WASHINGTON STATE DEPARTMENT OF
Natural Resources
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Washington State Nearshore Exotics Expedition 2000

A Comparison of Exotic Species in Three Regions

In the spring of 2000, the Washington State Department of Natural Resources conducted a rapid survey of exotic organisms in order to provide baseline information about marine invasions. The cooperative study brought together 22 scientists from diverse institutions to survey exotic species in a broad range of shallow water habitat types. Three regions in Washington State were sampled in order to compare spatial patterns across 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 2000 Expedition collected 40 exotic species during 7 days of sampling and taxonomic analysis (Table 1). Most of the exotic species 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. Four of the exotic species collected in Willapa Bay 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 nativenudibranch, *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.

Table 1. 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
- OA - with shipments of Atlantic oysters
- SB - in solid ballast
- OJ - with shipments of Japanese oysters
- BW - in ships' ballast water or seawater systems
- PL - with shipments of aquatic plants
- PM - as packing material for shipped goods

	Native Range	**1st Pacific Coast Record**	**1st Washington State Record**	**Mechanism of Introduction**
Phaeophyceae				
Sargassum muticum	NW Pacific	1944	1948	OJ
Anthophyta				
	NW Atlantic	ca. 1938	ca. 1938	OA,SB,PM
Spartina alterniflora	W Pacific	1957	1957	OJ
Zostera japonica				
Porifera				
Clathria prolifera	NW Atlantic	1945-49	≤1967	OA,SF
Cnidaria				
	Black/Caspian Seas	ca. 1920	ca. 1920	BW,SF

Cordylophora caspia	NW Pacific	1906	≤1939	OA,SF
Diadumene lineata				
Annelida: Polychaeta				
	NW Atlantic	1940	1940	OA,SF,PL
Hobsonia florida	N Atlantic	1896	≈1995	OA,SF
	N Atlantic	1932	1937	OA,SF,(BW)
Neanthes succinea	NW Pacific	2000	2000	OJ,SF,BW
	NW Pacific	1951	1968	OJ,SF,BW
Polydora cornuta	N Atlantic	1932	≤1971	BW,OA,(SF)
Pseudopolydora bassarginensis				
Pseudopolydora kempi japonica				
Streblospio benedicti				
Mollusca: Gastropoda				
	NW Pacific	1924	1924	OJ
Batillaria attramentaria	NW Atlantic	1905	1905	OA
	NW Atlantic	1907	≤1945	OA
Crepidula fornicata	NW Pacific	1924	1924	OJ
Ilyanassa obsoleta	NW Atlantic	1890	≤1929	OA
Ocinebrellus inornatus				
Urosalpinx cinerea				
Mollusca: Bivalvia				
	NW Pacific	1875	1875	OJ
Crassostrea gigas	NW Atlantic	1874	1884	OA
	NW Pacific	1924	1924	OJ
Mya arenaria	NW Atlantic	1927	≤1943	OA
Neotrapezium liratum	NW Pacific	1924	1924	OJ
Petricolaria pholadiformis				
Venerupis philippinarum				
Arthropoda: Crustacea: Ostracoda	NW Atlantic	1953	1998	OA,SF,(BW)
Eusarsiella zostericola				
Arthropoda: Crustacea: Cirripedia	N Atlantic	1853	1955	OA,SF
Balanus improvisus				
Arthropoda: Crustacea: Cumacea	NW Pacific	1979	1980	BW
Nippoleucon hinumensis				

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				
	NW Atlantic	1941	1966	OA,SF,BW
	NW Pacific	1973-77	1998	OJ,BW
Ampithoe valida	N Atlantic	1905	1915	OA,SF
	N Atlantic	1915	1915	OA,SF
Caprella mutica	NW Pacific	1966	1977	OJ,SF,BW
	NW Atlantic	1938	≤1995	SF,BW
Corophium acherusicum *Corophium insidiosum* *Grandidierella japonica* *Jassa marmorata* *Melita nitida*	NW Atlantic	1938	1966	OA,SF,SB,BW
Bryozoa				
	NW Atlantic?	≤1923	≤1953	OA,SF
Bowerbankia gracilis	N Atlantic	1943-44	1998	OA,SF
Cryptosula pallasiana *Schizoporella unicornis*	NW Pacific	1927	1927	OJ,SF
Urochordata				
	NW Pacific	1973	1977	OJ,SF
Botrylloides violaceus	NE Atlantic	1944-47	late 1960s-1970s	OA,SF
Botryllus schlosseri *Molgula manhattensis*	NW Atlantic	1949	1998	O A,SF,BW

Source: Natural Resources.

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 and 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.

A study of the causes of species introductions throughout North America found the same vectors, aquaculture and shipping, to be the predominant vectors associated with species introductions into marine communities throughout North America (Ruiz *et al*., 2000). However, the order of importance of the vectors was reversed; shipping was found to be the most important vector for introductions into North America. Beyond the predominance of these two vectors, there remains a great deal of uncertainty about the relative contribution of each mechanism.