOTT BAY	
Low tide -0.9 ' at 1156 (Seattle prediction).	
5. Duwamish River, western channel across from Kellogg Island	9:30-10:40 am
47° 33' 33.256" N; 122° 21' 04.845" W	
6. Seacrest Park, Duwamish Head, south Elliott Bay	10:50-11:50 am
47° 35' 20.417" N; 122° 22' 49.255" W	
7a. Turning basin, Duwamish River	12:40-1:20 pm
47° 30' 38.590" N; 122° 18' 11.484" W	
7b. Duwamish Yacht Club marina, Duwamish River	1:45-2:15 pm
(no GPS, approximately 1/4 mile north of the Turning Basin site)	
May 19 (Friday) TOTTEN INLET	
Low tide -1.1 ' at 1328 (Seattle prediction + 1 hour).	
8a. Taylor Shellfish boat ramp, Totten Inlet	9:20-9:50 am
47° 09' 10.043" N; 122° 57' 51.991" W	
8b. Taylor Shellfish mussel rafts, Gallagher Cove, Totten Inlet	10:00-11:10 am
47° 09' 10.043" N; 122° 57' 51.991" W	
9. Kamilche Point at junction of Little Skookum Inlet and Totten Inlet	12:30-1:40 pm
47° 09' 07.253" N; 123° 01' 06.195" W	
10. Kennedy Creek at head of Totten Inlet	2:25-3:15 pm
47° 05' 56.949" N; 123° 05' 10.404" W	
May 20 (Saturday) ELD INLET AND TOTTEN INLET	
Low tide -1.1 ' at 1402 (Seattle prediction + 1 hour).	
11. The Evergreen State College Beach, Eld Inlet	12:20-1:00 pm
47° 05' 11.682" N; 122° 58' 31.869" W	
12. Steamboat Island at junction of Totten Inlet and Eld Inlet	1:45-3:00 pm
47° 11' 05.687" N; 122° 56' 22.366" W	
13. Mud Bay at head of Eld Inlet	4:55-5:25 pm
47° 03' 20.778" N; 122° 59' 19.758" W	

May 21 (Sunday) WILLAPA BAY

Low tide -1.0 ' at 1036 (Aberdeen prediction + 30 minutes).

14. Naselle River Bridge — 9:15-10:00 am
    46° 26'.05 " N; 123° 54' 08.350 " W
15. Goose Point near Bay Center — 10:45am-12:30 pm
    46° 37' 57.466 " N; 123° 57' 21.486 " W
16. Port of Bay Center, small boat harbor — 1:10-1:45 pm
    46° 37' 42.572'' N; 123° 57' 09.040 " W
17. Palix River "freshwater" site (#1) — 9:55-10:35 am
    46° 36' 06.236" N; 123° 52' 58.946" W
18. Palix River pilings site (#2) — 10:50-11:05 am
    46° 36' 10.700" N; 123° 54' 47.270" W
19. Oyster flats south of Wilson Point — 11:20-11:40 am
    46° 38' 57.879" N; 123° 57' 09.608" W
20. Palix River *Spartina* control site and Palix River Bridge pilings — 12:00-12:20 pm,
    46° 36' 46.551" N; 123° 54' 56.389" W

May 22 (Monday) WILLAPA BAY

Low tide -0.7 ' at 1113 (Aberdeen prediction + 30 minutes).

21. Stackpole Slough in Leadbetter Point State Park — 10:45am-12:00 noon
    46° 36' 21.345" N; 124° 02' 35.516" W
22. Nahcotta Small Boat Basin, Port of Peninsula — 1:40-2:30 pm
    46° 30' 02.348" N; 124° 01' 50.635" W
23. Omeara Point mudflat — 9:45-11:00 am
    46° 24' 10.914" N; 123° 57' 12.399" W
24. Round Island — 11:20-11:50 am
    46° 23' 42.536" N; 123° 57' 32.749" W
25. Bear River — 12:00-12:30 pm
    46° 22' 11.559" N; 123° 57' 04.895" W
26. Shoalwater Bay — 1:00-1:15 pm
    46° 23' 04.358" N; 123° 58' 29.670" W
27. Long Island, south end — 1:20-1:45 pm
    46° 24' 17.338" N; 123° 57' 51.365" W

May 23 (Tuesday) WILLAPA BAY

Low tide -0.2 ' at 1152 (Aberdeen prediction + 30 minutes).

28. Leadbetter Point sandy beach — 12:30-1:00pm
    _~1/2 mile north of 46° 36' 21.345" N; 124° 02' 35.516" W

APPENDIX 3
Equipment list for the Washington Exotics Expedition, May 17-23, 2000

10-person van	DNR
pick-up truck for equipment transportation	DNR
cellular phone	DNR
Trimble GPS meter	DNR
48 plastic liter-jars for voucher samples	DNR
300 scintillation vials	DNR
24, 125 ml jars	DNR
18, 250 ml jars	DNR
24, 500 ml jars	DNR
Ziploc bags in various sizes	DNR
duct tape	DNR
pencils, Sharpies for labels	DNR
YSI salinity/temperature meter	DNR
refractometer and field thermometer	DNR
camera and film	DNR
rubber gloves	DNR
Rubbermaid tubs - 2, about 15 gallon	DNR
6-10 buckets	DNR
trowels, shovels and clam gun	DNR
3 clipboards and large rubber bands	DNR
3-ring notebook for field notes	DNR
3-hole punched site forms for field notes	DNR
3-hole punched species forms for field notes	DNR
books: Kozloff's Keys to NW Invertebrates and Light's Manual	DNR
and other various field guides to marine and saltmarsh fauna and flora	DNR
laptop computer and floppy disks	DNR
3 coolers	DNR
boat ramp/ marina guides	DNR
charts and DNR site maps	DNR
plant press for algae	Tom Mumford/DNR
plant press for algae	Kevin Britton-Simmons
vehicle	King County Environmental Lab
dip net sampler on 8 foot pole	King County Environmental Lab
benthic sampler with 1 mm steel screen	King County Environmental Lab
steel sieves	King County Environmental Lab
additional bottles	King County Environmental Lab
plastic petri dishes and plastic sorting trays for lab work	King County Environmental Lab
digital camera	King County Environmental Lab
coolers and ice	King County Environmental Lab
cellular phone	King County Environmental Lab
rubber gloves	King County Environmental Lab
microscope and light	King County Environmental Lab
relevant local field guides and detailed King County maps	King County Environmental Lab
label paper	Leslie Harris
small steel sieves	Leslie Harris
3 squeeze bottles for lab work	Leslie Harris
photomicroscope	Leslie Harris
Peets coffee	Leslie Harris

2 buckets	Claudia Mills/FHL
225 µm mesh 1/4 m-plankton net	Claudia Mills/FHL
2 jellyfish scoops	Claudia Mills/FHL
3 dishpans	Claudia Mills/FHL
3 dipnets	Claudia Mills/FHL
3 metal sieves: 0.5, 1, 2 mm	Claudia Mills/FHL
2-gallon carboy for 10% formalin solution	Claudia Mills/FHL
6 gallons 95% ETOH	Claudia Mills/FHL
1 gallon 37% formaldehyde	Claudia Mills/FHL
1 liter 7% magnesium chloride	Claudia Mills/FHL
squeeze bottle for lab	Claudia Mills/FHL
camera and film	Claudia Mills/FHL
digital camera	Claudia Mills/FHL
10, site-location maps for drivers	Claudia Mills/FHL
bowls and petri dishes for labwork	Claudia Mills/FHL
5, 1 gallon container for seawater for labwork	Claudia Mills/FHL
extra boots and raingear for Vasily	Claudia Mills/FHL
vehicle	John Chapman
custom-built scraper for pilings	John Chapman
steel sieves (1.0 mm and 0.5 mm mesh)	John Chapman
several plastic tubs for mud samples	John Chapman
microscope and light	John Chapman
field thermometer	John Chapman
0.5 m^2 Van Veen benthic grab sampler	John Chapman
laptop computer and floppy disks	John Chapman
crutches	John Chapman
assorted taxonomic references to North Pacific Crustacea	John Chapman
small sieve for formalin samples	Andy Cohen
refractometer and field thermometer	Andy Cohen
Jim Carlton's field notes from the 1970s, for comparison	Andy Cohen
10 dissecting microscopes	Dave Secord/UWT
6 dual gooseneck halogen illuminators	Dave Secord/UWT
2 compound microscopes	Dave Secord/UWT
4 hand lenses	Dave Secord/UWT
camera with zoom/macro lens	Dave Secord/UWT
Books: Kozloff field guide, Kozloff keys, Light's manual,	Dave Secord/UWT
miscellaneous Willapa Bay / oyster history sources	Dave Secord/UWT
cellular phone	Dave Secord/UWT
vehicle	Dave Secord/UWT
102-125 mm mesh plankton nets and associated gear	Jeff Cordell/UW
boots and full raingear	everyone
gloves, scrapers	everyone
personal dissecting tools	everyone
additional vials or bags for individual use	everyone
sleeping bags	everyone
specialized literature for identifications	everyone

Appendix 4. Recent Name Changes for Some Species in Washington

Current Name	**Previous Name (s)**
Clathria prolifera	*Microciona prolifera*
Cordylophora caspia	*Cordylophora lacustris*
Diadumene lineata	*Haliplanella luciae*
Polydora cornuta	*Polydora ligni*
Pseudopolydora kempi japonica	*Pseudopolydora kempi*
Batillaria attramentaria	*Batillaria zonalis, Batillaria cumingi*
Ocinebrellus inornatus	*Ceratostoma inornata, Ocenebra japonica*
Myosotella myosotis	*Ovatella myosotis*
Ostrea conchaphila	*Ostrea lurida*
Neotrapezium liratum	*Trapezium liratum*
Petricolaria pholadiformis	*Petricola pholadiformis*
Venerupis philippinarum	*Tapes japonica, Ruditapes philippinarum*
Nippoleucon hinumensis	*Hemileucon hinumensis*