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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). Variously 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)

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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 (Erlich 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) phillippinarum*), 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 harrisii,* 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 *Mytilcola 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	SF[1]	HU[2]	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 sinesis*), European green crab (*Carcinus maenas*), Asian or Amur River Corbula clam (*Potamocorbula amurensis*), the isopod *Sphaeroma quoyanum* and the sabellid polychaete *Terebrasabella hetrouncintata*, 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.erdc.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. barstschi*. 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).

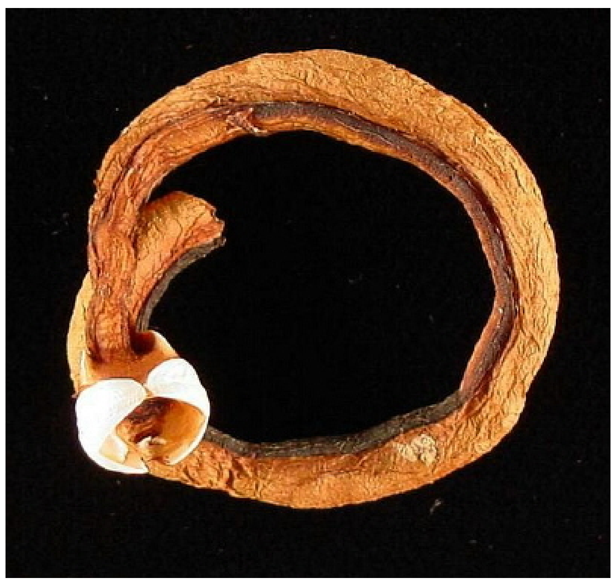

Figure 2. A shipworm - *Teredo sp.* (marine) (image courtesy of U.S. Geological Survey)

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. quadripuncatata*, 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 ^{o}C and 26 ^{o}C (Groshloz 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), *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). 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 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).

Finally, there is the sabellid polychaete *Terebrasabella hetrouncintata.* 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 funebralis*). 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 CALIFORNIA[1]

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

Species	Group	NISBAse	State of CA 2002	SF	HU
Boccardiella ligerica	Polychaete	NB	ST	SF	HU
Dipolydora caulleryi	Polychaete		ST		
Dipolydora quadrilobata	Polychaete		ST		
Dodecaceria concharum	Polychaete				HU
Ficopomarus enigmaticus	Polychaete	NB	ST	SF	HU
Geminosyllis ohma	Polychaete		ST		
Heteromastus filiformis	Polychaete	NB	ST	SF	HU
Hobsonia florida	Polychaete		ST		
Hydroides dirampa	Polychaete		ST		
Lanassa neusta venusta	Polychaete		ST		
Laonice cirrata	Polychaete		ST		
Lycastopsis pontica	Polychaete		ST		
Manayunkia speciosa	Polychaete	NB	ST	SF	
Maranzellaria viridis	Polychaete	NB	ST	SF	
Marphysa sanguinea	Polychaete	NB	c	SF	HU
Melinna oculata	Polychaete		ST		
Myrianida pachycera	Polychaete		ST		
Myxicola infundibulum	Polychaete		ST		HU
Neanthes acuminata	Polychaete		ST		
Neodexiospira pseudocorrugata	Polychaete		ST		
Nicolea gracilibranchis	Polychaete		ST		
Nereis pelagica	Polychaete		c		HU
Nereis (Neanthes) succinea	Polychaete	NB	c	SF	
Pionosyllis typica	Polychaete		ST		
Polydora ligni	Polychaete		ST	SF	
Polydora limnicola	Polychaete		ST		HU
Polydora websteri	Polychaete		ST		
Potamothrix bavaricus	Polychaete		ST		
Potamilla sp.	Polychaete			SF	
Pseudopolydora kempi	Polychaete		ST	SF	HU
Pseudopolydora paucibranchiata	Polychaete		ST	SF	HU
Sabaco elongatus	Polychaete		ST	SF	
Sabellaria gracilis	Polychaete		n		HU
Sabellaria spinulosa	Polychaete		ST		
Scolelepis squamata	Polychaete		ST		
Serpula gracilis	Polychaete				HU
Serpula vermicularis	Polychaete		ST		
Spiochaetopterus costarum	Polychaete		ST		
Spiophanes bombyx	Polychaete		c		HU
Streblospio benedicti	Polychaete		ST	SF	HU
Terebrasabella heterouncinata	Polychaete		ST		
Typosyllis nipponica	Polychaete		ST		
Paranais frici	Oligochaete	NB	c		
Peloscolex gabriellae	Oligochaete			SF	
					(Sheet 2 of 7)

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

(Sheet 3 of 7)

Species	Group	NISBAse	State of CA 2002	SF	HU
Litorina saxatilis	Gastropod		ST	SF	
Melanoides tubercuatus	Gastropod	NB	ST	SF	
Myostella myoostis	Gastropod	NB	ST		
Nassarius obsoletus	Gastropod	NB	ST	SF	
Okenia plana	Gastropod	NB	ST	SF	
Philine auriformis	Gastropod	NB	ST	SF	
Pseudosuccinea columella	Gastropod		ST		
Urosalpinx cincerea	Gastropod		ST	SF	HU
Sakuraeolis enosimensis	Gastropod		ST	SF	
Tenellia aspersa	Gastropod		ST	SF	
Ovatella myosotis	Gastropod		ST	SF	HU
Catriona rickettsi	Nudibranch	NB	ST	SF	
Cuthona perca?	Nudibranch	NB	ST	SF	
Balanus improvisus	Barnacle			SF	
Balanus amphitrite	Barnacle	NB	ST	SF	
Balanus eburneus	Barnacle		ST		
Acartiella sinensis	Copepod	NB	ST	SF	
Argulus japonicus	Copepod	NB			
Coullana candensis	Copepod		ST		
Eurytemora affinis	Copepod	NB	c		
Limnoithona sinensis	Copepod	NB	ST		
Limnoithona tetraspina	Copepod	NB	ST		
Mtyicola orientalis	Copepod	NB	ST	SF	HU
Oithona davisae	Copepod	NB	ST	SF	
Oithona sinensis	Copepod	NB	ST		
Pseudodiaptomus forbesi	Copepod		ST	SF	
Pseudodiaptomus marinus	Copepod		ST	SF	
Tortanus sp.	Copepod		ST	SF	
Ampelisca abdita	Amphipod	NB	ST	SF	
Ampithoe longimana	Amphipod	NB			
Ampithoe valida	Amphipod	NB		SF	HU
Caprella mutica	Amphipod	NB		SF	HU
Caprella acanthogaster	Amphipod		ST	SF	
Caprella humboldiensis	Amphipod			SF	
Caprella natalensis	Amphipod		ST		
Caprella scaura	Amphipod		ST		
Caprella simia	Amphipod		ST		
Chaetocorophium lucsai	Amphipod		ST		HU
Chelura terebrans	Amphipod	NB	ST	SF	HU
Corophium acherusicum	Amphipod	NB	ST	SF	HU
Corophium aliense	Amphipod	NB	ST	SF	
Corophium heteroceratum	Amphipod	NB	ST	SF	
Corophium insidiosum	Amphipod	NB	ST	SF	HU
Corophium uenoi	Amphipod	NB	ST		HU
					(Sheet 4 of 7)

Species	**Group**	**NISBAse**	**State of CA 2002**	**SF**	**HU**
Elasmopus rapax	Amphipod		ST		
Eochelidium miraculum	Amphipod		ST		
Ericthonius brasiliensis	Amphipod		ST		
Gamarus daideri	Amphipod		ST	SF	
Grandidierella japonica	Amphipod	NB	ST	SF	HU
Hyale plumulosa	Amphipod		n		HU
Incisocalliope nipponensis	Amphipod		ST		HU
Ischyrocerus anguipes	Amphipod		ST		HU
Jassa marmorata	Amphipod	NB	ST	SF	
Leucothoe sp.	Amphipod	NB	ST	SF	
Melita nitida	Amphipod	NB	ST	SF	HU
Melita sp.	Amphipod	NB		SF	
Microdeutopus gryllotalpa	Amphipod		ST		HU
Paracorophium sp.	Amphipod				HU
Paradexamine sp.	Amphipod	NB	ST	SF	
Parapleustes derzhavini	Amphipod	NB	ST	SF	
Podocerus cristatus	Amphipod		ST		
Pontogenia rostrata	Amphipod		ST		
Stenothoe valida	Amphipod		ST		HU
Transorchestia enigmata	Amphipod		ST	SF	
Nippoleucon hinumensis	Cumacean	NB	ST	SF	
Caecidotea racovitizae	Isopod		ST		
Dynoides dentisinus	Isopod	NB	ST	SF	
Eurylana aruata	Isopod	NB	ST		
Iais californica	Isopod	NB	ST	SF	HU
Ianiropsis serricaudis	Isopod		ST		
Ianiropsis tridens	Isopod		ST		
Limnoria lignorum	Isopod		ST		HU
Limnoria quadripunctata	Isopod	NB	ST	SF	HU
Limnoria tripunctata	Isopod	NB	ST		
Munnogonium wilsoni	Isopod		ST		
Paranthura sp.	Isopod		ST	SF	
Paranthura elegans	Isopod		ST		
Paranthura japonica	Isopod		ST		
Sphaeroma quoyanum	Isopod	NB	ST	SF	HU
Sphaeroma walkeri	Isopod		ST		
Synidotea laevidorsalis	Isopod		ST	SF	
Leptochelia savigni	Tanaid				HU
Sinelobus sp.	Tanaid			SF	HU
Acanthomysis aspera	Mysid	NB	ST	SF	
Acanthomysis bowmani	Mysid	NB	ST	SF	
Deltamysis holmquistae	Mysid		ST	SF	
Nebalia sp.	Nebalian	NB		SF	
Nebalia pugettensis	Nebalian		ST		HU
					(Sheet 5 of 7)

Species	**Group**	**NISBAse**	**State of CA 2002**	**SF**	**HU**
Eusariella zostericola	Ostracod	NB	ST	SF	
Carcinus maenas	Crab	NB	ST	SF	HU
Eriocheir sinensis	Crab	NB	ST	SF	
Rithropanopeus harrisii	Crab		ST	SF	
Exopalaemon carincaudata	Shrimp		ST		
Palaemon macrodactylus	Shrimp		ST	SF	
Homarus americanus	Lobster	NB	ST		
Anisolabis maritima	Insect		ST	SF	
Trigonotylus uhleri	Insect		ST	SF	
Alcyonidium gelatinosum	Bryozoan	NB	ST	SF	
Alcyonidium polyoum	Bryozoan		ST		HU
Anguinella palmata	Bryozoan	NB	ST	SF	
Bowerbankia gracilis	Bryozoan	NB	ST	SF	HU
Bugula flabellata	Bryozoan		ST		
Bugula "neritina"	Bryozoan		ST	SF	HU
Bugula stolonifera	Bryozoan	NB	ST	SF	
Conopeum tenuissimum	Bryozoan	NB	ST	SF	HU
Cryotosula pallasiana	Bryozoan	NB	ST	SF	HU
Schizoporella unicornis	Bryozoan		ST	SF	HU
Victorella pavida	Bryozoan		ST	SF	
Watersipora arctuata	Bryozoan		ST		
Watersipora "subtorquata"	Bryozoan		ST	SF	HU
Zoobotyrion verticillatum	Bryozoan		ST	SF	
Barentsia benedini	Entoproct	NB	ST	SF	HU
Urnatella gracilis	Entoproct		ST		
Ascidia sp.	Tunicate		ST	SF	
Botrylloides perspicuum	Tunicate		ST		
Botrylloides schosseri	Tunicate	NB	ST	SF	HU
Botryllus aurantius	Tunicate		ST		
Botryllus firmus	Tunicate		ST		
Botryllus sp.	Tunicate				HU
Botryllus tuberatus	Tunicate		c		HU
Ciona intestinalis	Tunicate	NB	ST	SF	HU
Ciona savignyi	Tunicate	NB	ST	SF	
Didemnum cf. lahillei	Tunicate	NB	ST		
Diplosoma listerianum	Tunicate		ST		
Mogula manhattensis	Tunicate	NB	ST	SF	HU
Styella canopus	Tunicate		ST		
Styella clavata	Tunicate		ST	SF	HU
Styella plicata	Tunicate		ST		
Acanthogobius flavimanus	Fish		ST	SF	
Alosa sapidissima	Fish	NB	ST	SF	
Anguilla anguilla	Fish	NB	ST		
Anguilla australis	Fish	NB	ST		
					(Sheet 6 of 7)

Species	**Group**	**NISBAse**	**State of CA 2002**	**SF**	**HU**
Anguilla rostrata	Fish	NB	ST		
Dorosoma petenense	Fish	NB	ST	SF	
Morone saxatilis	Fish	NB	ST	SF	
Oncorhtynchus kisutch	Fish	NB			
Tautoga onitis	Fish		ST		
Tridentiger barbatus	Fish		ST		
Tridentiger bifasciatus	Fish		ST		
Tridentiger trigonocephalus	Fish		ST	SF	
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