



Invasive Marine and Estuarine Animals of the Pacific Northwest and Alaska

by Gary L. Ray

PURPOSE: New species of estuarine and marine animals are inadvertently or intentionally introduced into the waters of the United States every year (Figure 1). Various referred to as introduced, nonindigenous (NIS), alien, nonnative, or exotic species, most pose little or no threat; however, a few have the potential to disrupt local ecosystems, fisheries, and human infrastructure. Such invasions directly impact the mission of the U.S. Army Corps of Engineers (USACE) through its responsibilities for construction and maintenance of harbors, ports and waterways, erosion control, management of water resources, and wetland and coastal habitat restoration. The general biology and ecology of invasive estuarine and marine animals have been described in previous works (Carlton 2001, Ray 2005). This report is part of a series describing the biology and ecology of known invasive estuarine and marine animals in the major geographic regions of the United States. Invasive animals of the Pacific Northwest and Alaska are described and species that pose a specific threat to USACE activities are identified.

BACKGROUND: Invasive species are officially defined as “alien species whose introduction does or is likely to cause economic or environmental harm to human health” (Executive Order 13112, Federal Register 1999). Any species removed from its native range has the potential to become invasive. This is because within its normal range, predation, disease, parasites, competition, and other natural controls act to keep population levels in check (Torchin et al. 2003, Wolfe 2002). Once released from these controls, species abundances have the potential to reach levels that interfere with or displace local fauna. Such effects may occur immediately, after some period of delay, or never be realized at all depending on the characteristics of the individual species and the conditions into which it is introduced.

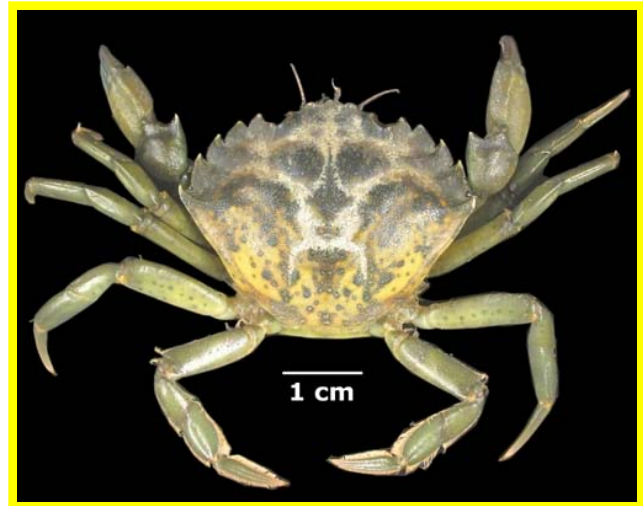


Figure 1. Example of an invasive species, the European green crab, *Carcinus maenas* (image courtesy of California Academy of Sciences)

Lists of estuarine and marine nonindigenous species are often dominated by molluscs, crustaceans, and polychaete worms; however, this may reflect their ease of identification and detection rather than the degree to which they are representative. Ultimately it is an organism’s biological characteristics (e.g., reproductive capacity, growth rate) and not its taxonomic affinities that determine if it becomes invasive. Successful invaders tend to be those that are abundant over a large

range in their native region, have broad feeding and habitat preferences, wide physiological tolerances, short generation times, and high genetic variability (Erlich 1989, Williams and Meffe 1999). Despite the fact that these characteristics can be identified, predicting which species pose the greatest threat remains problematic since many species possess these characteristics, most are not obvious in their native range, and the opportunities for introduction and subsequent likelihood of survival are difficult to assess. The situation is further complicated by difficulty in distinguishing invaders from species with naturally wide distributions and those that are cryptogenic; that is, species whose original distributions are uncertain.

Predicting which habitats are likely to be invaded is much simpler. Invaded habitats tend to have low natural diversity, relatively simple (low-connectance) foodwebs, and a history of recent natural or anthropogenic disturbance (Williams and Meffe 1999). Estuaries and sheltered coastal areas are among the most invaded habitats, presumably due to the fact that they are naturally disturbed, low-diversity systems and are historically centers of anthropogenic disturbance associated with navigation, industrial development, and urbanization.

Most estuarine and marine species introductions are associated with shipping (Ruiz et al. 2000). Species capable of attaching to hard surfaces may be transported on ship hulls, navigational buoys, floatation devices, anchors, chains, ropes, and flotsam or jetsam (Carlton 2001). During the heyday of wooden-hulled ships, woodborers (e.g., shipworms) and species associated with “dry” ballast such as stones, rock, sand, or other materials were frequently introduced (Carlton and Hodder 1995). Presently, the largest single source of shipping-related introductions is ballast water (Carlton 1985, Lavoie et al. 1999). Ballast water is taken onboard vessels for a variety of purposes related to ship maneuverability and control (Carlton et al. 1995). Animals suspended in the water column or present in bottom sediments are taken in and then introduced to a new location when the ballast is pumped out.

Recently, concerns have also been raised with introduction of fish, invertebrates, and “live” rock from the aquarium trade (Padilla and Williams 2004, Weigle et al. 2005). Other introductions may result from accidental release of animals, inappropriate disposal of packing material by restaurants serving live seafood, and the live bait industry (Cohen et al. 2001a). Many species have been deliberately introduced to develop new fisheries. For example, the Atlantic striped bass *Morone saxatilis* has been introduced both outside its normal geographic range and in nonnative habitats (e.g., reservoirs) throughout much of the United States.

METHODS: Lists of invasive species in the Pacific Northwest and Alaska were prepared by querying NISBase, a national database of NIS listings maintained by the Smithsonian Institution (<http://www.nisbase.org/nisbase/index.jsp>). Part of the National Exotic Marine and Estuarine Species Information System (NEMESIS), this database permits simultaneous searches of multiple NIS listings. Searches return up to 300 species and include links to individual species’ fact sheets and collection data. Queries were performed by state and included searches of the U. S. Geological Survey’s Nuisance Aquatic Species (NAS) database (<http://nas.er.usgs.gov/>) and Australia’s National Introduced Pest Species Information System (<http://www.cmar.csiro.au/>). The resulting lists were examined and separate lists were prepared for estuarine and marine animals. Cryptogenic species were excluded from consideration due to the uncertainty of their origins. The NIS list was amended as necessary after comparison with individual state NIS listings and other reports (Table 1).

An excellent review of the NIS problem by Elston (1997) with special regard to the Puget Sound region is available online at <http://www.psat.wa.gov/shared/nis.html>. The State of Washington maintains a listing of marine NIS specific to the state and adjacent waters at <http://www.wdfw.wa.gov/fish/nuisance/ans4.htm>, while a similar list (Carlton et al. 2003) for Oregon waters can be found at <http://science.oregonstate.edu/~yamadas/>. The Prince William Sound Regional Advisory Board also maintains downloadable fact sheets describing the species of greatest concern in Alaskan waters (<http://www.pwsrca.org/NIS/pws3.html>).

Table 1 State NIS Listings and Other Reports Utilized in This Report
Carlton et al. 2003
Cohen et al. 2001b
Cohen 2004
Hanson and Sytsma 2001
Hines and Ruiz 2000
Hines and Ruiz 2001
Mills 2003
State of Alaska 2002
State of Washington 2001
Wonham and Carlton 2005

RESULTS: NIS listings for the Pacific Northwest and Alaska included 162 species (Table 2). The largest number of species was found among the molluscs (47 species) and crustaceans (39 species) (Appendix A). Many of these represent species that were deliberately introduced such as the oysters *Crassostrea gigas*, *C. rivularis*, *C. virginica*, and *Ostrea edulis*; the Japanese littleneck clam *Venerupis (Tapes) phillipinarum*; the hard clam *Mercenaria mercenaria*, the softshell clam *Mya arenaria*; and the blue mussel *Mytilus edulis*. Introduced crustaceans include the shrimp *Palaemon macrodactylus* and *Exopalaemon modestus* and American lobster *Homarus vulgaris*. A number of fish were also deliberately introduced such as American shad *Alosa sapidissima*, gizzard shad *Dorosoma petenense*, Atlantic salmon *Salmo salar*, and Atlantic striped bass *Morone saxatilis*. The coho salmon *Onchorhynchus kisutch*, a native of the Pacific Northwest, has been stocked in so-called nonindigenous waters, i.e., waters where they do not naturally occur.

Table 2 Numbers of NIS in the Pacific Northwest and Alaska				
Group	WA	OR	AK	Total for Region
Protozoan	1	1		1
Hydrozoan	5	6	1	8
Schyzophzoan	1			1
Porifera	6	3	1	7
Anthozoan	1	3	1	3
Platyhelminth	2			2
Polychaete	13	16	2	21
Oligochaete	4	3		6
Bivalve	17	6	2	17
Gastropod	25	5		27
Nudibranch		1		1
Chiton	1			1
Barnacle	1	1		1
Copepod	7	7		10
Amphipod	10	9		11
Isopod	3	3		5
Tanaid	2	2		3
Cumacean	1	1		1
Crab	3	3		4
Shrimp	1	3		3
Lobster	1			1
Bryozoan	7	9		10
Entoproct	1	1	1	1
Tunicate	7	5	2	9
Fish	5	8	2	8
Total	125	96	12	162

Several species may have been unintentionally introduced during shellfish introductions from both the Atlantic coast and Japan. Species associated with Atlantic oysters are slipper shells *Crepidula fornicata*, *C. convexa* and *C. plana*, Atlantic oyster drill *Urosalpinx cinerea*, boring-sponge *Cliona* sp., ribbed marsh mussel *Geukensia demissa*, Eastern mud snail *Nassarius obsoletus*, and the pileworm *Nereis succinea*. Species associated with Japanese oyster and Japanese littleneck clam plantings are the mussel

Musculista sp., the parasitic copepod *Pseudomyicola (Myticola) ostreae*, and the Japanese false cerith *Battilaria attramentaria*.

Approximately 38 NIS species (24 percent of total) are associated with hard structures and may contribute to fouling. Probably introduced on ships' hulls or in ballast water, they include eight hydrozoans, seven sponges, three anthozoans (anemones), one barnacle, ten bryozoans, one entoproct, and nine tunicates. Only two of these species, the boring sponge *Cliona thoosina* and *Schizoporella unicornis*, a bryozoan, are considered to be species of concern.

Geographic distribution of NIS varies substantially among states, with Washington having the largest number (125 species) and Alaska the least (12 species). The relatively low number of NIS in Alaska waters has been attributed to a poor historical record from which to assess what fauna are native and the limited number and scope of biological surveys for NIS (Hines and Ruiz 2000).

DISCUSSION: Species identified as invasive or of concern in the state of Washington are European green crab *Carcinus maenas*, Chinese and Japanese mitten crabs *Eriocheir sinensis* and *E. japonicus*, Asian clam *Potamocorbula amurensis*, Japanese oyster drill *Ceratostoma inornatum*, Asian copepod *Pseudodiaptomus inopinus*, Mediterranean mussel *Mytilus galloprovincialis*, and Atlantic salmon (State of Washington 2001). Although the State of Alaska (State of Alaska 2002) officially lists only green and mitten crabs as species of immediate concern, the Prince William Sound Regional Advisory Board includes the foraminiferan *Trochammina hadai*, boring sponge *Cliona thoosina*, the capitellid polychaete *Heteromastus filiformis*, Japanese oysters (*C. gigas*), softshell clams, single-horn bryozoan *Schizoporella unicornis*, and Atlantic salmon on this list. Oregon specifically prohibits introduction of mitten crabs, Japanese oyster drills, and Asian clams (*P. amurensis* and its relatives) as well as the Atlantic blue crab *Callinectes sapidus* (Hanson and Sytsma 2001).

Potential Threats to Infrastructure. Several introduced wood-boring species are present in the Pacific Northwest, such as the shipworm *Teredo navalis* and the isopods *Limnoria tripunctata* and *Sphaeroma quoyanum*. *Teredo navalis*, a bivalve mollusc, is a threat to wooden structures including boats, marinas, docks, and pilings. It reportedly was responsible for \$615 million in damage in San Francisco Bay during an outbreak in the 1920's (Cohen and Carlton 1995). Likewise, severe damage was reported in Barnegat Bay, New Jersey and Long Island Sound, New York after outbreaks of the closely related species *T. bartschi* (Hoagland 1983). These pests can be effectively controlled by chemical treatment (e.g., creosote) or use of alternative materials (Highley 1999). While creosote deters shipworm infestations, the same cannot be said of the marine isopod genus *Limnoria*, more commonly known as gribbles (Figure 2). Gribbles are able to burrow into treated wood and may even derive nutrition from bacteria in their gut that break down creosote hydrocarbons (Zachary et al. 1983). Recently, engineers with the City of Seattle have discovered that a seawall and its wooden supports along the Seattle waterfront have become so damaged by gribbles that the structure may collapse (Figure 2). Replacement costs have been estimated at \$700 million (Roach 2004). Gribbles in the Pacific Northwest include both the native species *Limnoria lignorum* and the invasive Mediterranean gribble *L. tripunctata*. Maximum size of gribbles is approximately 4 mm (Kozloff 1983).



Figure 2. *Limnoria* sp. and the damage it can cause (images courtesy of Washington State Department of Transportation)

The Chinese mitten crab *Eriocheir sinensis* first appeared as an invasive species in Germany during the early 1900's and has since spread through most of Europe (Clark et al. 1998). It has been reported in the United States from Lake Erie, San Francisco Bay, the Columbia River, and Mississippi Sound. Mitten crabs are catadromous, spending most of their adult life in fresh water, then returning to the sea to reproduce. They form extensive burrows in riverbanks and levees, thus posing a direct threat to earthen water control structures. The life history of the Japanese mitten crab (*E. japonicus*) is believed to be similar. Further information on the life history of mitten crabs can be found either in Veldhuizen and Stanish (2002) or an ANS fact sheet (http://el.ercd.usace.army.mil/ansrp/eriocheir_sinensis.htm).

Potential Threats to Habitat Restoration. The European green crab *Carcinus maenas* (Figure 1) inhabits a wide range of habitats in sheltered areas including rocky intertidal, unvegetated intertidal and subtidal mud and sand, salt marsh, and seagrass. Capable of tolerating a wide range of salinity and temperature, it prefers mesohaline to polyhaline salinities (10-30 ppt) and temperatures between 3 and 26 °C (Grosholz and Ruiz 2002). The green crab was introduced to the east coast of North America sometime in the 1800's (Scattergood 1952) and subsequently invaded the west coast. It has been detected in San Francisco Bay (Cohen et al. 1995) and other California estuaries (Grosholz and Ruiz 1995). It has been reported as far north as Oregon (Miller 1996) and Vancouver Island, Canada (Yamada et al. 2001) and could move into Alaskan waters (Gray Hitchcock et al. 2003). Genetic studies show that invasion of the Pacific coast was from east coast populations (Bagley and Geller 1999) with secondary expansion along the west coast attributable to oceanic transport of the planktonic larvae (Yamada et al. 2001). Larvae take approximately 90 days to develop, metamorphose, and settle out in mussel beds, eelgrass beds, or patches of filamentous algae (Moksnes 2002). Older juveniles actively migrate to mussel beds. Juvenile green crabs feed primarily on detritus, then shift to algae, snails, bivalves, annelids, crustaceans, and other benthic organisms as they mature (Pihl 1985, Ropes 1968). Predation on both natural and cultured bivalve populations has led to declines in softshell clams in New England (Glude 1955), *Nutricola* spp. in Central California (Grosholz et al. 2000), and the venerid clam *Katelysia scalarum* in Tasmania (Walton et al. 2002, Ross et al. 2004). While the green crab may outcompete Dungeness crab *Cancer magister* for food, their habitats generally do not overlap (McDonald et al. 2001). Control measures

have generally been unsuccessful and limited to trapping. For more information on this species, see Ray (2005) and Grosholz and Ruiz (2002).

The Asian or Amur River corbula clam *Potamocorbula amurensis* (Figure 3), a native of Chinese, Japanese, and Korean waters, inhabits both intertidal and subtidal mud and sand. It tolerates a wide range of salinities and temperatures and feeds on bacteria, phytoplankton, and copepod larvae (Cohen and Carlton 1995, Kimmerer et al. 1994, Werner and Hollibaugh 1993). Since its initial detection in San Francisco Bay in 1987 it has become the dominant infaunal species in the bay, displacing native fauna (Carlton et al. 1990, Nichols et al. 1990). It appears to be responsible for a significant decline in bay phytoplankton (Alpine and Cloern 1992), which in turn has had negative impacts on resident zooplankton and fish populations (Kimmerer et al. 1994, Feyrer et al. 2003). Although presently limited to San Francisco Bay, it has the potential for widespread distribution via planktonic larvae. This species may interfere with the natural recolonization of dredged material deposits or sediments employed in beneficial use projects.



Figure 3. *Potamocorbula amurensis* (image courtesy of California Academy of Sciences)

Mytilus galloprovincialis, the Mediterranean blue mussel, has been introduced to both west coast and Hawaiian waters (Eldredge and Evenhuis 2002). Currently found worldwide in temperate seas, it has been nominated as one of the “top 100 world’s worst invaders.” On the Pacific coast, its range extends from Coos Bay, Oregon to San Diego, California. This mussel has the potential to interfere with restoration of rocky intertidal habitats by excluding native species. The same may be true of the bryozoan *Schizoporella unicornis*. Introduced from Japan, it encrusts hard surfaces, excluding or inhibiting settlement by native species. The Prince William Sound Regional Advisory Board maintains a fact sheet containing additional information on this species (<http://www.pwsrccac.org/NIS/pws3.html>).

Of the several copepod species introduced along the west coast, the Asian species *Pseudodiaptomus inopinus* is most commonly listed as one of concern in the Pacific Northwest. Invading the Columbia River estuary sometime in the 1980’s, it is now established in the upper reaches of estuaries from Oregon to British Columbia. It can be the most abundant copepod present from summer to fall (Cordell and Morrison 1996, 1999; Cordell and Rasmussen 2001). There is concern that it may represent a less desirable food source for developing fish than native species. Meng and Orsi (1991) have suggested that the dominance of introduced copepods in Northern California bays, including the closely related invasive *P. marinus*, may have contributed to the failure of a year class of striped bass.

Sphaeroma quoyanum is a wood-boring marine isopod, similar in size and shape to the common garden pillbug, which poses a threat to marsh restoration efforts. Introduced from Australasia on ship hulls during the California gold rush, it can now be found from San Diego, California to

Coos Bay, Oregon. It burrows into a variety of substrates including wood, soft rock, and salt marsh peat (Talley et al. 2001). It prefers the salt marsh peat of *Salicornia* spp.-dominated marshes and is found predominately high in the intertidal zone on bay-front rather than creek edge marsh banks. It forms horizontal burrows on vertical and undercut banks, weakening them, eventually resulting in collapse and severe erosion. Burrow densities are vastly greater on vertical rather than sloping banks so it may be possible to limit its effects by incorporating sloped banks into salt marsh restoration designs (Talley et al. 2001).

Unintentional introduction of NIS during stocking of nonnative oysters has been identified by Wonham and Carlton (2005) as the single largest source of NIS in the Pacific Northwest. More than 20 percent of all marine and estuarine NIS are believed to have arrived with these shipments. Species of concern introduced with Japanese oysters (*C. gigas*) include the Japanese oyster drill *Ceratostoma inornatum*, the Japanese false cerith *Batillaria attramentaria* (= *zonalis*), and the Asian date mussel *Musculista senhousia*. As its name implies, the drill is an oyster predator that preferentially feeds on young oysters. It has been reported to prefer *C. gigas*, but will also eat native oysters such as *Ostreola conchaphila* (Buhle and Ruesink 2003). Like most muricid gastropods, the larvae are not planktonic so control is possible by quarantining infested oyster beds. Japanese false cerith has become the dominant snail species on many California and Pacific Northwest mudflats and salt marshes. Its ability to replace the native marsh snail *Cerithidea californica* has been attributed to resistance to parasites, lower mortality, greater tolerance of low oxygen conditions, and more efficient food conversion (Byers 2000a, 2000b; Byers and Goldwasser 2001). The Asian date mussel is native to intertidal and subtidal sediments from Siberia to the Red Sea and is now found in Australia, New Zealand, the eastern Mediterranean, and southern France (Crooks 1996). Probably introduced into the United States in 1924 during introduction of Japanese oysters to Samish Bay, Washington, it has since spread as far as Southern California most likely via ballast water. Its planktonic larvae can remain in the water column as long as 55 days before settling out on either muddy or sandy substrates. This species forms dense beds that significantly alter nearby sediments and native benthic assemblages (Crooks 1996, 1998; Crooks and Khim 1999). Since much of dredged material is comprised of soft sediments, this species may interfere with the natural recolonization of dredged material deposits or sediments employed in beneficial use projects. Transplantation success of seagrass restoration projects may also be reduced in infested areas (Reutsch and Williams 1998). Ironically, dense, intact beds of native seagrass directly inhibit the growth of *Musculista* populations by limiting delivery of phytoplankton within the bed (Allen and Williams 2003).

Species believed to have been introduced with Atlantic oysters (*C. virginica*) include the eastern mud snail *Nassarius* (= *Ilyanassa*) *obsoleta*, the Atlantic oyster drill *Urosalpinx cinerea*, and the ribbed mussel *Geukensia* (= *Ischadium*) *demissa*. *Nassarius* is presently distributed from San Francisco Bay to British Columbia (Cohen and Carlton 1995). Most abundant in salt marshes and tidal creeks (sloughs) it, like *Batillaria*, has displaced the native snail *C. californica* in many California salt marshes (Race 1982). *Nassarius* produces planktonic larvae capable of tolerating wide ranges of temperature, salinity, and oxygen concentrations (Vernberg and Vernberg 1975). Adults feed primarily on surface algae and other microorganisms (Scheltema 1964, Pace et al. 1979, Feller 1984), but the physical disturbance caused by their feeding activities and removal of algal cover can have a disproportionate effect on other infaunal populations. *Nassarius* has been shown to affect both larval settlement (Hunt et al. 1987, Dunn et al. 1999) and adult distributions of other

infauna (DeWitt and Levinton 1985, Kelaher et al. 2003). Like the Japanese oyster drill, the Atlantic oyster drill is a threat to both stocked and native oyster populations. It also has non-planktonic larvae and its spread can be controlled by quarantine of infected stocks. The ribbed mussel dominates marsh channel bank habitats in much of San Francisco Bay (Cohen and Carlton 1995). While its ecological impact is uncertain, its presence may threaten the endangered California clapper rail (*Rallus longiorostrus obsoletus*). It has been claimed that birds feeding on the mussel may become entangled in the mussels and either drown or lose their toes (Cohen and Carlton 1995).

Another species of concern associated with oysters is the boring sponge *Cliona thosina*. The sponge encrusts the surface of mollusc shells, secreting enzymes that etch the shell. Once weakened, the shellfish are more vulnerable to predators. The sponge is suspected of being introduced either via ballast water or in shellfish shipments. The Prince William Sound Regional Advisory Board maintains a fact sheet containing additional information on this species at the website listed above.

The introduced Japanese purple varnish clam *Nuttallia obscurata* is one of the dominant bivalves of intertidal sands from northern Washington to British Columbia (Byers 2001). It has a brown outer layer that peels off like old varnish and purple inner shell lining, hence its name (Mills 2002). Most likely introduced into British Columbia in ballast water during the 1980's, it is most abundant just below mean low water (MLW). Its success appears to be due to superior burrowing ability, since local predatory crabs prefer it to native species (Dudas et al. 2003). This species is actively harvested in its native range and some consideration is being given to establishing a fishery for it (Washington Department of Fish and Wildlife 2004).

Finally, the impact of Atlantic salmon *Salmo salar* escaping from mariculture facilities in British Columbia is a matter of vigorous debate (Volpe 2001). Escaped fish have been collected as far north as Alaska (Wing et al. 1992). Prior to introduction, it was assumed that escapees would not be able to survive, breed, establish viable populations, or compete with native species. Volpe et al. (2000) indicate that not only have escaped salmon survived, but they have also spawned in the rivers of British Columbia. There is also some evidence to suggest competition with native species (Volpe et al. 2001).

ACKNOWLEDGEMENTS: This review was sponsored by the U. S. Army Engineer Research and Development Center, Vicksburg, MS, under the Aquatic Nuisance Species Research Program (ANSRP).

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Ray, G. L. (2005). "Invasive estuarine and marine animals of the Pacific Northwest and Alaska," ANSRP Technical Notes Collection (ERDC TN-ANSRP-05-6), U.S. Army Engineer Research and Development Center, Vicksburg, MS.
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**APPENDIX A: NIS LISTINGS BY STATE FOR THE PACIFIC NORTHWEST
AND ALASKA**

Species	Group	WA	OR	AK
<i>Trochammina hadai</i>	Protozoan	WA	OR	
<i>Blackfordia virginica</i>	Hydrozoan		OR	
<i>Bouganvillia muscus</i>	Hydrozoan	WA		
<i>Clava</i> sp.	Hydrozoan		OR	
<i>Cladonema radiatum</i>	Hydrozoan	WA		
<i>Corydolophora caspia</i>	Hydrozoan	WA	OR	
<i>Ectopleura (Tubularia) crocea</i>	Hydrozoan	WA	OR	AK
<i>Gonothyrea clarki</i>	Hydrozoan		OR	
<i>Obelia</i> sp.	Hydrozoan	WA	OR	
<i>Aurelia aurita</i>	Schizophozoan	WA		
<i>Clathria prolifera</i>	Porifera	WA		
<i>Clionoa thoosina</i>	Porifera	WA		
<i>Cliona</i> sp.	Porifera	WA	OR	AK
<i>Halichondria bowerbanki</i>	Porifera	WA	OR	
<i>Haliclona loosanoffi</i>	Porifera		OR	
<i>Haliclona luciae</i>	Porifera	WA		
<i>Microciona prolifera</i>	Porifera	WA		
<i>Diadumene lineata</i>	Anthozoan	WA	OR	AK
<i>Diadumene leucolema</i>	Anthozoan		OR	
<i>Nematostella vectensis</i>	Anthozoan		OR	
<i>Cercaria batillariae</i>	Platyhelminth	WA		
<i>Pseudostylochus ostreaphagus</i>	Platyhelminth	WA		
<i>Hobsonia (Amphicteis) florida</i>	Polychaete	WA	OR	
<i>Capitella capitata</i>	Polychaete	WA		
<i>Capitella</i> spp.	Polychaete	WA	OR	
<i>Capitomastus</i> sp.	Polychaete		OR	
<i>Eteone tchangsii</i>	Polychaete		OR	
<i>Eteone</i> sp.	Polychaete		OR	
<i>Fabricia sabella</i>	Polychaete		OR	
<i>Harmothoe imbricata</i>	Polychaete		OR	
<i>Heteromastus filiformis</i>	Polychaete	WA	OR	AK
<i>Manayunkia aestuarina</i>	Polychaete		OR	
<i>Manayunkia speciosa</i>	Polychaete		OR	AK
<i>Nereis (Neanthes) succinea</i>	Polychaete	WA	OR	
<i>Owenia fusiformis</i>	Polychaete		OR	
<i>Pionospyllis uraga</i>	Polychaete	WA		
<i>Polydora cornuta</i>	Polychaete	WA	OR	
<i>Pseudopolydora kempfi</i>	Polychaete	WA	OR	
<i>Pseudopolydora paucibranchiata</i>	Polychaete	WA	OR	
<i>Pygospio elegans</i>	Polychaete	WA		
<i>Sabaco elongates</i>	Polychaete	WA		

(Sheet 1 of 4)

Species	Group	WA	OR	AK
<i>Streblospio benedicti</i>	Polychaete	WA	OR	
<i>Thayrx tessellata</i>	Polychaete	WA		
<i>Limnodrilus monotheucus</i>	Oligochaete	WA		
<i>Paranais frici</i>	Oligochaete	WA	OR	
<i>Tubificoides apectinatus</i>	Oligochaete	WA		
<i>Tubificoides brownae</i>	Oligochaete		OR	
<i>Tubificoides diazi</i>	Oligochaete		OR	
<i>Tubificoides wasselli</i>	Oligochaete	WA		
<i>Crassostrea gigas</i>	Bivalve	WA	OR	AK
<i>Crassostrea rivularis</i>	Bivalve	WA		
<i>Crassostrea virginica</i>	Bivalve	WA		
<i>Gemma gemma</i>	Bivalve	WA		
<i>Mercenaria mercenaria</i>	Bivalve	WA		
<i>Meretrix lusoria</i>	Bivalve	WA		
<i>Musculista senhousia</i>	Bivalve	WA		
<i>Mya arenaria</i>	Bivalve	WA	OR	AK
<i>Mysella tumida</i>	Bivalve	WA		
<i>Mytilus edulis</i>	Bivalve	WA		
<i>Mytilus galloprovincialis</i>	Bivalve	WA	OR	
<i>Neotrapezium liratum</i>	Bivalve	WA		
<i>Nuttallia obscurata</i>	Bivalve	WA	OR	
<i>Ostrea edulis</i>	Bivalve	WA		
<i>Petricola pholadiformis</i>	Bivalve	WA		
<i>Teredo navalis</i>	Bivalve	WA	OR	
<i>Venerupis (Tapes) philippinarum</i>	Bivalve	WA	OR	
<i>Batillaria (zonalis) attramentaria</i>	Gastropod	WA		
<i>Cecina manchurica</i>	Gastropod	WA		
<i>Collisella striata</i>	Gastropod	WA		
<i>Crepidula convexa</i>	Gastropod	WA		
<i>Crepidula fornicata</i>	Gastropod	WA		
<i>Crepidula plana</i>	Gastropod	WA		
<i>Cumanotus beaumonti</i>	Gastropod	WA	OR	
<i>Haliotis rufescens</i>	Gastropod	WA		
<i>Littorina brevicula</i>	Gastropod	WA		
<i>Littornia littorea</i>	Gastropod	WA		
<i>Melanoides tubercuatus</i>	Gastropod		OR	
<i>Monodonta labio</i>	Gastropod	WA		
<i>Myostella myoostis</i>	Gastropod	WA	OR	
<i>Nassarius fraticularis</i>	Gastropod	WA		
<i>Nassarius obsoletus</i>	Gastropod	WA		
<i>Neptunea arthritica</i>	Gastropod	WA		
<i>Ocenebra japonica</i>	Gastropod	WA		
<i>Ocenebrellus (Ceratoasotma) inornatus</i>	Gastropod	WA	OR	
<i>Philine auriformis</i>	Gastropod		OR	
<i>Purpura clavigera</i>	Gastropod	WA		

(Sheet 2 of 4)

Species	Group	WA	OR	AK
<i>Radix auricularia?</i>	Gastropod	WA		
<i>Rapana thomasiana</i>	Gastropod	WA		
<i>Rapana venosa</i>	Gastropod	WA		
<i>Thais clavigera</i>	Gastropod	WA		
<i>Turbo marmoratus</i>	Gastropod	WA		
<i>Turbo sornatus coreensis</i>	Gastropod	WA		
<i>Urosalpinx cinerea</i>	Gastropod	WA		
<i>Tenellia aspersa</i>	Nudibranch		OR	
<i>Acanthichitona achaetes</i>	Chiton	WA		
<i>Balanus improvisus</i>	Barnacle	WA	OR	
<i>Argulus japonicus</i>	Copepod	WA		
<i>Coullana candensis</i>	Copepod		OR	
<i>Eurytemora affinis</i>	Copepod		OR	
<i>Limnoithona sinensis</i>	Copepod	WA	OR	
<i>Paramisophria</i> sp.	Copepod	WA		
<i>Pseudomyicola (Myticola orientalis) ostreae</i>	Copepod	WA	OR	
<i>Pseudodiaptomus forbesi</i>	Copepod		OR	
<i>Pseudodiaptomus marinus</i>	Copepod	WA		
<i>Pseudodiaptomus inopinus</i>	Copepod	WA	OR	
<i>Ampithoe valida</i>	Amphipod	WA	OR	
<i>Caprella mutica</i>	Amphipod	WA	OR	
<i>Chelura terebrans</i>	Amphipod	WA		
<i>Monocorophium acherusicum</i>	Amphipod	WA	OR	
<i>Monocorophium insidiosum</i>	Amphipod	WA	OR	
<i>Eobrolgus spinosus</i>	Amphipod		OR	
<i>Eochelidium</i> sp.	Amphipod	WA		
<i>Grandidierella japonica</i>	Amphipod	WA	OR	
<i>Jassa marmorata</i>	Amphipod	WA	OR	
<i>Melita nitida</i>	Amphipod	WA	OR	
<i>IncisCALLiope (Parapleustes) derzhavini</i>	Amphipod	WA	OR	
<i>Caecidotea racovitzai</i>	Isopod		OR	
<i>Iais californica</i>	Isopod	WA	OR	
<i>Limnoria tripunctata</i>	Isopod		OR	
<i>Sphaeroma quoyanum</i>	Isopod	WA		
<i>Synidotea laevidorsalis</i>	Isopod	WA		
<i>Leptocheilia dubia</i>	Tanaid		OR	
<i>Sinelobus stanfordi</i>	Tanaid	WA	OR	
<i>Tanais</i> sp.	Tanaid	WA		
<i>Nippoleucon hinumensis</i>	Cumacean	WA	OR	
<i>Carcinus maenas</i>	Crab	WA	OR	
<i>Eriocheir japonicus</i>	Crab	WA	OR	
<i>Eriocheir sinensis</i>	Crab	WA		
<i>Rithropanopeus harrisi</i>	Crab		OR	
<i>Crangon pseudogracilis</i>	Shrimp		OR	
<i>Palaemon macrodactylus</i>	Shrimp		OR	

(Sheet 3 of 4)

Species	Group	WA	OR	AK
<i>Exopalaemon modestus</i>	Shrimp	WA	OR	
<i>Homarus americanus</i>	Lobster	WA		
<i>Alcyonidium polyoum</i>	Bryozoan		OR	
<i>Alcyonidium</i> sp.	Bryozoan		OR	
<i>Bowerbankia gracilis</i>	Bryozoan	WA	OR	
<i>Bugula neritina</i>	Bryozoan	WA	OR	
<i>Bugula stolonifera</i>	Bryozoan	WA		
<i>Conopeum tenuissimum</i>	Bryozoan		OR	
<i>Cryptosula pallasiana</i>	Bryozoan	WA	OR	
<i>Schizoporella unicornis</i>	Bryozoan	WA	OR	
<i>Triticella</i> sp.	Bryozoan		OR	
<i>Watersipora "subtorquata"</i>	Bryozoan		OR	
<i>Barentsia benedini</i>	Entoproct	WA	OR	AK
<i>Botrylloides violaceus</i>	Tunicate	WA	OR	AK
<i>Botryllus schosseri</i>	Tunicate	WA	OR	
<i>Botryllus</i> sp.	Tunicate			AK
<i>Ciona intestinalis</i>	Tunicate	WA		
<i>Ciona savignyi</i>	Tunicate	WA		
<i>Didemnum cf. lahillei</i>	Tunicate	WA		
<i>Diplosoma lsiteirianum</i>	Tunicate		OR	
<i>Mogula manhattensis</i>	Tunicate	WA	OR	
<i>Styela clavata</i>	Tunicate	WA	OR	
<i>Alosa sapidissima</i>	Fish	WA	OR	
<i>Anguilla</i> sp.	Fish		OR	AK
<i>Dorosoma petenense</i>	Fish		OR	
<i>Gambusia affinis</i>	Fish	WA	OR	
<i>Lucania parva</i>	Fish		OR	
<i>Morone saxatilis</i>	Fish	WA	OR	
<i>Oncorhynchus kisutch</i>	Fish	WA	OR	
<i>Salmo salar</i>	Fish	WA	OR	AK

(Sheet 4 of 4)