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Invasive Marine and Estuarine Animals of Hawai'i and other Pacific Islands

by Gary L. Ray

PURPOSE: Nonnative 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, 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 can 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 known invasive estuarine and marine animals in the major geographic regions of the United States. Invasive animals of Hawai'i and other Pacific islands are described and examples of species posing 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 a nonindigenous species, the black-striped mussel *Mytilopsis sallei* (image courtesy of CRIMP, CSIRO Marine Research)

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 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 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 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 historically 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 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 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 into Atlantic waters when a private aquarium was demolished in the Miami area in 1992 during Hurricane Andrew (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. 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., landlocked freshwater reservoirs) in much of the United States.

METHODS: Lists of invasive species in Hawai'i and other Pacific Islands 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/*), Australia's National Introduced Pest Species Information System (*http://www.marine.csiro.au/crimp/nimpis/*), and the Introduced Marine Species of Hawai'i 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).

Table 1
State NIS Listings and Other Reports Utilized in This Report

Coles et al. 1997, 1999, 2001, 2002a, 2002b, 2004a, 2004b
Eldredge and Smith 2001
Godwin et al. 2004
Randall (1987)
State of Hawai'i (2003)

Of particular note among these sources are the technical reports of the Bishop Museum (Coles et al. 1997, 1999, 2001, 2002a, 2002b, 2004a, 2004b; Godwin et al. 2004). The museum has also produced a well-illustrated guidebook to invertebrate NIS (Eldredge and Smith 2001). Copies of all of these reports can be downloaded from the Bishop Museum website (*http://hbs.bishopmuseum.org/hbspubs.html*).

RESULTS: NIS listings for Hawai'i include a total of 293 species (Table 2). The island of Guam shares 34 of these species (Paulay et al. 2002, Smith 1987) and Johnson Atoll shares 5 species (Coles et al. 2001). The largest numbers of species were found among molluscs (72 species), crustaceans (70 species), and fish (38 species). Many of the fish, in particular, represent deliberate introductions. Randall (1987) reviewed the history of these introductions to Hawai'i and concluded that most of the efforts to introduce marine species were unsuccessful. Only the blacktail snapper *Lutjanus fulvus* appears to have established self-sustaining populations.

Table 2
Summary NIS Results for Hawai'i and Other Pacific Islands

Group	Hawai'i	Guam	Johnson Atoll
Protozoan	3		
Hydrozoan	13	5	1
Cubozoan	1		
Schyphozoa	4		
Anthozoa	6		
Ctenophora	1		
Porifera	12		
Platyhelminth	4		
Nematode	1		
Polychaete	23	1	
Bivalve	38	5	
Gastropod	32	3	
Nudibranch	2		
Barnacle	8	3	
Copepod	4		
Amphipod	18		
Isopod	10		
Tanaid	1		
Cumacea	2		
Mysid	1		
Pyncnogonid	2		
Crab	15		
Shrimp	7	3	
Stomatopod	2		
Bryozoan	18	1	1
Entoproct	1		
Tunicate	26	12	3
Fish	38	1	
Grand Total	293	34	5

DISCUSSION: Marine and estuarine animals generally considered to be invasive in the state of Hawai'i are the sponges *Mycale armata* and *Sigmadocia caerulea*, Christmas tree hydroid *Pennaria distica*, Snowflake coral *Carijoa riisei*, Caribbean barnacle *Cthamalus proteus*, the bryozoans *Amthia distans* and *Schizoporella errata,* the tunicate *Didemnum candida*, and the Philippine mantis shrimp *Gonodactylus falcatus* (Yamamoto et al. 2003). A number of invasive species not presently found in Hawai'i or other Pacific islands, but likely candidates for introduction, include Chinese mitten crab *Eriocheir sinensis,* European green crab *Carcinus maenas,* Mediterranean blue mussel *Mytilus galloprovincialis*, Asian green (or green-lipped) mussel *Perna viridis*, Asian date mussel *Musculista senhousia,* and black striped mussel *Mytilopsis sallei* (Yamamoto et al. 2003).

Potential Threats to Infrastructure: More than 30 percent of all NIS in Hawai'i and all but one (*G. falcatus*) of the priority NIS are fouling species. Most likely introduced on ships' hulls or in ballast water, they include 13 species of hydrozoans, 6 anemones, 8 barnacles, 3 bryozoans, 1 entoproct, 26 tunicates, 16 polychaetes, and several bivalves (Appendix A). Over 63 percent of NIS encountered at Guam and all NIS found at Johnson Island are fouling organisms. Because of their potential to clog coastal structures such as intake pipes, members of this group may interfere with USACE operations.

Wood-boring species. Wood-boring species such as shipworms, a form of bivalve mollusc, and small isopods commonly known as gribbles are also a potential threat to infrastructure. Shipworms do not actually feed on wood, but form extensive burrow systems in any submerged wooden structure (e.g., boats, marinas, docks, and pilings). Species known to be present in Hawai'i are the Blacktip shipworm, *Lyrodus pedicellatus,* and three species in the genus *Teredo* (*T. barstschi, T. clappi*, and *T. furcifera*). 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 construction materials (Highley 1999).

While creosote deters shipworm infestations, the same cannot be said of gribbles. 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 discovered that a seawall and its wooden supports along the Seattle waterfront are so damaged by gribbles that collapse of the structure is a real possibility. Replacement costs are estimated at $700 million (Roach 2004). The Mediterranean gribble *Limnoria tripunctata* is the only species now reported from Hawai'i.

Chinese mitten crab. Although not presently established in Hawai'i, the Chinese mitten crab *Eriocheir sinensis* has been shown to be a threat to infrastructure worldwide. 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 from Lake Erie, the Columbia River, Mississippi Sound, and San Francisco Bay. Mitten crabs are catadromous, spending most of their adult life in fresh water, then returning to the sea to reproduce (Veldhuizen and Stanish 2002). The adults can live up to 5 years and are omnivorous. Their planktonic larvae grow best in relatively high salinities (~25 ppt), while late stage or megalopal larvae prefer 15 to 25 ppt. Late-stage larvae settle out of the plankton in late spring and early summer as they metamorphose into early juvenile stages. They then begin to migrate towards the fresher portions of the estuary. They 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 and Liston 1999). There is also a potential threat to human health because this species harbors the parasitic Chinese lung fluke. Thus far no flukes have been detected in U.S. crab populations (National Oceanographic and Atmospheric Administration (NOAA), Sea Grant News, 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*), another invasive species, is believed to be similar. Further information on mitten crabs can be found in Veldhuizen and Stanish (2002), Ray (2005), and an ANSRP fact sheet (*http://el.erdc.usace.army.mil/ansrp/eriocheir_sinensis.htm*).

Asian green mussel. The Asian green or green-lipped mussel *Perna viridis* is another invasive species not currently present in Hawai'i, but considered to be a threat if it becomes established. A native of the tropical Indo-Pacific, it has spread to Florida and Jamaica (Buddo et al. 2003). Its planktonic larvae are capable of wide dispersal and settle on almost any hard surface. Its discovery in Tampa Bay was due to the fact it was clogging water intake pipes at local power plants (Fuller 2005). It fouls navigation buoys and ship hulls, interferes with shellfish culture, and displaces local fauna. This species also potentially harbors algal species that produce toxic shellfish poisoning (Buddo et al. 2003).

Black striped mussel. The black striped mussel, *Mytilopsis sallei* (Figure 1), a native of tropical Western Atlantic and Caribbean waters, is a close relative of the infamous zebra mussel (*Dreissena polymorpha*) and shares many of its invasive qualities. It has already invaded the Indian Ocean and Australia (Hewitt 2002). This species tolerates wide ranges of temperature and salinity, is fast growing, matures within a month of settlement, and produces large numbers of planktonic larvae. It is able to settle on nearly any hard substrate and can form beds up to 15 cm thick (New South Wales Fishnote 2003). Preferring sheltered habitats, it fouls hulls, pilings, and buoys and can settle in shellfish beds resulting in major damage to aquaculture facilities. Historically, this is one of only two examples where an established marine invader has been eradicated from an invaded site. In 1999, an invasion of *Mytilopsis* was detected at Darwin Harbor, Australia, in marinas closed off from the surrounding waters by gates. The marinas were quarantined and chemically treated with sodium hypochlorite and copper sulphate. Subsequent monitoring confirmed that the pest had been eradicated (Bax et al. 2002).

Potential Threats to Habitat Restoration:

Snowflake coral. The Snowflake coral *Carijoa riiseri* is a Caribbean species that first appeared in Hawai'i in 1972 (Eldredge and Smith 2001). This or a related species may also be present in Chuuk, Federated States of Micronesia (ibid). Coles et al. (2002b) describe it as the most prominent NIS at Waikiki, covering the inner surfaces of a shipwreck, and the principal fouling organism on pilings and other hard surfaces associated with a bridge at Kuapa Pond. *Carijoa* is also considered a pest species because it overgrows commercially valuable black coral (*Antipathes dichotoma* and *A. grandis*), threatening a $30-million jewelry industry (Grigg and Kelley 2002). Coles et al. (2004a) indicate that both *Carijoe* and the sponge *Mycale armata* are increasing in abundance on many coral reefs. *Mycale* has been reported to be overgrowing coral on some patch reefs (Eldredge and Smith 2001). In both cases, efforts to restore coral reef habitats may be hindered by the spread of these species. The Philippine mantis shrimp *Gonodactylus falcatus* is also of concern on many coral reefs where it has successfully displaced the native species *Pseudosquilla ciliata* (Kinzie 1984).

Caribbean barnacle. The Caribbean barnacle *Chthamalus proteus* is perhaps the most abundant of Hawai'ian NIS. Native to the Gulf of Mexico, Trinidad, and northeast Brazil, it was probably introduced to Hawai'i sometime in the 1970's (Southward et al. 1998). It reaches high densities in sheltered rocky intertidal areas or pilings. Another hard-bottom invader is the Mediterranean blue mussel *Mytilus galloprovincialis*. It is found worldwide in temperate seas and along with *Chthamalus* has the potential to interfere with restoration of rocky intertidal habitats by excluding native species.

Australian spotted jellyfish. An invasive pelagic species is the Australian spotted jellyfish *Phylloriza punctata* (Figure 2). The spotted jelly has an average adult bell width of 35 cm and can be found in swarms of up to 500,000 in a 150-km^2 area. Feeding intensively on zooplankton and fish larvae, they represent a threat to fisheries and fisheries restoration operations.

Figure 2. The Australian jellyfish, *Phylloriza punctata* (image courtesy of Dauphin Island Sea Lab)

Another invasive jellyfish is the upside down jelly *Cassiopea andromeda*, a shallow-water form common in lagoons and intertidal sand flats and mud flats. This species is not a threat to USACE operations, but is considered a nuisance because its nematocysts can deliver a painful sting resulting in welts or a rash (Eldredge and Smith 2001).

European green crab. The European green crab *Carcinus maenas* has not been found in Hawai'i, but may disrupt habitat restoration efforts if it becomes established. It 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 wide ranges of salinity and temperature, it 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. 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 the Pacific coast was invaded by 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 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 (*Mya arenaria*) 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 Ray (2005) and Grosholz and Ruiz (2002).

Asian date mussel. Another potential invader is the Asian date mussel *Musculista senhousia.* Native to intertidal and subtidal sediments from Siberia to the Red Sea, it is now found in Australia, New Zealand, the eastern Mediterranean, and southern France (Crooks 1996). Probably introduced into the United States in 1924 during the intentional 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. It 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 availability of phytoplankton within the bed (Allen and Williams 2003).

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POINTS OF CONTACT: For additional information contact Dr. Gary L. Ray (601-634-2589, Gary.Ray@erdc.usace.army.mil) or the Program Manager of the Aquatic Nuisance Species Research Program (ANSRP), Mr. Glenn Rhett (601-634-3717), Glenn.G.Rhett@erdc.usace.army.mil. This technical note should be cited as follows:

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APPENDIX A: NIS LISTINGS FOR HAWAI'I AND OTHER PACIFIC ISLANDS

Species	Group	State[1]	NISBase	Bishop[2]	Guam	Johnson
Cephaloidophora communis	Protozoan	ST				
Eufolliculina lignicola	Protozoan	ST				
Microfolliculina limnoriae	Protozoan	ST		B		
Clytia hemispherica	Hydrozoan	ST	HI	B	GU	
Bougainvilllia muscus	Hydrozoan	ST		B		
Dynamena cristiodes	Hydrozoan		HI	B		
Garveia humilis	Hydrozoan		HI			
Halecium beanie	Hydrozoan		HI			
Halocordyle disticha	Hydrozoan			B		
Obelia bidentata	Hydrozoan	ST	HI	B		
Obelia dichotoma	Hydrozoan	ST	HI	B	GU	
Pennaria (Halocordyle) distichia	Hydrozoan	ST	HI	B	GU	J
Sarsia tubulosa	Hydrozoan	ST				
Synthecium megathecum	Hydrozoan	ST		B		
Thyroscyphus fruticosus	Hydrozoan		HI		GU	
Turritopsis nutricola	Hydrozoan	ST	HI	B	GU	
Carybdea sivickisi	Cubozoan	ST				
Aurelia sp.	Schyphozoan	ST	HI	B		
Cassiopea andromeda	Schyphozoan	ST	HI	B		
Cassiopea medusa	Schyphozoan		HI	B		
Phyllorhiza punctata	Schyphozoan	ST	HI	B		
Actinodiscus nummiformis	Anthozoan	ST		B		
Anomalorhiza shawi	Anthozoan	ST		B		
Carijoa riisei	Anthozoan	ST	HI	B		
Diadumene franciscana	Anthozoan	ST	HI	B		
Diadumene leucolena	Anthozoan	ST	HI	B		
Diadumene lineate	Anthozoan	ST	HI	B		
Vallicula multifrons	Ctenophora	ST		B		
Dysidea cf. avara	Poriferan	c	HI	B		
Dysidea cf. ethereal	Poriferan			B		
Dysidea sp.	Poriferan	ST	HI	B		
Echinodictyum asperum	Poriferan	c	HI			
Gelliodes fibrosa	Poriferan	ST	HI	B		
Halichondria melanadocia	Poriferan	ST	HI	B		
Mycale (Aegogropila) armata	Poriferan	ST	HI	B		
Mycale (Camia) Cecilia	Poriferan	ST	HI	B		
Neofolitispa unguiculata	Poriferan		HI	B		
Sigmadocia caerulea	Poriferan	ST	HI	B		
Suberites zeteki	Poriferan	ST	HI	B		
Zygomycale parishii	Poriferan	ST	HI	B		
						(Sheet 1 of 7)

[1] State of Hawai'i (2003), c = Listed as cryptogenic, R = Randall (1987); references can be found at the end of the main text.
[2] Bishop Museum references.

Species	**Group**	**State[1]**	**NISBase**	**Bishop[2]**	**Guam**	**Johnson**
Camallanus cotti	Nematode	ST				
Ascocotyle tenuicollis	Platyheminth	ST				
Bothriocephalus acheilognathi	Platyheminth	ST				
Salsuginus seculus	Platyheminth	ST				
Taenioplana teredini	Platyheminth	ST		B		
Chaetopterus variopedatus	Polychaete		HI			
Circeis cf. armoricana	Polychaete			B		
Eulalia sanguinea	Polychaete	ST		B		
Ficopomarus enigmaticus	Polychaete	ST	HI	B		
Hydroides branchacantha	Polychaete	ST	HI	B		
Hydroides crucigera	Polychaete	ST	HI	B		
Hydroides dirampha	Polychaete	ST	HI	B		
Hydroides elegans	Polychaete	ST	HI	B		
Janua pagenstecheri	Polychaete	ST		B		
Nereis areanacoedentata	Polychaete	ST	HI	B		
Nereis succinea	Polychaete	ST				
Pileolaria militaris	Polychaete			B		
Polydora nuchalis	Polychaete	ST	HI			
Polydora websteri	Polychaete	ST	HI	B		
Pomatoceros cf. minutus	Polychaete			B		
Pomatoleios kraussi	Polychaete	ST	HI	B		
Sabellastarte sanctujosephi	Polychaete		HI			
Sabellastarte spectabilis	Polychaete	ST	HI	B		
Salmacina dysteri	Polychaete		HI	B	GU	
Salmicina tribranchiata	Polychaete			B		
Serpula vermicularis	Polychaete		HI	B		
Serpula watsoni	Polychaete			B		
Streblospio benedicti	Polychaete	ST	HI			
Abra sp.	Bivalve	ST	HI	B		
Anomia nobilis	Bivalve	ST	HI	B	GU	
Bankia bipalmulata	Bivalve	ST	HI			
Chama brassica	Bivalve		HI			
Chama elatensis	Bivalve	ST		B		
Chama fibula	Bivalve	ST	HI	B	GU	
Chama lazarus	Bivalve	ST	HI		GU	
Chama macerophylla	Bivalve		HI	B		
Chama pacifica	Bivalve	ST	HI	B		
Clinocardium nuttalli	Bivalve	ST				
Crassostrea amasa	Bivalve	ST	HI			
Crassostrea commercialis	Bivalve		HI			
Crassostrea gigas	Bivalve	ST	HI	B	GU	
Crassostrea virginica	Bivalve	ST	HI	B		
Crucibulum spinosum	Bivalve		HI	B		
Dendrostrea sandvichensis	Bivalve		HI			
						(Sheet 2 of 7)

Species	**Group**	**State[1]**	**NISBase**	**Bishop[2]**	**Guam**	**Johnson**
Hiatella arctica	Bivalve	ST	HI	B		
Lopha cristigalli	Bivalve		HI			
Lyrodus affinis	Bivalve	ST	HI	B		
Lyrodus pedicellatus	Bivalve	ST	HI	B		
Martesia striata	Bivalve	ST	HI	B		
Meretrix meretrix	Bivalve	ST		B		
Mya arenaria	Bivalve	ST				
Mytilus galloprovincialis	Bivalve	ST	HI	B		
Ostrea conchaphila	Bivalve	ST	HI			
Pinctada furcata martensi	Bivalve	ST	HI			
Saccostrea cucullata	Bivalve	ST		B		
Sphenia luticola	Bivalve	ST	HI			
Spehnia sp.	Bivalve		HI	B		
Teredo bartschi	Bivalve	ST	HI	B		
Teredo clappi	Bivalve	ST		B		
Teredo furcifera	Bivalve	ST	HI	B		
Tivela stultorum	Bivalve	ST				
Tridacna crocea	Bivalve	ST	HI			
Tridacna derasia	Bivalve	ST				
Tridacna gigas	Bivalve		HI			
Tridacna squamosa	Bivalve	ST	HI		GU	
Venerupis (=Tapes) philippanarum	Bivalve	ST	HI	B		
Amphithalamus inclusus	Gastropod	ST				
Boonea cincta	Gastropod	ST				
Bulla adamsi	Gastropod	ST		B		
Crepidula aculeate	Gastropod	ST	HI	B	GU	
Crucibulum spinosum	Gastropod	ST	HI	B	GU	
Chrysallida trachis	Gastropod	ST				
Cypraea clandestine	Gastropod		HI			
Cypraea cribaria	Gastropod		HI			
Cypraea cylindrical	Gastropod		HI			
Cypraea depressa	Gastropod		HI			
Cypraea gaspardi	Gastropod		HI			
Cypraea hirundo	Gastropod		HI			
Cypraea kuroharai	Gastropod	ST				
Cypraea poraria	Gastropod		HI			
Diodora ruppelli	Gastropod	ST	HI	B		
Eualetes tulipa	Gastropod	ST		B		
Evalea sp.	Gastropod	ST				
Fossaria viridis	Gastropod		HI			
Haliotis spp.	Gastropod	ST		B		
Helisoma sp.	Gastropod		HI			
Hinemoa indica	Gastropod	ST	HI	B		
Iolea eucosmia	Gastropod	ST				
						(Sheet 3 of 7)

Species	Group	State[1]	NISBase	Bishop[2]	Guam	Johnson
Ivadella navisa	Gastropod	ST				
Melanoides tuberculatus	Gastropod	ST	HI			
Pila conica?	Gastropod		HI			
Peristichia pedoroana	Gastropod	ST				
Planorbella duryi ?	Gastropod		HI			
Pseudosuccinna columella	Gastropod		HI			
Tarebia granifera	Gastropod	ST	HI			
Trochus niloticus	Gastropod	ST		B	GU	
Vermetus alii	Gastropod		HI	B		
Vitularia miliaris	Gastropod		HI			
Cuthona perca	Nudibranch	ST	HI	B		
Okenia pellucida	Nudibranch	ST		B		
Balanus amphitrite	Barnacle	ST	HI	B	GU	
Balanus eburneus	Barnacle	ST	HI	B	GU	
Balanus reticularis	Barnacle	ST	HI	B		
Balanus trigonus	Barnacle			B		
Balanus venustus	Barnacle			B		
Chthamalus proteus	Barnacle	ST	HI	B	GU	
Megabalanus californicus	Barnacle			B		
Megabalanus penisularis	Barnacle			B		
Argulus japonicus	Copepod		HI			
Psammopsyllus sp.	Copepod	ST				
Pseudodiaptomus marinus	Copepod	ST	HI			
Teridicola typical	Copepod	ST				
Caprella penantis	Amphipod	ST		B		
Caprella scaura	Amphipod	ST	HI	B		
Corophium acherusicum	Amphipod	ST	HI	B		
Corophium baconi	Amphipod	ST	HI	B		
Corophium insidiosum	Amphipod	ST	HI	B		
Elasmopus rapax	Amphipod	ST	HI	B		
Ericthonius brasiliensis	Amphipod	ST	HI	B		
Grandidierella bispinosa	Amphipod	ST	HI			
Grandidierella japonica	Amphipod	ST	HI	B		
Jassa falcate	Amphipod		HI	B		
Leucothoe micronesiae	Amphipod	ST	HI	B		
Orchestia platensis	Amphipod	ST		B		
Paracaprella pusilla	Amphipod	ST		B		
Paraleucothoe flindersi	Amphipod	ST	HI	B		
Parapleustes derzhavini	Amphipod	ST		B		
Podocerus brasiliensis	Amphipod	ST	HI	B		
Stenothoe gallensis	Amphipod	ST	HI	B		
Stenothoe valida	Amphipod	ST	HI	B		
Exosphaeroma sp. *A*	Isopod	ST	HI			
Gnorimosphaeroma rayi	Isopod	ST				
						(Sheet 4 of 7)

Species	Group	State[1]	NISBase	Bishop[2]	Guam	Johnson
Ligia exotica	Isopod	ST	HI			
Limnoria tripunctata	Isopod	ST	HI	B		
Mesanthura sp.	Isopod	ST		B		
Parapsudes pedispinus	Isopod	ST		B		
Paracereis sculpta	Isopod	ST	HI	B		
Paralimnoria andrewsi	Isopod	ST				
Sphaeroma quoyanum	Isopod	ST				
Sphaeroma walkeri	Isopod	ST	HI	B		
Parapseudes pedispinis	Tanaid	ST	HI	B		
Holmesimysis costata	Mysid	ST				
Nannastacus sp.	Cumacean	ST		B		
Schereocumella sp.	Cumacean	ST				
Anoplodactylus arescus	Pyncnogonid	ST	HI	B		
Pigrogromitus timsanus	Pyncnogonid	ST	HI	B		
Atergatopsis immigrans	Crab	ST	HI			
Callinectes sapidus	Crab	ST	HI	B		
Carcinus maenas	Crab	ST	HI			
Charybdis helleri	Crab	ST	HI			
Glabropilumnus seminudus	Crab	ST	HI	B		
Nanosesarme minuta	Crab	ST	HI	B		
Neopanope sp.	Crab	ST				
Pachygrapsus fakaravensis	Crab	ST	HI			
Panopeus lacustris	Crab	ST				
Panopeus pacificus	Crab	ST	HI	B		
Pilumnus oahuensis	Crab	ST		B		
Porcellio lamellatus lamellatus	Crab	ST				
Rithropanopeus harrisi	Crab		HI			
Schizophrys aspersa	Crab	ST	HI			
Scylla serrata	Crab	ST	HI	B		
Neocaridina denticulate	Shrimp		HI			
Peneaus japonicus	Shrimp		HI			
Peneaus monodon	Shrimp		HI		GU	
Penaeus stylirostris	Shrimp		HI		GU	
Penaeus vannamei	Shrimp		HI		GU	
Upogebia sp.	Shrimp	ST				
Gonodactylus aloha	Stomatopod		HI			
Gonodactylus falcatus	Stomatopod	ST	HI	B		
Caridina weberi	Shrimp		HI			
Aetea truncate	Bryozoan	ST	HI	B		
Amathia distans	Bryozoan	ST	HI	B	GU	
Bowerbankia gracilis	Bryozoan	ST		B		
Bowerbankia imbricate	Bryozoan	ST		B		
Bugula dentate	Bryozoan	ST	HI	B		
Bugula neritina	Bryozoan	ST	HI	B		
						(Sheet 5 of 7)

Species	Group	State[1]	NISBase	Bishop[2]	Guam	Johnson
Bugula robusta	Bryozoan	ST	HI	B		
Bugula stolonifera	Bryozoan	ST	HI	B		
Caulibugula caliculata	Bryozoan	ST	HI	B		
Caulibugula dendrograpta	Bryozoan	ST	HI	B		J
Cryptosula pallasiana	Bryozoan	ST				
Diaperoforma intricate	Bryozoan		HI			
Savignyella lafonti	Bryozoan	ST	HI	B		
Schizoporella errata	Bryozoan	ST	HI	B		
Schizoporella unicornis	Bryozoan	ST	HI	B		
Watersipora edmondsoni	Bryozoan	ST		B		
Watersipora subtorquata	Bryozoan	ST				
Zoobotyrion verticillatum	Bryozoan	ST		B		
Barentsia sp.	Entoproct	ST				
Ascidia sp. *A.*	Tunicate			B		
Ascidia sp. *B.*	Tunicate	ST	HI	B	GU	
Ascidia sydneiensis	Tunicate	ST	HI	B	GU	J
Botrylloides simodensis	Tunicate		HI	B		
Botryllus sp.	Tunicate		HI		GU	
Ciona intestinalis	Tunicate	ST	HI	B		
Cnemidocarpa Irene	Tunicate	ST		B		
Corella minuta	Tunicate	ST	HI	B		
Didemnum candidum	Tunicate	ST	HI	B		
Didemnum perfucidum	Tunicate	ST		B	GU	
Diplosoma listerianum	Tunicate	ST	HI	B	GU	J
Eusynstyela aliena	Tunicate	ST	HI	B		
Eusynstyela hartmeyeri	Tunicate			B		
Herdmania momus	Tunicate	ST	HI	B		
Herdmania pallida	Tunicate			B		
Lissoclinum fragilie	Tunicate				GU	
Microcosmus exasperatus	Tunicate	ST	HI	B	GU	J
Phallusia nigra	Tunicate	ST	HI	B	GU	
Polyandrocarpa sagamiensis	Tunicate	ST	HI	B	GU	
Polyandrocarpa zorritensis	Tunicate	ST	HI	B		
Polyclinum constellatum	Tunicate	ST	HI	B	GU	
Styela canopus	Tunicate	ST	HI	B	GU	
Styela clavata	Tunicate			B		
Styela plicata	Tunicate			B		
Symplegma brakenhielmi	Tunicate	ST	HI	B	GU	
Symplegma oceania	Tunicate		HI	B		
Symplegma reptans	Tunicate	ST	HI	B		
Anchoa compressa	Fish	R				
Anguilla marmorata	Fish		HI			
Centropyge flavissima	Fish	ST	HI	B		
Cephalopholis argus	Fish	ST	HI	B		
						(Sheet 6 of 7)

Species	Group	State[1]	NISBase	Bishop[2]	Guam	Johnson
Cephalopholis urodeta	Fish		HI			
Dorosoma petenense	Fish	ST	HI			
Epinephelus fasciatus	Fish		HI			
Epinephelus guttatus	Fish		HI			
Epinephelus hexagonatus	Fish		HI			
Epinephelus irroratus	Fish		HI			
Epinephelus merra	Fish		HI			
Epinephalus spiniger	Fish	R				
Fundulus grandis	Fish		HI			
Gambusia affinis	Fish	ST	HI		GU	
Herklotsichthys quadrimaculatus	Fish	ST	HI	B		
Lethrinus sp.	Fish	R				
Limia vittata	Fish	ST	HI			
Lutjanus fulvus	Fish	ST	HI	B		
Lutjanus gibbus	Fish	ST	HI	B		
Lutjanus guttatus	Fish	R	HI			
Lutjanus kasmira	Fish	ST	HI	B		
Monopterus albus	Fish		HI			
Moolgarda engeki	Fish	ST		B		
Morone saxatilis	Fish	R	HI			
Mugilgobius cavifrons	Fish	ST	HI	B		
Mugilgobius parvus	Fish		HI			
Omobranchus ferox	Fish	ST	HI			
Omobranchus rotundiceps	Fish	ST		B		
Oncorhynchus tshawytscha	Fish	R	HI			
Oreochromis mossambicus	Fish	ST		B		
Parablennius thysanius	Fish	ST	HI			
Poecilia latipinna	Fish	ST		B		
Poecilia mexicana	Fish	ST		B		
Poecilia vittata	Fish	R		B		
Plecoglossus altivelis	Fish		HI			
Sardinella marquesensis	Fish	ST	HI			
Upeneus vittatuus	Fish	ST	HI			
Valmugil engeli	Fish	R	HI			
						(Sheet 7 of 7)