



Invasive Marine and Estuarine Animals of California

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, non-native, 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 reports (Carlton 2001, Ray 2005). This technical note is part of a series describing known invasive estuarine and marine animals in the major geographic regions of the United States. Unlike previous works in this series, this report focuses on a single state, California. This is due to the fact that California has the largest number of known introduced estuarine and marine animals. San Francisco Bay alone has approximately 212 NIS (Cohen and Carlton 1995) and been described as the most invaded estuary in North America (Cohen and Carlton 1998). Introduced species now dominate all major benthic communities within the bay (Carlton et al. 1990, Nichols et al. 1990, Lee et al. 2003). This report identifies species posing a specific threat to USACE activities.

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 can 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 Chinese Mitten Crab, *Eriocheir sinensis* (image courtesy of California Department of Fish and Game)

Lists of estuarine and marine nonindigenous species are often dominated by mollusks, 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 issue of an organism's biological characteristics (e.g., reproductive capacity, growth rate, etc.) and not its taxonomic affinities that determine if it becomes invasive. Successful invaders tend to be 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 (Erlach 1989, Williams and Meffe 1999).

Despite the fact that we can identify these characteristics, predicting which species pose the greatest threat remains problematic since many species possess these characters, most are not obvious in their native range, and opportunities for their 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) food webs 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 historic centers of anthropogenic disturbance associated with navigation, industrial development, and urbanization.

Species are introduced by a variety of different mechanisms; however, 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, wood-borers (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 believed to be ballast water (Carlton 1985, Lavoie et al. 1999). Ballast water is taken on board 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 regarding introductions of fish, invertebrates, and "live" rock from the aquarium trade (Padilla and Williams 2004, Weigle et al. 2005). The lionfish *Pterois volitans* may have been introduced when a private aquarium was demolished in the Miami area during Hurricane Andrew in 1992 (Hare and Whitfield 2003). Other introductions may result from accidental release of animals, inappropriate disposal of packing material by restaurants serving live seafood, and by the live bait industry (e.g., Chapman et al. 2002). 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 non-native habitats (e.g., reservoirs) in much of the United States.

METHODS: Lists of invasive species for California were prepared by querying NISBase, a national database of NIS listings maintained by the Smithsonian Institution (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 included searches of the United States Geological Survey's Nuisance Aquatic Species (NAS) Database (nas.er.usgs.gov/), Australia's National Introduced Pest Species Information System (<http://www.marine.csiro.au/crimp/nimpis/>), and the Introduced Marine Species of Hawaii Guidebook (Eldredge and Smith 2001). The resulting lists were examined and separate lists of only estuarine and marine animals were prepared. Cryptogenic species were excluded from consideration due to the uncertainty of their origins. These lists were amended as necessary after comparison with individual state NIS listings and other reports (Table 1).

Two information sources were particularly useful. Cohen and Carlton (1995) is an excellent source of both background material on the invasive species problem with specific regard to San Francisco Bay and detailed information on individual species. State of California (2002) includes a list of NIS species and copies of Boyd et al. (2002) and Cohen et al. (2002) as appendices. In addition, Appendices D and E of the report provide species collection information for the entire California coast.

Table 1 State NIS Listings and Other Reports Utilized in This Report
Anonymous 2005
Boyd et al. 2002
Cohen and Carlton 1995
Carlton et al. 2004
Cohen et al. 2002
State of California 1995
State of California 2002

RESULTS: NIS listings for California included 267 species (Table 2). The largest numbers of species were found among molluscs (54 species), polychaetes (47 species), and amphipods (36 species). Many of these represent species that were deliberately introduced such as the oysters *Crassostrea gigas*, *C. virginica*, *Ostrea edulis*, *O. lurida*, and *O. sinuata*, the Japanese littleneck clam (*Venerupis (Tapes) phillipinarum*), the hard clam (*Mercenaria mercenaria*), and the softshell clam (*Mya arenaria*) (Appendix A). Introduced crustaceans include the shrimps *Palaemon macrodactylus* and *Exopalaemon modestus* and the American lobster (*Homarus vulgaris*). A number of fish species have also been deliberately introduced: 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, is also listed because it has been stocked in waters where it doesn't naturally occur.

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*), the snail *Boonea bisuturalis*, boring-sponge *Cliona* sp., red beard sponge (*Microciona prolifera*), channeled whelk (*Busycotpus canaliculatus*), Harris's mud crab (*Rithropanopeus harrisi*), Atlantic 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 *Mytilicola orientalis*, the Japanese false cerith (*Battilaria attramentaria*(=*zonalis*)), and the Japanese oyster drill (*Ceratostoma inoratum*).

Table 2 Summary of NIS in California					
Group	NISBase	State of CA 2002	SF¹	HU²	Total for State
Protozoan		7	7		7
Hydrozoan	10	12	9	1	13
Scyphozoan	2	2	1	1	2
Anthozoan	4	5	4	3	5
Porifera	5	5	5	3	7
Polychaete	7	45	13	15	47
Oligochaete	1	4	4		5
Bivalve	16	25	12	6	26
Gastropod	16	23	14	6	26
Nudibranch	2	2	2		2
Barnacle	1	2	2		3
Copepod	8	11	6	1	12
Amphipod	17	30	19	15	36
Isopod	6	16	6	4	16
Tanaid			1	2	2
Cumacean	1	1	1		1
Ostracod	1	1	1		1
Mysid	2	3	3		3
Nebalian	1	1	1	1	2
Crab	2	3	3	1	3
Shrimp		2	1		2
Lobster	1	1			1
Insect		2	2		2
Tunicate	5	14	6	6	15
Bryozoan	6	14	11	7	14
Entoproct	1	2	1	1	2
Fish	7	11	5		12
Grand Total	122	244	140	73	267
¹ SF = Cohen and Carlton (1995).					
² HU= Boyd et al. (2002).					

Approximately 64 NIS species (24 percent of total) are associated with hard structures and may contribute to fouling. Most likely introduced on ships' hulls or ballast water, they include species of 13 hydrozoans, 7 sponges (porifera), 5 anemones (anthozoans), 3 barnacles, 14 bryozoans, 2 entoprocts, 15 tunicates, and 4 polychaetes.

DISCUSSION: Marine and estuarine animals generally considered to be invasive in the state of California are Chinese mitten crab (*Eriocheir sinensis*), European green crab (*Carcinus maenas*), Asian or Amur River Corbula clam (*Potamocorbula amurensis*), the isopod *Sphaeroma quoyanum* and the sabellid polychaete *Terebrasabella hetrouncinata*, a pest of abalone aquaculture facilities (Gear 2001).

Potential Threats to Infrastructure.

Chinese mitten crab. The Chinese mitten crab (Figure 1) is perhaps the principal threat to infrastructure in California waters. It 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). In the United States it has been reported in Lake Erie, the Columbia River, Mississippi Sound, and San Francisco Bay. Mitten crabs are catadromous, spending most of their adult life in freshwater, then returning to the sea only to reproduce (Veldhuizen and Stanish 2002). The adults can live up to five years and are omnivorous. Their planktonic larvae grow best in relatively high salinities (~25 ppt), while late stage (megalopae) larvae prefer 15 ppt and 25 ppt. Late stage larvae settle out of the plankton from late spring to early summer, metamorphosing into juveniles, which migrate towards the fresher portions of the estuary. Juveniles are most abundant along steep clay banks just below the root zone of adjacent vegetation. Their extensive burrows weaken riverbanks and earthen water control structures, leading to severe erosion. The crab population in San Francisco Bay has disrupted fish salvage operations (e.g., the collection of fish at water control structures during drawdowns) and commercial fisheries (Culver and Walter 2001, Wynn et al. 1999). There is also a potential threat to human health because this species can harbor the parasitic Chinese lung fluke. Thus far, no flukes have been detected in U.S. crab populations (National Oceanographic and Atmospheric Administration (NOAA) 2001). A draft national management plan for *E. sinensis* promulgated by the Aquatic Nuisance Species Task Force (2002) focuses primarily upon early detection. A variety of potential control methods have been suggested including active trawling for adults during the reproductive phase. Culver and Walter (2001) claim some success with a passive system that traps the crabs as they migrate into the estuary. The life history of the Japanese mitten crab (*E. japonicus*) is believed to be similar. For further information see Veldhuizen and Stanish (2002), Ray (2005), or the ANSRP website (http://el.erd.usace.army.mil/ansrp/eriocheir_sinensis.htm) for a species fact sheet.

Wood-boring species. Wood-boring species are another potential threat to infrastructure. These include shipworms, a form of bivalve mollusc, and small isopods commonly known as gribbles. Shipworms do not actually feed on cellulose in the wood, but form extensive burrow systems in any submerged wooden structure such as boats, marinas, docks, and pilings. Species known to be present in California are the blacktip shipworm (*Lyrodus pedicellatus*) (Figure 2), the cosmopolitan *Teredo navalis*, and *T. bartschi*. Shipworms were reportedly responsible for \$615 million in damage in San Francisco Bay during an outbreak in the 1920's (Cohen and Carlton 1995). Severe damage was also reported in Barnegat Bay, New Jersey and Long Island Sound, New York after outbreaks of *T. bartschi* (Hoagland 1983). These pests can be effectively controlled by chemical treatment (e.g., creosote) or use of alternative materials (Highley 1999).



Figure 2. A shipworm - *Teredo* sp. (marine) (image courtesy of U.S. Geological Survey)

Gribbles. While creosote deters shipworm infestations, it does not deter gribbles. Gribbles are able to burrow into treated wood and may even derive nutrition from creosote, since bacteria associated with its gut break down creosote hydrocarbons (Zachary et al. 1983). Recently, engineers with the City of Seattle discovered a seawall and its wooden supports along the Seattle waterfront so damaged by gribbles that collapse of the structure is a serious possibility. Replacement costs have been estimated at \$700 million (Roach 2004). Three members of this genus are present in California, the Mediterranean gribble *Limnoria tripunctata*, *L. quadripunctata*, and *L. lignorum*. The last of these species, *L. lignorum*, is native from Alaska to Humboldt Bay and therefore may represent a range extension rather than a true invasion. Maximum size for gribbles is approximately 4 mm (Kozloff 1983).

Potential Threats to Habitat Restoration.

European green crab. The European green crab *Carcinus maenas* 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 temperatures, the green crab prefers mesohaline to polyhaline salinities (10-30 ppt) and temperatures between 3 °C 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 where 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. They preferentially settle in mussel beds, eelgrass beds, or patches of filamentous algae (Moksnes 2002). Older juveniles actively migrate to mussel beds.

Juvenile crabs feed primarily on detritus then shift to algae, snails, bivalves, annelids, crustaceans, and other benthic organisms as they age (Pihl 1985, Ropes 1968). Predation on both natural and cultured bivalve populations has led to declines in softshell clams in New England (Glude 1955), *Nutricula* spp. in Central California (Grosholz et al. 2000), and the venerid clam *Katelysia scalarum* in Tasmania (Walton et al. 2002, Ross et al. 2004). It may also outcompete the Dungeness crab *Cancer magister* for food; however, 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 Grosholz and Ruiz (2002) and Ray (2005).

Asian or Amur River Corbula clam. The Asian or Amur River Corbula clam (*P. amurensis*), 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 bacterioplankton, phytoplankton, and copepod larvae (Cohen and Carlton 1995, Kimmerer et al. 1994, Werner and Hollibaugh 1993). Since its 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, Lee et al. 2003). It may 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.

Mediterranean blue mussel. *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 and may contribute to the clogging of water intake structures. The same may be true of the single-horn bryozoan *Schizoporella unicornis*, a fouling species introduced from Japan.

***Sphaeroma quoyanum*.** *Sphaeroma quoyanum* is a wooding-boring marine isopod (Figure 3), similar in size and shape to the common garden pillbug that may pose 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 in 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 the bank and 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). The closely related *S. walkeri* is also present in California; however, its ecological impact is uncertain (Fuller 2005).



Figure 3. *Sphaeroma quoyanum* and the damage it causes to salt marsh peat, Hamilton Army Air Force Base, California (photos by author)

Other species of concern. Species of concern associated with introduced Japanese oysters are the Japanese oyster drill, the Japanese false cerith, and the Asian date mussel (*Musculista senhousia*). As its name implies, the drill is an oyster predator and feeds on young oysters, in particular. It has been reported to preferentially feed on *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, then settle 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 dredged material is often 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 of concern associated with introduced Atlantic oysters (*C. virginica*) are the eastern mud snail, the Atlantic oyster drill, the ectoparasitic snail *Boonea bisuturalis*, and the Atlantic ribbed mussel. Eastern mud snail is presently distributed from San Francisco Bay to British Columbia (Cohen and Carlton 1995). Most abundant in salt marshes and tidal creeks (sloughs), the Eastern mud snail, like *Battilaria*, 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 settlement (Hunt et al. 1987, Dunn et al. 1999) and adult distributions (DeWitt and Levinton 1985, Kelaher et al. 2003) of benthic invertebrates. 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 Atlantic 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 longirostris 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).

Finally, there is the sabellid polychaete *Terebrasabella hetruncinata*. A South African species, it was introduced to a mariculture facility with a shipment of South African abalone (Culver and Kuris 1999, Kuris and Culver 1999). The polychaete spread to a nearby intertidal area where it infected populations of the Black turban shell (*Tegula funebris*). The pest is believed to have been successfully eradicated by screening outflow pipes to prevent further escapes, then removing all the Black turban shell from the immediate area (Culver and Kuris 2000). Although it was necessary to remove 1.6 million turban shells, monitoring indicated the control procedures were successful. This is one of only two known instances, worldwide, of a successful eradication of an introduced marine or estuarine animal (Ray 2005).

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APPENDIX A: NIS LISTINGS FOR CALIFORNIA¹

Species	Group	NISBase	State of CA 2002	SF	HU
<i>Ancistrocoma pelseneeri</i>	Protozoan		ST	SF	
<i>Boveria teredinidi</i>	Protozoan		ST	SF	
<i>Cothurnia limnoriae</i>	Protozoan		ST	SF	
<i>Lobocona prorates</i>	Protozoan		ST	SF	
<i>Mirifolliculina limnoriae</i>	Protozoan		ST	SF	
<i>Sphenophyra dosinia</i>	Protozoan		ST	SF	
<i>Trochammina hadai</i>	Protozoan		ST	SF	
<i>Blackfordia virginica</i>	Hydrozoan	NB	ST	SF	
<i>Bunodeopsis</i> sp. A.	Hydrozoan		ST		
<i>Cladonema uchidae</i>	Hydrozoan	NB	ST	SF	
<i>Clava multicornis</i>	Hydrozoan	NB	ST	SF	
<i>Corymorpha</i> sp.	Hydrozoan	NB		SF	
<i>Ectopleura</i> (<i>Tubularia</i>) <i>crocea</i>	Hydrozoan		ST	SF	
<i>Garveia franciscana</i>	Hydrozoan	NB	ST	SF	
<i>Gonothyraea clarki</i>	Hydrozoan	NB	ST	SF	
<i>Maeotias inexpectat</i>	Hydrozoan	NB	ST	SF	
<i>Moerisia</i> sp.	Hydrozoan	NB	ST		
<i>Obelia bidentata</i>	Hydrozoan	NB	ST		
<i>Obelia dichotoma</i>	Hydrozoan	NB	ST	SF	HU
<i>Obelia geniculata</i>	Hydrozoan		ST		
<i>Aurelia aurita</i>	Scyphozoon	NB	ST	SF	HU
<i>Phyllorhiza punctatus</i>	Scyphozoon	NB	ST		
<i>Cliona</i> sp.	Porifera	NB	ST	SF	HU
<i>Halichondria bowerbanki</i>	Porifera	NB	ST	SF	HU
<i>Halichondria panicea</i>	Porifera		ST		
<i>Haliclona loosanoffi</i>	Porifera	NB	ST	SF	
<i>Hymeniacion</i> sp.	Porifera	NB			
<i>Microciona prolifera</i>	Porifera	NB	ST	SF	HU
<i>Prosuberites</i> sp.	Porifera			SF	
<i>Diadumene cincta</i>	Anthozoan	NB	ST	SF	
<i>Diadumene franciscana</i>	Anthozoan	NB	ST	SF	
<i>Diadumene leucolena</i>	Anthozoan	NB	ST	SF	HU
<i>Diadumene (Haliplanella) lineata</i>	Anthozoan	NB	ST	SF	HU
<i>Nematostella vectensis</i>	Anthozoan		c		HU
<i>Amblyosyllis speciosa</i>	Polychaete		ST		
<i>Amphitrite edwardsi</i>	Polychaete		ST		
<i>Ancistrosyllis groenlandica</i>	Polychaete		ST		
<i>Anobothrus gracilis</i>	Polychaete		ST		HU
<i>Autolytus cornutus</i>	Polychaete		ST		

(Sheet 1 of 7)

¹ NB = NISBase, ST = State of California 2002, SF = San Francisco Bay (Cohen and Carlton (1995), HU = Humboldt Bay (Boyd et al. 2002), n = Listed as native in ST, c = Listed as cryptogenic in ST.

Species	Group	NISBase	State of CA 2002	SF	HU
<i>Boccardiella ligERICA</i>	Polychaete	NB	ST	SF	HU
<i>Dipolydora caulleryi</i>	Polychaete		ST		
<i>Dipolydora quadrilobata</i>	Polychaete		ST		
<i>Dodecaceria concharum</i>	Polychaete				HU
<i>Ficopomarus enigmaticus</i>	Polychaete	NB	ST	SF	HU
<i>Geminosyllis ohma</i>	Polychaete		ST		
<i>Heteromastus filiformis</i>	Polychaete	NB	ST	SF	HU
<i>Hobsonia florida</i>	Polychaete		ST		
<i>Hydroides dirampa</i>	Polychaete		ST		
<i>Lanassa neusta venusta</i>	Polychaete		ST		
<i>Laonice cirrata</i>	Polychaete		ST		
<i>Lycastopsis pontica</i>	Polychaete		ST		
<i>Manayunkia speciosa</i>	Polychaete	NB	ST	SF	
<i>Maranzellaria viridis</i>	Polychaete	NB	ST	SF	
<i>Marphysa sanguinea</i>	Polychaete	NB	c	SF	HU
<i>Melinna oculata</i>	Polychaete		ST		
<i>Myrianida pachycera</i>	Polychaete		ST		
<i>Myxicola infundibulum</i>	Polychaete		ST		HU
<i>Neanthes acuminata</i>	Polychaete		ST		
<i>Neodexiospira pseudocorrugata</i>	Polychaete		ST		
<i>Nicolea gracilibranchis</i>	Polychaete		ST		
<i>Nereis pelagica</i>	Polychaete		c		HU
<i>Nereis (Neanthes) succinea</i>	Polychaete	NB	c	SF	
<i>Pionosyllis typica</i>	Polychaete		ST		
<i>Polydora ligni</i>	Polychaete		ST	SF	
<i>Polydora limnicola</i>	Polychaete		ST		HU
<i>Polydora websteri</i>	Polychaete		ST		
<i>Potamothrix bavaricus</i>	Polychaete		ST		
<i>Potamilla sp.</i>	Polychaete			SF	
<i>Pseudopolydora kempfi</i>	Polychaete		ST	SF	HU
<i>Pseudopolydora paucibranchiata</i>	Polychaete		ST	SF	HU
<i>Sabaco elongatus</i>	Polychaete		ST	SF	
<i>Sabellaria gracilis</i>	Polychaete		n		HU
<i>Sabellaria spinulosa</i>	Polychaete		ST		
<i>Scolelepis squamata</i>	Polychaete		ST		
<i>Serpula gracilis</i>	Polychaete				HU
<i>Serpula vermicularis</i>	Polychaete		ST		
<i>Spiochaetopterus costarum</i>	Polychaete		ST		
<i>Spiophanes bombyx</i>	Polychaete		c		HU
<i>Streblospio benedicti</i>	Polychaete		ST	SF	HU
<i>Terebrasabella heterouncinata</i>	Polychaete		ST		
<i>Typosyllis nipponica</i>	Polychaete		ST		
<i>Paranais frici</i>	Oligochaete	NB	c		
<i>Pelosclex gabriellae</i>	Oligochaete			SF	

Species	Group	NISBase	State of CA 2002	SF	HU
<i>Tubificoides apectinatus</i>	Oligochaete		ST	SF	
<i>Tubificoides brownae</i>	Oligochaete		ST	SF	
<i>Tubificoides wasselli</i>	Oligochaete		ST	SF	
<i>Arca transversa</i>	Bivalve	NB	ST		
<i>Arctica islandica</i>	Bivalve		ST		
<i>Crassostrea gigas</i>	Bivalve	NB	ST		HU
<i>Crassostrea virginica</i>	Bivalve	NB	ST		
<i>Gemma gemma</i>	Bivalve	NB	ST	SF	HU
<i>Geukensia demissa</i>	Bivalve	NB	ST	SF	
<i>Laternula marilina</i>	Bivalve		ST		HU
<i>Lyrodus pedicellatus</i>	Bivalve	NB	ST	SF	
<i>Macoma balthica</i>	Bivalve	NB	ST		HU
<i>Macoma petalum</i>	Bivalve	NB	ST	SF	
<i>Mercenaria mercenaria</i>	Bivalve	NB	ST		
<i>Meretrix lusoria</i>	Bivalve	NB			
<i>Musculista senhousia</i>	Bivalve	NB	ST	SF	
<i>Mya arenaria</i>	Bivalve	NB	ST	SF	HU
<i>Mytilus galloprovincialis</i>	Bivalve	NB	ST	SF	
<i>Ostrea edulis</i>	Bivalve	NB	ST		
<i>Ostrea lurida</i>	Bivalve		ST		
<i>Ostrea sinuata</i>	Bivalve	NB	ST		
<i>Petricola pholadiformis</i>	Bivalve	NB	ST	SF	
<i>Potamocorbula amurensis</i>	Bivalve		ST	SF	
<i>Sphenia fragilis</i>	Bivalve		ST		
<i>Teredo bartschi</i>	Bivalve		ST		
<i>Teredo navalis</i>	Bivalve		ST	SF	
<i>Theora fragilis</i>	Bivalve		ST	SF	
<i>Theora rubica</i>	Bivalve		ST		
<i>Venerupis philippinarum</i>	Bivalve		ST	SF	HU
<i>Alderia modesta</i>	Gastropod		ST		HU
<i>Dendronotus frondosus</i>	Gastropod				HU
<i>Astrarium triumphans</i>	Gastropod	NB			
<i>Batillaria attramentaria</i>	Gastropod	NB	ST		
<i>Boonea bisuturalis</i>	Gastropod	NB	ST	SF	
<i>Busycotypus canaliculatus</i>	Gastropod	NB	ST	SF	
<i>Ceratostoma inornatum</i>	Gastropod	NB	ST		
<i>Crepidula convexa</i>	Gastropod	NB	ST		
<i>Crepidula fornicata</i>	Gastropod	NB	ST		
<i>Crepidula glauca</i>	Gastropod	NB		SF	HU?
<i>Crepidula onyx</i>	Gastropod		ST		
<i>Crepidula plana</i>	Gastropod	NB	ST	SF	HU?
<i>Eubranchnus misakiensis</i>	Gastropod	NB	ST	SF	
<i>Haliotis rufescens</i>	Gastropod		ST		
<i>Littornia littorea</i>	Gastropod	NB	ST		

(Sheet 3 of 7)

Species	Group	NISBase	State of CA 2002	SF	HU
<i>Litorina saxatilis</i>	Gastropod		ST	SF	
<i>Melanoides tuberculatus</i>	Gastropod	NB	ST	SF	
<i>Myostella myoostis</i>	Gastropod	NB	ST		
<i>Nassarius obsoletus</i>	Gastropod	NB	ST	SF	
<i>Okenia plana</i>	Gastropod	NB	ST	SF	
<i>Philine auriformis</i>	Gastropod	NB	ST	SF	
<i>Pseudosuccinea columella</i>	Gastropod		ST		
<i>Urosalpinx cincerea</i>	Gastropod		ST	SF	HU
<i>Sakuraeolis enosimensis</i>	Gastropod		ST	SF	
<i>Tenellia aspersa</i>	Gastropod		ST	SF	
<i>Ovatella myosotis</i>	Gastropod		ST	SF	HU
<i>Catriona rickettsi</i>	Nudibranch	NB	ST	SF	
<i>Cuthona perca?</i>	Nudibranch	NB	ST	SF	
<i>Balanus improvisus</i>	Barnacle			SF	
<i>Balanus amphitrite</i>	Barnacle	NB	ST	SF	
<i>Balanus eburneus</i>	Barnacle		ST		
<i>Acartiella sinensis</i>	Copepod	NB	ST	SF	
<i>Argulus japonicus</i>	Copepod	NB			
<i>Coullana candensis</i>	Copepod		ST		
<i>Eurytemora affinis</i>	Copepod	NB	c		
<i>Limnoithona sinensis</i>	Copepod	NB	ST		
<i>Limnoithona tetraspina</i>	Copepod	NB	ST		
<i>Mtyicola orientalis</i>	Copepod	NB	ST	SF	HU
<i>Oithona davisae</i>	Copepod	NB	ST	SF	
<i>Oithona sinensis</i>	Copepod	NB	ST		
<i>Pseudodiaptomus forbesi</i>	Copepod		ST	SF	
<i>Pseudodiaptomus marinus</i>	Copepod		ST	SF	
<i>Tortanus</i> sp.	Copepod		ST	SF	
<i>Ampelisca abdita</i>	Amphipod	NB	ST	SF	
<i>Ampithoe longimana</i>	Amphipod	NB			
<i>Ampithoe valida</i>	Amphipod	NB		SF	HU
<i>Caprella mutica</i>	Amphipod	NB		SF	HU
<i>Caprella acanthogaster</i>	Amphipod		ST	SF	
<i>Caprella humboldtensis</i>	Amphipod			SF	
<i>Caprella natalensis</i>	Amphipod		ST		
<i>Caprella scaura</i>	Amphipod		ST		
<i>Caprella simia</i>	Amphipod		ST		
<i>Chaetocorophium lucsai</i>	Amphipod		ST		HU
<i>Chelura terebrans</i>	Amphipod	NB	ST	SF	HU
<i>Corophium acherusicum</i>	Amphipod	NB	ST	SF	HU
<i>Corophium aliense</i>	Amphipod	NB	ST	SF	
<i>Corophium heteroceratum</i>	Amphipod	NB	ST	SF	
<i>Corophium insidiosum</i>	Amphipod	NB	ST	SF	HU
<i>Corophium uenoi</i>	Amphipod	NB	ST		HU

Species	Group	NISBase	State of CA 2002	SF	HU
<i>Elasmopus rapax</i>	Amphipod		ST		
<i>Eochelidium miraculum</i>	Amphipod		ST		
<i>Erichthonius brasiliensis</i>	Amphipod		ST		
<i>Gammarus daideri</i>	Amphipod		ST	SF	
<i>Grandidierella japonica</i>	Amphipod	NB	ST	SF	HU
<i>Hyale plumulosa</i>	Amphipod		n		HU
<i>Incisocalliope nipponensis</i>	Amphipod		ST		HU
<i>Ischyrocerus anguipes</i>	Amphipod		ST		HU
<i>Jassa marmorata</i>	Amphipod	NB	ST	SF	
<i>Leucothoe</i> sp.	Amphipod	NB	ST	SF	
<i>Melita nitida</i>	Amphipod	NB	ST	SF	HU
<i>Melita</i> sp.	Amphipod	NB		SF	
<i>Microdeutopus gryllotalpa</i>	Amphipod		ST		HU
<i>Paracorophium</i> sp.	Amphipod				HU
<i>Paradexamine</i> sp.	Amphipod	NB	ST	SF	
<i>Parapleustes derzhavini</i>	Amphipod	NB	ST	SF	
<i>Podocerus cristatus</i>	Amphipod		ST		
<i>Pontogenia rostrata</i>	Amphipod		ST		
<i>Stenothoe valida</i>	Amphipod		ST		HU
<i>Transorchestia enigmata</i>	Amphipod		ST	SF	
<i>Nippoleucon hinumensis</i>	Cumacean	NB	ST	SF	
<i>Caecidotea racovitzae</i>	Isopod		ST		
<i>Dynoides dentisinus</i>	Isopod	NB	ST	SF	
<i>Eurylana aruata</i>	Isopod	NB	ST		
<i>Iais californica</i>	Isopod	NB	ST	SF	HU
<i>Ianiropsis serricaudis</i>	Isopod		ST		
<i>Ianiropsis tridens</i>	Isopod		ST		
<i>Limnoria lignorum</i>	Isopod		ST		HU
<i>Limnoria quadripunctata</i>	Isopod	NB	ST	SF	HU
<i>Limnoria tripunctata</i>	Isopod	NB	ST		
<i>Munnogonium wilsoni</i>	Isopod		ST		
<i>Paranthura</i> sp.	Isopod		ST	SF	
<i>Paranthura elegans</i>	Isopod		ST		
<i>Paranthura japonica</i>	Isopod		ST		
<i>Sphaeroma quoyanum</i>	Isopod	NB	ST	SF	HU
<i>Sphaeroma walkeri</i>	Isopod		ST		
<i>Synidotea laevidorsalis</i>	Isopod		ST	SF	
<i>Leptochelia savigni</i>	Tanaid				HU
<i>Sinelobus</i> sp.	Tanaid			SF	HU
<i>Acanthomysis aspera</i>	Mysid	NB	ST	SF	
<i>Acanthomysis bowmani</i>	Mysid	NB	ST	SF	
<i>Deltamysis holmquistae</i>	Mysid		ST	SF	
<i>Nebalia</i> sp.	Nebalian	NB		SF	
<i>Nebalia pugettensis</i>	Nebalian		ST		HU

(Sheet 5 of 7)

Species	Group	NISBase	State of CA 2002	SF	HU
<i>Eusariella zostericola</i>	Ostracod	NB	ST	SF	
<i>Carcinus maenas</i>	Crab	NB	ST	SF	HU
<i>Eriocher sinensis</i>	Crab	NB	ST	SF	
<i>Rithropanopeus harrisi</i>	Crab		ST	SF	
<i>Exopalaemon carincaudata</i>	Shrimp		ST		
<i>Palaemon macrodactylus</i>	Shrimp		ST	SF	
<i>Homarus americanus</i>	Lobster	NB	ST		
<i>Anisobatis maritima</i>	Insect		ST	SF	
<i>Trigonotylus uhleri</i>	Insect		ST	SF	
<i>Alcyonidium gelatinosum</i>	Bryozoan	NB	ST	SF	
<i>Alcyonidium polyoum</i>	Bryozoan		ST		HU
<i>Anguinella palmata</i>	Bryozoan	NB	ST	SF	
<i>Bowerbankia gracilis</i>	Bryozoan	NB	ST	SF	HU
<i>Bugula flabellata</i>	Bryozoan		ST		
<i>Bugula "neritina"</i>	Bryozoan		ST	SF	HU
<i>Bugula stolonifera</i>	Bryozoan	NB	ST	SF	
<i>Conopeum tenuissimum</i>	Bryozoan	NB	ST	SF	HU
<i>Cryotosula pallasiana</i>	Bryozoan	NB	ST	SF	HU
<i>Schizoporella unicornis</i>	Bryozoan		ST	SF	HU
<i>Victorella pavida</i>	Bryozoan		ST	SF	
<i>Watersipora arctuata</i>	Bryozoan		ST		
<i>Watersipora "subtorquata"</i>	Bryozoan		ST	SF	HU
<i>Zoobotryion verticillatum</i>	Bryozoan		ST	SF	
<i>Barentsia benedini</i>	Entoproct	NB	ST	SF	HU
<i>Urnatella gracilis</i>	Entoproct		ST		
<i>Ascidia</i> sp.	Tunicate		ST	SF	
<i>Botrylloides perspicuum</i>	Tunicate		ST		
<i>Botrylloides schosseri</i>	Tunicate	NB	ST	SF	HU
<i>Botryllus aurantius</i>	Tunicate		ST		
<i>Botryllus firmus</i>	Tunicate		ST		
<i>Botryllus</i> sp.	Tunicate				HU
<i>Botryllus tuberatus</i>	Tunicate		c		HU
<i>Ciona intestinalis</i>	Tunicate	NB	ST	SF	HU
<i>Ciona savignyi</i>	Tunicate	NB	ST	SF	
<i>Didemnum cf. lahillei</i>	Tunicate	NB	ST		
<i>Diplosoma listerianum</i>	Tunicate		ST		
<i>Mogula manhattensis</i>	Tunicate	NB	ST	SF	HU
<i>Styella canopus</i>	Tunicate		ST		
<i>Styella clavata</i>	Tunicate		ST	SF	HU
<i>Styella plicata</i>	Tunicate		ST		
<i>Acanthogobius flavimanus</i>	Fish		ST	SF	
<i>Alosa sapidissima</i>	Fish	NB	ST	SF	
<i>Anguilla anguilla</i>	Fish	NB	ST		
<i>Anguilla australis</i>	Fish	NB	ST		

Species	Group	NISBase	State of CA 2002	SF	HU
<i>Anguilla rostrata</i>	Fish	NB	ST		
<i>Dorosoma petenense</i>	Fish	NB	ST	SF	
<i>Morone saxatilis</i>	Fish	NB	ST	SF	
<i>Oncorhynchus kisutch</i>	Fish	NB			
<i>Tautoga onitis</i>	Fish		ST		
<i>Tridentiger barbatus</i>	Fish		ST		
<i>Tridentiger bifasciatus</i>	Fish		ST		
<i>Tridentiger trigonocephalus</i>	Fish		ST	SF	
					<i>(Sheet 1 of 7)</i>