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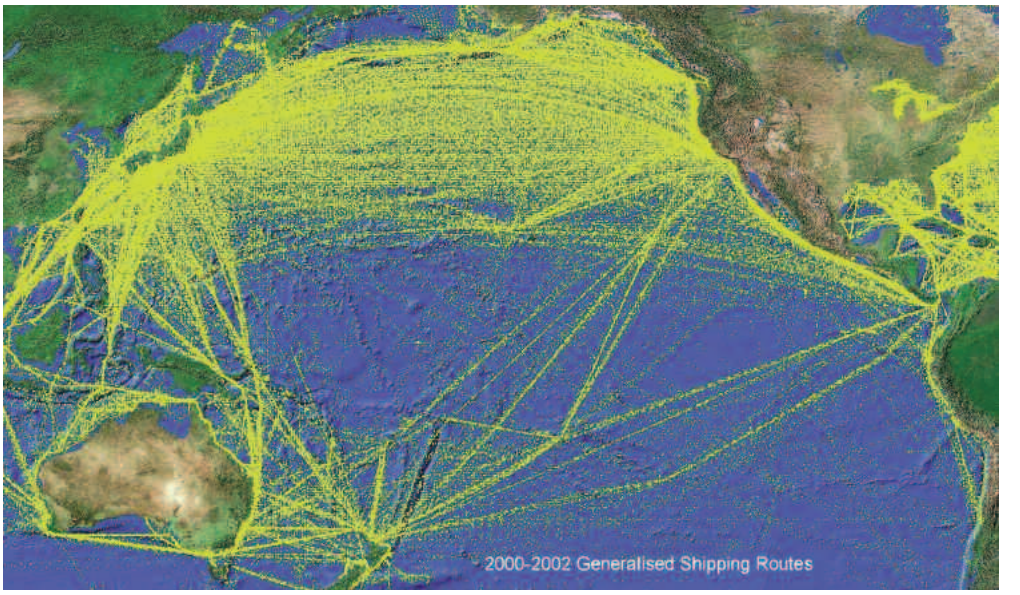
Marine Bioinvasions of Hawai‘i

The Introduced and Cryptogenic
Marine and Estuarine
Animals and Plants of the Hawaiian Archipelago

JAMES T. CARLTON AND LUCIUS G. ELDREDGE

Bishop Museum Bulletin in Cultural and Environmental Studies 4



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Cover: Map of the 2000–2002 Pacific shipping routes. It is 24 months of data from the voluntary WMO/NOAA weather reports generated automatically from vessels fitted with met stations; taken usually every 6 hours but sometimes less frequently. Data from fixed buoys, floating buoys, research vessels were extracted. The data show approximately 825,000 records for that 24-month period. [courtesy Maritime Safety and Environmental Strategy, Australian Maritime Safety Authority]

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INTRODUCTION

We present here the first comprehensive monograph of the introduced and cryptogenic marine and estuarine organisms of the Hawaiian Archipelago, from the island of Hawai‘i to Kure and Midway Atolls, between the latitudes of 19° N and 29° N. Covered here are protoctists, fungi, invertebrates, fish, algae, and flowering plants, inhabiting coastal environments influenced by the sea. The habitats we cover are thus the supralittoral zone (supporting “strand” or “maritime” species), the intertidal zone, and the sublittoral (subtidal), including non-native parasites, commensals, or other symbionts. We treat 490 species, of which 301 are introduced and 117 are cryptogenic (Table 1). These and other categories are defined below. The rest of the species (Table 2) are either of unknown establishment, species that escaped or were intentionally released but did not establish, species that were unintentionally introduced but failed to establish, intercepted species, species that represent doubtful or erroneous records, native species previously treated as introduced, waifs, or species that are of uncertain presence in marine waters. Brock (1952, 1960) reviewed introduced marine and freshwater species, covering 61 taxa in the latter paper. Eldredge (1994) reviewed the history of introductions of commercially significant species to the Pacific Islands, including Hawai‘i.

The marine and estuarine biota of the Hawaiian Islands are derived from a combination of non-human mediated and human-mediated dispersal processes. “Natural” processes include ocean currents transporting larval, juvenile, or adult stages (as plankton or by rafting), and migratory birds on long-established flyways (Zimmerman, 1948a; Newman, 1986; Jokiel, 1990; Mueller-Dombois & Fosberg, 1998). Human-mediated processes involve a long list of vectors (*sensu* Carlton & Ruiz, 2005), the major ones of which for the Archipelago include ships and intentional importations (and the hitchhikers associated with such transplantations) (Table 3).

Drifting organisms began colonizing the aboriginal islands soon after they were formed; this process has been on-going for tens of millions of years, leading to the evolution of many endemic marine, freshwater, and terrestrial organisms in the Archipelago. As the most isolated islands in the world, however, a great many species failed to naturally colonize, and thus assisted passage was required to bridge vast expanses of ocean.

We presume that Polynesian (Kirch, 2002) vessels of the 11th century (if not earlier human colonization waves) brought the first hull-fouling (if not bilge and solid ballast) organisms to Hawai‘i. We have not systematically attempted here to sift through the paleontological, archeological, or historical sedimentological record to identify Polynesian-mediated introductions of marine organisms. If and when such species are identified, we would still regard them as introduced species, as part of the human-influenced construction of the biota, as do our terrestrial colleagues who discern the translocation of distant plants by aboriginal settlers to the Hawaiian flora. Speculation about the role of Polynesians in introducing marine or brackish species has not been extensive; we note, however, that the freshwater and brackish water snails *Tarebia granifera* and *Melanoides tuberculata*, transportable in taro roots, are two of a number of candidate species (Cowie, 1998).

Captain James Cook’s arrival in 1778 marked the beginning of the modern era of vessel-mediated invasions in Hawai‘i (Beechert, 1991). By the early 1800s, global vessel traffic visiting the Islands had become common. Between 1820 and 1840 alone, more than 1,500 visits to the Port of Honolulu were made by whaleships (hailing from all over the world) and more than 400 visits were made by Trans-Pacific traders from around the Pacific Rim (Richards, 2000). Rapid interisland exchange was facilitated by over 1,100 interisland transits in the same period (Richards, 2000). By the 1900s many tens of thousands of vessel visits (for example, Worden, 1980; Beechert, 1991) with

thousands of species on and in their hulls, and in their solid and water ballast, from the world over, had come to the port and harbor systems of the islands that had evolved from the original coastal rivers and estuaries.

In a separate work (Carlton & Eldredge, in prep.) we analyze the temporal history of accidental and intentional introductions, the proportional role of vectors, biogeographic tracks, the systematic and taxonomy history, and the ecological and societal impacts of the introduced fauna and flora. Most species have arrived through international shipping (as fouling and in ballast), and most species hail from the Indo-West Pacific, Eastern Pacific, or North Atlantic. The absence of historical surveys in the Islands prevents the timely detection of virtually all early invasions: many species first collected in the first half of the 20th century were almost certainly introduced in the 1700s and 1800s. Thus by 1900, only nine ship-dispersed species had been collected in Hawai‘i, representing fouling, boring, and solid ballast introductions (Carlton & Eldredge, in prep.), a number that soberingly reflects the nearly complete lack of knowledge of what was living in Pearl Harbor, Honolulu Harbor, Kāne‘ohe Bay, or other archipelago estuaries, only a century ago.

Thus the history of marine invasions in Hawai‘i, perhaps more so than any other region in the world, is intimately tied to the history of interested and dedicated biologists, and their visits or residency in the Islands. Premier among these (Carlton & Eldredge, in prep.) was Charles Howard Edmondson, to whom we owe the early 20th century documentation of many presumably 19th century invaders (Eldredge, 2007).

METHODS

We became interested in the marine bioinvasions of the Hawaiian Islands in the 1970s, and after accumulating numerous incidental records, began a systematic study in the 1990s. We studied most of the published systematic and biogeographic literature on marine and brackish-water invertebrates, algae, flowering plants, and fish of the Hawaiian Islands, corresponded with many colleagues (see Acknowledgments), and examined museum collections (referenced at individual species), particularly the Bishop Museum (Honolulu) and the National Museum of Natural History (Washington, D.C.). Along with numerous colleagues over the years, we conducted field work in Pearl Harbor and Kāne‘ohe Bay (species and pertinent dates of collection are noted throughout the text). Commencing in 1996, Lu Eldredge, Steven Coles, Scott Godwin, Ralph DeFelice, and their associates (Bishop Museum), began a series of port, harbor, estuary, and reef studies through the entire Archipelago, revealing a plethora of invasions that had arrived over prior decades.

We assigned all species (Tables 1 and 2) with which we were concerned to one of the categories listed below. We assessed historical, systematic, biogeographic, and other criteria (see Chapman & Carlton, 1991, 1994) relative to the potential history of a given species, as detailed in many of the individual treatments. Many species that had never been previously considered relative to their biogeographic status in the Hawaiian Islands are newly treated in this monograph as introductions or cryptogens. In addition to the categories listed below, we relegated 19 species (Table 2) to doubtful or erroneous records, natural waifs, or uncertain presence in marine waters. These are shown in the “Other” category on Table 2, which also include several species that we concluded were native, although previously suggested as introduced.

INTRODUCED:

Species that have been transported by human agency, whether intentionally or accidentally, and are established in the wild. The following terms are included here: *nonindigenous, invasive, adventive, acclimatized, exotic, nonnative, immigrant, alien, foreign, naturalized, transplant, transfer*, and *import*.

Subcategories:

Establishment Unknown: continued presence and reproduction are unknown, and for which subsequent species-specific searches may not have been undertaken. Examples include the snails *Amphithalamus inclusus*, *Boonea cincta*, *Ividella navisa,* and *Peristichia pedroana*.

Failed: known to have reproduced or grown in the wild but then subsequently died out. Examples include the soft coral *Dendronephthya* sp., the snail *Bulla adamsi*, and the mussel *Mytilus galloprovincialis.*

Intercept: associated with fisheries products or fouled vessels brought to Hawai‘i, with the species concerned having subsequent access to open ocean waters. Examples include the polychaete *Boccardia proboscidea*, the crab *Charybdis helleri*, and the alga *Sargassum muticum*.

Deleted: one or a few individuals collected more than 50 years ago, and for which subsequent searches have not revealed the species. Examples include the isopod *Sphaeroma terebrans*, the mudshrimp *Upogebia pugettensis*, the crab *Carcinus maenas* and the sea spider *Anoplodactylus eroticus*.

Released; **Not Established**: intentional release but with no subsequent evidence of having established a naturally reproducing population in the wild. Examples include the snails *Haliotis* spp. and *Trochus niloticus*, the shrimp *Macrobrachium rosenbergii*, and numerous marine fish species.

Escaped; **Not Established**: species that escaped from culture operations, but with no subsequent evidence of having established a naturally reproducing population in the wild. Examples include penaeid shrimp, the alga *Mazzaella volans,* and the alga *Macrocystis pyrifera*.

CRYPTOGENIC:
Species that are not clearly native or introduced (Carlton, 1996a).

NATIVE:
Species present prior to human contact. ***endemic*** species are found only in Hawai‘i; ***indigenous*** species are native but not unique to the Islands.

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Table 1. Marine and estuarine introduced and cryptogenic species of the Hawaiian Islands

Species	Date	Vector*	Native to	Status**
FUNGI				
Cytospora rhizophorae	1902	R	Western Atlantic	I
Etheirophora blepharospora	1902	R	Western Atlantic	I
PROTOCTISTA				
Dinoflagellata: Dinophyceae				
Perkinsus marinus	1972	R	Atlantic Ocean	I
Ciliophora (ciliates)				
Zoothamnium sp./spp.	1935	SF, BW, R		C
Halofolliculina annulata	—	SF, R		C
Parafolliculina violaceae	—	SF, R		C
Metafolliculina nordgardi	—	SF, R		C
Metafolliculina andrewsi	—	SF, R		C
Lagotia viridis	—	SF, R		C
Ascobius simplex	—	SF, R		C
Eufolliculina lignicola	1961	SB	Unknown	I
Mirofolliculina limnoriae	1961	SB	Indo-Pacific	I
Cephaloidophora communis	1949	SF	Unknown	I
PORIFERA (sponges)				
Cliona sp./*Pione* sp.	1947	SF, R		C
Tethya ornata	1985	SF		C
Suberites aurantiacus	1902	SF	Unknown	I
Halichondria melanadocia	1960s [<1967]	SF	Western Atlantic	I
Halichondria coerulea	1960s [<1967]	SF	Unknown	I
Oceanapia/Halichondria sp.	1948	SF		C
Topsentia dura	1948	SF		C
Topsentia sp.	1996	SF		C
Callyspongia diffusa	1945	SF		C
Haliclona caerulea	1996	SF	Unknown	I
Chalinid species	1997	SF		C
Toxiclona sp.	1997	SF		C
Gelliodes fibrosa	1996	SF	Philippines	I
Biemna sp.	1996	SF		C
Clathria procera	1960s [<1967]	SF		C
Mycale cecilia	1947	SF	Caribbean	I
Mycale grandis	1996	SF	Indo-Pacific	I
Mycale parishii	1947	SF	Indo-Pacific	I
Monanchora sp.	1997	SF	Unknown	I
Tedania sp.	1960s [<1967]	SF		C
Tedania reticulata	1947	SF		C
Echinodictyum asperum	1997	SF		C
Dysidea sp.	1996	SF		C
Dysidea sp. cf. *D. avara*	1948	SF		C
Dysidea sp. cf. *D. arenaria*	1996	SF		C
Hyattella intestinalis	1996	SF		C
Heteropia glomerosa	1955	SF		C
CNIDARIA				
Hydrozoa (hydroids)				
Cordylophora caspia	1974	SF, BW	Ponto-Caspian	I
Turritopsis nutricula	1972	SF, BW	Atlantic?	I
Moerisia horii	1972	SF, BW		C
Garveia sp.	1972	SF, BW	Unknown	I

* see Table 3
** I = introduced; C = cryptogenic

Table 1. (continued)

Species	Date	Vector	Native to	Status
CNIDARIA				
Hydrozoa (hydroids)				
Bougainvillia muscus	1967	SF, BW	Atlantic	I
Eudendrium sp.	1972	SF, BW		C
Cladonema radiatum	1972	SF, BW	North Atlantic	I
Pennaria disticha	1928	SF, BW	Unknown	I
Halecium beani	1943	SF, BW		C
Ventromma halecioides	1999	SF, BW		C
Plumularia floridana	1999	SF, BW		C
Plumularia strictocarpa	1999	SF, BW		C
Plumularia setacea	1972 (1946?)	SF, BW		C
Antennella secundaria	1999	SF, BW		C
Halopteris diaphana	1970s	SF, BW		C
Halopteris polymorpha	1999	SF, BW		C
Lytocarpia phyteuma	2001	SF, BW		C
Anthohebella parasitica	1999	SF, BW		C
Obelia dichotoma	1972	SF, BW	Unknown	I
Obelia bidentata	1946	SF, BW	Unknown	I
Clytia latitheca	1999	SF, BW		C
Clytia hemisphaerica	1972	SF, BW		C
Thyroscyphus fruticosus	1973	SF, BW		C
Synthecium megathecum	1972	SF, BW		C
Dynamena crisioides	1972	SF, BW		C
Dynamena cornicina	1972	SF, BW		C
Dynamena quadridentata	2001	SF, BW		C
Sertularella areyi	1999	SF, BW		C
Sertularella tongensis	1999	SF, BW		C
Sertularella diaphana	1972	SF, BW		C
Tridentata loculosa	1972	SF, BW		C
Tridentata hupferi	1972	SF, BW		C
Tridentata turbinata	2001	SF, BW		C
Tridentata distans	2001	SF, BW		C
Tridentata marginata	2001	SF, BW		C
Anthozoa (corals and sea anemones)				
Culicia rachelfitzhardingeae	1983	SF	Indo-Pacific	I
Sarcothelia sp.	2000	SF, BW		C
Carijoa riisei	1972	SF, BW	Indo-Pacific	I
Diadumene leucolena	1950s	SF, BW, R	NW Atlantic	I
Diadumene lineata	1999	SF, BW, R	Japan	I
Diadumene franciscana	1998	SF, BW	Unknown	I
Scyphozoa (jellyfish)				
Aurelia sp.	1953	SF, BW	Indo-Pacific	I
Cassiopea andromeda	1950	SF, BW	Indo-Pacific	I
Phyllorhiza punctata	1933	SF, BW	Indo-Pacific	I
Anomalorhiza shawi	1983	SF, BW	Philippines	I
Cubozoa (cubomedusae)				
Carybdea sivickisi	1996	BW	Indo-Pacific	I
CTENOPHORA (comb jellyfish)				
Vallicula multiformis	1992	BW	Caribbean	I

Table 1. (continued)

Species	Date	Vector	Native to	Status
NEMATODA (roundworms)				
Camallanus cotti	1993	R	Asia	I
Spirocamallanus istiblenni	1962	R?		C
ROTIFERA (rotifers)				
Brachionus plicatilis	2001	R, BW		C
Colurella adriatica	2001	R, BW		C
Hexarthra oxyuris	<1941	R, BW		C
Lecane hastata	2001	R, BW		C
Proalides sp. cf. *P. wulferti*	2001	R, BW		C
PLATYHELMINTHES (flatworms)				
Turbellaria				
Convolutriloba sp.	1970s	BW		C
Taenioplana teredini	1938	SB	Unknown	I
Trematoda (flukes)				
Ascocotyle tenuicollis	1993	R	North America	I
Monogenea				
Salsuginus seculus	1970s	R	North America	I
Neobenedenia melleni	1981	R	North America	I
Cestoidea (tapeworms)				
Bothriocephalus acheilognathi	1993	R	Asia	I
ANNELIDA (true worms)				
Oligochaeta (oligochaetes)				
Bathydrilus adriaticus	1986	BW, SBA		C
Pectinodrilus rectisetosus	1987	BW, SBA		C
Pectinodrilus molestus	1986	BW, SBA		C
Thalassodrilides gurwitschi	1987	BW, SBA		C
Smithsonidrilus minusculus	1987	BW, SBA		C
Limnodriloides rubicundus	1987	BW, SBA		C
Tectidrilus bori	1986	BW, SBA		C
Polychaeta (polychaetes)				
Spinther japonicus	1976	SF, BW		C
Lumbrineris sphaerocephala	1987	SF, BW		C
Mesonerilla fagei	1997	BW, SBA		C
Ophryotrocha adherens	1973	SF, BW	Europe	I
Neanthes arenaceodentata	1950s	SF, BW	NW Atlantic	I
Neanthes succinea	1941	SF, BW, R	NW Atlantic	I
Myrianida pachycera	1959	SF, BW	Indo-West Pacific	I
Platynereis abnormis	1950s	SF, BW		C
Namalycastis abiuma	1995	BW, SBA		C
Namalycastis hawaiiensis	1900	BW, SBA		C
Namanereis amboinensis	1987	BW, SBA		C
Namanereis littoralis	1970s	BW, SBA		C
Eumida sanguinea	1966	SF, BW, R	Unknown	I
Capitella sp.	1975-1976	BW, SF		C
Polydora nuchalis	1988	R	Northeast Pacific	I
Polydora websteri	1940s	R	Northeast Atlantic	I
Streblospio benedicti	1977	SF, BW, R	NW Atlantic	I

Table 1. (continued)

Species	Date	Vector	Native to	Status
ANNELIDA (true worms)				
Polychaeta (polychaetes)				
Malacoceros sp.	1978	SF, BW		C
Minuspio sp.	1970s	BW		C
Armandia intermedia	1979	SF, BW		C
Chaetopterus sp.	1960	SF, BW	Unknown	I
Branchiomma japonica	1946	SF, BW	Japan	I
Sabellastarte spectabilis	1946	SF, BW	Philippines	I
Ficopomatus enigmaticus	1937	SF, BW	Australia	I
Hydroides brachyacanthus	1939	SF, BW	Eastern Pacific	I
Hydroides cruciger	1936	SF, BW	Eastern Pacific	I
Hydroides diramphus	1900	SF, BW	Western Atlantic?	I
Hydroides elegans	1929	SF, BW	Indo-Pacific?	I
Pomatoleios kraussii	1967	SF, BW	Indo-Pacific	I
Salmacina tribranchiata	1935	SF, BW	Eastern Pacific	I
Serpula watsoni	1936	SF, BW	Indo-West Pacific	I
Eulaeospira orientalis	1960s	SF, BW		C
Janua pagenstecheri	1960s	SF, BW	Northeast Atlantic	I
Leodora knightjonesi	1960s	SF, BW		C
Neodexiospira foraminosa	1960s	SF, BW		C
Neodexiospira nipponica	1960s	SF, BW		C
Neodexiospira pseudocorrugata	1960s	SF, BW		C
Pileolaria militaris	1960s	SF, BW	Northeast Atlantic?	I
Pileolaria pseudoclavus	1960s	SF, BW		C
Simplicaria pseudomilitaris	1960s	SF, BW		C
Spirorbis marioni	1960s	SF, BW		C
Vinearia koehleri	1960s	SF, BW		C
MOLLUSCA				
Gastropoda (snails)				
Diodora ruppelli	1962	SF, BW	Indo-Pacific	I
Tarebia granifera	1856	R	Indo-Pacific	I
Melanoides tuberculata	1994	R?	Asia-Africa	I
Pyrgophorus coronatus	1998	BW?	Caribbean	I
Vermetus alii	<1972	SF	Eastern Pacific	I
Hipponix australis	1850s	SF		C
Bostrycapulus calyptraeformis	1913	SF	Unknown	I
Crucibulum spinosum	1946	SF, BW	Northeast Pacific	I
Cypraea kuroharai	1971	SF, BW		C
Hinemoa indica	<1907	SF		C
Pyrgulina oodes	<1979	SF, BW		C
Cuthona perca	1972	SF, BW	NW Atlantic	I
Caloria indica	1968	SF, BW	Indo-Pacific	I
Okenia pellucida	1972	SF, BW	Indo-West Pacific	I
Phyllodesmium poindimieri	1995	SF, BW	Indo-West Pacific	I
Bivalvia (bivalves)				
Anomia nobilis	<1859	SF	Indo-Pacific	I
Crassostrea virginica	1895	R	Western Atlantic	I
Crassostrea gigas	1939	R	Japan	I
Saccostrea "cucullata"	1996	SF	Indo-Pacific	I
Chama fibula	<1915	SF	Indo-Pacific	I
Chama macerophylla	1996	SF	NW Atlantic, Caribbean	I
Chama lazarus	1996	SF	Indo-West Pacific	I

Table 1. (continued)

Species	Date	Vector	Native to	Status
MOLLUSCA				
Bivalvia (bivalves)				
Chama pacifica	1996	SF	Indo-West Pacific	I
Sphenia coreanica	1968	SF	Japan	I
Abra sp.	1996	SF, BW	Unknown	I
Venerupis philippinarum	1918	R	Japan	I
Lioconcha fastigiata	1985	BW	Northwest Pacific	I
Hiatella arctica	<1920	SF	Unknown	I
Martesia striata	1915	SF, SB	Southern Hemisphere	I
Bankia bipalmulata	1939	SB	Southern Hemisphere	I
Lyrodus affinis	1923	SB	Southern Hemisphere	I
Lyrodus pedicellatus	1902	SB	Southern Hemisphere	I
Teredo bartschi	1935	SB	Southern Hemisphere	I
Teredo clappi	1922	SB	Southern Hemisphere	I
Teredo fulleri	1935	SB	Southern Hemisphere	I
Teredo furcifera	<1921	SB	Southern Hemisphere	I
CRUSTACEA				
Copepoda (copepods)				
Pseudodiaptomus marinus	1964	BW	Japan	I
Psammopsyllus stri	1979	SBA	Panama (Caribbean)	I
Teredicola typica	1939	SF	Southern Hemisphere?	I
Haplostomides hawaiiensis	1995	SF		C
Amphipoda: Caprellidea (skeleton shrimp)				
Caprella scaura	1929	SF	Unknown	I
Caprella penantis	1921	SF	Unknown	I
Caprella equilibra	1944	SF	Unknown	I
Caprella danilevskii	1921	SF	Unknown	I
Paracaprella pusilla	1937	SF	Unknown	I
Amphipoda: Gammaridea (gammarids)				
Incisocalliope derzhavini	1967	SF, BW	Japan	I
Jassa falcata	1997	SF, BW	North Atlantic	I
Ruffojassa ventosa	1967	SF, BW		C
Ruffojassa angularis	1967	SF, BW		C
Photis hawaiensis	1936	SF, BW		C
Monocorophium acherusicum	1943	SF, BW	Northwest Atlantic	I
Monocorophium insidiosum	1959	SF, BW	Northwest Atlantic	I
Laticorophium baconi	1967	SF, BW	Northeast Pacific	I
Grandidierella bispinosa	1996	SF, BW	Indo-Pacific	I
Grandidierella japonica	1992	SF, BW	Japan	I
Paraleucothoe sp.	1996	SF, BW	Unknown	I
Leucothoe micronesiae	1997	SF, BW	Indo-Pacific	I
Ericthonius brasiliensis	1935	SF, BW	North Atlantic	I
Elasmopus "rapax"	1937	SF, BW	North Atlantic	I
Elasmopus pectenicrus	1937	SF, BW		C
Podocerus brasiliensis	1935	SF, BW	North Atlantic	I
Stenothoe gallensis	1935	SF, BW	Unknown	I
Stenothoe valida	<1924	SF, BW	North Atlantic	I
Tropichelura insulae	1922	SB	Indo-West Pacific	I
Platorchestia platensis	<1922	SBA		C

Table 1. (continued)

Species	Date	Vector	Native to	Status
CRUSTACEA				
Tanaidacea (tanaids)				
Parapseudes pedispinis	1996	SF, BW	Northeast Pacific	I
Apseudes sp.	1996	SF, BW	Japan?	I
Leptochelia "*dubia*"	1932	SF, BW		C
Isopoda (isopods)				
Gnorimosphaeroma rayi	1972	SF, BW	Japan	I
Sphaeroma walkeri	1943	SF, BW	Indian Ocean	I
Paradella dianae	2002	SF, BW	eastern Pacific	I
Pistorius bidens	2002	SF, BW	Australia	I
Paracerceis sculpta	1943	SF, BW	Northeast Pacific	I
Exosphaeroma sp.	1996	SF, BW	Unknown	I
Mesanthura sp.	1996	SF, BW	Unknown	I
Limnoria tripunctata	1922	SB	Southern Hemisphere?	I
Paralimnoria andrewsi	1922	SB	Indo-West Pacific	I
Caecijaera horvathi	1975	SB	Southern Hemisphere?	I
Littorophiloscia culebrae	1984	SBA	North Atlantic?	I
Halophiloscia couchii	1997	SBA	Northeast Atlantic	I
Armadilloniscus ellipticus	1985	SBA	Unknown	I
Alloniscus oahuensis	1879	SBA	Indo-Pacific	I
Porcellio lamellatus	1973	SBA	Northeast Atlantic	I
Buchnerillo sp.	1985	SBA	Atlantic Ocean?	I
Olibrinus truncatus	1985	SBA	Southern Hemisphere?	I
Ligia exotica	1996	SBA, SF	Unknown	I
Cumacea (cumaceans)				
Nannastacus sp.	1996	BW	Unknown	I
Scherocumella sp.	<1996	BW	Unknown	I
Mysidacea (opossum shrimp)				
Holmesimysis costata	1967	BW	Northeast Pacific	I
Cirripedia (barnacles)				
Ampibalanus amphitrite	1902	SF	Southern Hemisphere	I
Ampibalanus eburneus	1929	SF	Northwest Atlantic	I
Ampibalanus reticulatus	1929	SF	Southern Hemisphere	I
Chthamalus proteus	1993	SF	Western Atlantic	I
Decapoda (crabs)				
Macrobrachium lar	1956	R	Guam and Tahiti	I
Scylla serrata	1926	R	Samoa	I
Panopeus lacustris	1947	SF, BW	Western Atlantic	I
Acantholobulus pacificus	1929	SF, BW	E Tropical Pacific	I
Pilumnus oahuensis	1929	SF, BW	Unknown	I
Glabropilumnus seminudus	2003	SF, BW	Indo-Pacific	I
Nanosesarma minutum	1996	SF, BW	Japan, Indo-Pacific	I
Pachygrapsus fakaravensis	1996	SF, BW	Japan, Fr. Polynesia	I
Metopograpsus oceanicus	2006	SF, BW	Indo-Pacific	I
Hyastenus spinosus	<1965	SF, BW	Indo-West Pacific	I
Stomatopoda (mantis shrimps)				
Gonodactylaceus falcatus	1954	SF, BW	Indo-West Pacific	I

Table 1. (continued)

Species	Date	Vector	Native to	Status
INSECTA				
Odonata (damselflies and dragonflies)				
Enallagma civile	1936	R, O	Western North America	I
Ischnura ramburii	1973	R, O	North/South America	I
Crocothemis servilia	1994	R, O	Middle East, Asia, Australia	I
Tramea lacerata	1873	R, O	Eastern North America	I
Hemiptera (water bugs)				
Trichocorixa reticulata	1877	R, O	North America	I
Mesovelia amoena	1971	R, O	North/South America	I
Mesovelia mulsanti	1933	R, O	North/South America	I
Micracanthia humilis	1988	R, O	North America	I
Hymenoptera (wasps)				
Kleidotoma bryani	1923	R, O	Guam, Palmyra	I
Coleoptera (beetles)				
Enochrus sayi	1931	O	Western North Atlantic	I
Tropisternus salsamentus	1968	BW	California	I
Cercyon fimbriatus	2001	R, O	Eastern Pacific	I
Parathroscinus murphyi	1996	BW	Southeast Asia	I
Diptera (flies)				
Canaceoides angulatus	1922	R, O	Tropical E Pacific	I
Procanace williamsi	1944	R, O	Asia (Japan?)	I
Tethina willistoni	1919	R, O	North America	I
Atrichopogon jacobsoni	1958	R, O	Western Pacific	I
Atrichopogon sp.	1998	R, O	Unknown	I
Cricotopus bincinctus	1955	R, O	Unknown	I
Goeldichironomus holoprasinus	1969	R, O	North/South America	I
Dolichopus exsul	1930	R, O	W Indian (Caribbean)	I
Medetera grisescens	1914	R, O	Indo-Pacific	I
Syntormon flexible	1917	R, O	Indo-West Pacific	I
Psychoda salicornia	1945	R, O	California	I
Brachydeutera ibari	1980	R, O	Asia	I
Ceropsilopa coquilletti	1946	R, O	North America	I
Clasiopella uncinata	1946	R, O	Taiwan, Australasia	I
Discocerina mera	1948	R, O	Western/South Pacific	I
Donaceus nigronotatus	1958	R, O	Asia	I
Ephydra gracilis	1946	R, O	Eastern Pacific	I
Ephydra milbrae	1950	R, O	Eastern Pacific	I
Hecamede granifera	1923	R, O	Western/South Pacific	I
Mosillus tibialis	1944	R, O	North America	I
Paratissa pollinosa	1945	R, O	Caribbean, S America	I
Placopsidella marquesana	1951	R, O	Indo-Pacific	I
Psilopa girschneri	1952	R, O	Unknown	I
Scatella stagnalis	1967	R, O	Unknown	I
Hostis guamensis	1946	R, O	Australia	I
Collembola				
Oudemansia esakii	1939	R, O		C
Dermaptera (earwigs)				
Anisolabis maritima	1953	SBA		C

Table 1. (continued)

Species	Date	Vector	Native to	Status
INSECTA				
Coleoptera (beetles)				
Thinophilus hardyi	1996	R, O		C
Orthoptera (crickets)				
Thetella tarnis	<1994	SBA		C
PYCNOGONIDA (sea spiders)				
Ammothella pacifica	1930	SF, BW	Indo-Pacific	I
Tanystylum rehderi	2000	SF, BW	Indo-Pacific	I
Pigrogromitus timsanus	1930	SF, BW	Unknown	I
Endeis biseriata	1960	SF, BW	Indo-Pacific	I
Endeis nodosa	1924	SF, BW	Indo- West Pacific	I
Endeis procera	1996	SF, BW	Indo-West Pacific	I
Anoplodactylus arescus	1998	SF, BW	Indo-Pacific	I
Anoplodactylus "californicus"	1937	SF, BW	Unknown	I
Anoplodactylus digitatus	2000	SF, BW	Unknown	I
Anoplodactylus erectus	<1942	SF, BW	Eastern Pacific	I
Anoplodactylus marshallensis	2000	SF, BW	Marshall Islands	I
Anoplodactylus pycnosoma	2000	SF, BW	Indo-West Pacific	I
PHORONIDA (phoronids)				
Phoronis hippocrepia	1976	SF	North/South Atlantic	I
KAMPTOZOA (Entoprocta) (nodding heads)				
Barentsia sp.	1966	SF	Unknown	I
BRYOZOA (Ectoprocta) (bryozoans)				
Amathia distans	1935	SF	Unknown	I
Bowerbankia sp., cf. *gracilis*	1966	SF	Unknown	I
Bowerbankia sp., cf. *B. imbricata*	1966	SF	Unknown	I
Zoobotryon verticillatum	<1921	SF	Unknown	I
Aetea truncata	1935	SF	Unknown	I
Aetea anguina	1997	SF	Unknown	I
Bugula neritina	1921	SF	Unknown	I
Bugula stolonifera	1935	SF	Unknown	I
Bugula dentata	1997	SF	Unknown	I
Bugula minima	1996	SF	Unknown	I
Caulibugula dendrograpta	1997	SF	Indo-Pacific	I
Caulibugula caliculata	1997	SF	Indo-West Pacific	I
Synnotum aegyptiacum	1966	SF	Unknown	I
Caberea boryi	1966	SF	Unknown	I
Cryptosula pallasiana	1966	SF	North Atlantic	I
Savignyella lafontii	1935	SF	Unknown	I
Hippopodina tahitiensis	1948	SF	Indo-West Pacific	I
Schizoporella sp.	1935	SF	Unknown	I
Trypostega venusta	1966	SF	Unknown	I
Watersipora edmondsoni	1966	SF	Indo-Pacific	I
Watersipora arcuata	1998	SF	Eastern Pacific	I
Watersipora subtorquata	1966	SF	Caribbean	I
ECHINODERMATA				
Ophiuroidea (brittle stars)				
Ophiactis modesta	1902	SF		C
Ophiactis savignyi	1847-1849	SF	Indo-Pacific	I

Table 1. (continued)

Species	Date	Vector	Native to	Status
CHORDATA				
Urochordata: Ascidiacea (sea squirts)				
Didemnum candidum	1930	SF	Northeast Atlantic	I
Didemnum perlucidum	1999	SF	Unknown	I
Didemnum psammathodes	1998	SF	Indo-West Pacific	I
Diplosoma listerianum	1900	SF	Unknown	I
Lissoclinum fragile	1962	SF	Unknown	I
Ciona intestinalis	1933	SF	North Atlantic	I
Ecteinascidia imperfecta	1979	SF	Western Pacific	I
Corella minuta	<1997	SF	Unknown	I
Phallusia nigra	1930s	SF	Red Sea-Indian Ocean	I
Ascidia archaia	1940	SF	Indo-West Pacific	I
Ascidia sydneiensis	1930s	SF	southern hemisphere	I
Ascidia species A	<1997	SF	Unknown	I
Ascidia species B	<1997	SF	Unknown	I
Styela canopus	1940	SF	Western Pacific	I
Eusynstyela hartmeyeri	1998	SF	Red Sea-Indian Ocean	I
Cnemidocarpa irene	1940	SF	Indo-West Pacific	I
Botrylloides simodensis	1998	SF	Western/South Pacific	I
Botryllus sp. or spp.	1973	SF	Unknown	I
Botrylloides sp. or spp.	1973	SF	Unknown	I
Polyandrocarpa sagamiensis	<1997	SF	Western/South Pacific	I
Polyandrocarpa zooritensis	<1997	SF	Unknown	I
Polycarpa aurita	<1997	SF		C
Symplegma reptans	1996	SF	Japan	I
Symplegma brakenhielmi	1967	SF	Indo-Pacific	I
Symplegma sp.	1998	SF	Unknown	I
Polyclinum constellatum	1873	SF	Unknown	I
Microcosmus exasperatus	1940	SF	Unknown	I
Herdmania mauritiana	1985	SF	Indo-Pacific	I
Herdmania momus	1930s	SF	Indo-Pacific	I
Herdmania pallida	1990	SF	Indo-Pacific	I
PISCES (fish)				
Herklotsichthys quadrimaculatus	1972	R	W Pacific: Marshall Is	I
Sardinella marquesensis	1955	R	S Pacific: Marquesas	I
Valamugil engeli	1955	R	S Pacific: Marquesas	I
Poecilia latipinna	1905	R	Texas	I
Poecilia salvatoris/mexicana	>1960	R	North America	I
Limia vittata	1950	R	Cuba	I
Gambusia affinis	1905	R	Easstern North America	I
Cephalopholis argus	1956	R	S Pacific: Society Is	I
Lutjanus gibbus	1958	R	S Pacific: Marquesas/ Moorea	I
Lutjanus fulvus	1956	R	S Pacific: Society Is	I
Lutjanus kasmira	1958	R	S Pacific: Marquesas	I
Upeneus vittatus	1955	R	S Pacific: Marquesas	I
Oreochromis mossambicus	1951	R	Singapore	I
Sarotherodon melanotheron	1962	R	West Africa	I
Parablennius thysanius	1971	SF, BW	Indo-Pacific	I
Omobranchus ferox	1998	SF, BW	Philippines, S China Sea	I
Omobranchus rotundiceps obliquus	1951	R	Indo-Pacific (Samoa)	I

Table 1. (continued)

Species	Date	Vector	Native to	Status
RHODOPHYTA (red algae)				
Acanthophora spicifera	1952	SF, R	Indo-Pacific	I
Eucheuma denticulatum	1970	R	Philippines	I
Kappaphycus alvarezii	1974	R	Philippines	I
Kappaphycus striatum	1970	R	Phliippines,Pohnpei	I
Asparagopsis "taxiformis" - Lineage 4	1991	SF?	Indo-Pacific	I
Gracilaria salicornia	<1950	SF, BW, SBA?	Indo-Pacific	I
Gracilaria tikvahiae	1970s	R	Florida	I
Hypnea musciformis	1974	R	Florida	I
Avrainvillea amadelpha	1981	BW, AN	Indo-Pacific	I
CHLOROPHYTA (green algae)				
Ulva expansa	1900	SF	Unknown	I
Ulva clathrata	—	SF		C
Ulva compressa	—	SF		C
Ulva fasciata	1819	SF		C
Ulva flexuosa	—	SF		C
Ulva intestinalis	—	SF		C
Ulva linza	—	SF		C
Ulva paradoxa	—	SF		C
Ulva prolifera	—	SF		C
Ulva reticulata	<1892	SF		C
Ulva rigida	—	SF		C
Ulva taeniata	—	SF		C
Chaetomorpha indica	1988	SF		C
PHAEOPHYTA (brown algae)				
Nemacystus decipiens	1963	R?	Indo-Pacific	I
Pilayella littoralis	1990s	SF	Unknown	I
Dictyota flabellata	1999	SF	California	I
ANTHOPHYTA (flowering plants)				
Halophila decipiens	1979	BW?/AN?	Indo-Pacific, Caribbean	I
Spergularia marina	1909	SBA, R	Eurasia-North America	I
Pluchea indica	1915	SBA, R	Asia	I
Pluchea carolinensis	1931	SBA, R	Caribbean, S America	I
Batis maritima	1859	SBA	Caribbean	I
Atriplex semibaccata	1895	R	Australia	I
Atriplex suberecta	1923	R	Australia, South Africa	I
Typha latifolia	1979	R	Eurasia, North America	I
Paspalum vaginatum	1936	R	Unknown	I
Bruguiera sexangula	1922	R	Philippines	I
Rhizophora mangle	1902	R	Florida	I
Conocarpus erectus	<1910	R	Florida, Bahamas	I

Table 2. Number of species treated in this monograph and their status

Taxon	Introduced	Cryptogenic	Establishment Unknown	Released/ Escaped Not Established	Failed	Intercept	Other*
Fungi	2	–	–	–	–	–	–
Dinoflagellata	1	–	–	–	–	–	–
Ciliophora	3	7	–	–	–	–	–
Porifera	9	18	–	–	–	–	–
Hydrozoa	8	27	–	–	–	–	1
Anthozoa	5	1	1	–	1	–	1
Scyphozoa	4	–	–	–	–	–	–
Cubozoa	1	–	–	–	–	–	–
Ctenophora	1	–	–	–	–	–	–
Nematoda	1	1	–	–	–	–	–
Rotifera	–	5	–	–	–	–	–
Turbellaria	1	1	–	–	–	–	–
Trematoda	1	–	–	–	–	–	1
Monogenea	2	–	–	–	–	–	–
Cestoidea	1	–	–	–	–	–	–
Hirudinea	–	–	–	–	–	–	1
Oligochaeta	–	7	–	–	–	–	–
Polychaeta	21	21	–	–	–	1	2
Gastropoda	11	4	7	2	1	–	3
Bivalvia	21	–	1	9	–	–	–
Copepoda	3	1	–	–	–	–	–
Amphipoda	20	5	–	–	–	–	–
Tanaidacea	2	1	–	–	–	–	–
Isopoda	18	–	–	–	–	–	1
Cumacea	2	–	–	–	–	–	–
Mysidacea	1	–	–	–	–	–	–
Cirripedia	4	–	–	–	–	–	–
Decapoda	10	–	–	6	–	3	7
Stomatopoda	1	–	–	–	–	–	–
Insecta	38	4	1	–	–	–	–
Pycnogonida	12	–	–	–	–	–	1
Phoronida	1	–	–	–	–	–	–
Kamptozoa	1	–	–	–	–	–	–
Bryozoa	21	–	–	–	–	–	–
Echinodermata	1	1	–	–	–	–	–
Ascidiacea	30	1	–	–	–	–	–
Pisces	18	–	3	10	–	–	1
Rhodophyta	9	–	–	1	1	–	–
Chlorophyta	1	12	–	–	–	–	–
Phaeophyta	3	–	–	–	–	1	–
Anthophyta	12	–	–	4	–	–	–
TOTALS	301	117	13	32	3	5	19

* Other: Doubtful or erroneous records, native species, natural waifs, uncertain presence in marine waters.

Table 3. Vectors transporting nonindigenous marine and estuarine species to the Hawaiian Islands

Abbreviation Used in Table 1	Vector
AN	***Ship anchor*** and anchor chains
BW	***Ballast water***
O	***Other***, including carriage with commercial products, in airplane cabins, resting or egg stages with luggage and clothing, etc.
R	***Releases,*** intentional or accidental, by private individuals or government agencies, and species associated with such releases
SB	***Ship boring*** (organisms boring into wooden ships, or living in such burrows)
SBA	***Solid ballast***, including rock and sand ballast
SF	***Ship fouling*** (organisms living on hulls, in sea chests, or other fouled areas)

SYSTEMATIC ACCOUNT OF INTRODUCED AND CRYPTOGENIC SPECIES

VIRUSES, BACTERIA, and FUNGI

Carr (1996) reviewed the introduced and indigenous viruses, bacteria, and fungi associated with introduced penaeid shrimp in mariculture in the Hawaiian Islands. Several of the viruses (but none of the bacteria or fungi), including IHHNV (infectious hypodermal and hematopoietic necrosis virus), MBV (*Penaeus monodon*-type baculovirus), and RPS (rhabdovirus of American penaeids) were imported to the Islands with live penaeid shrimp. Whether they are established in the wild is not known; we thus do not count these viruses in our tabulations of introduced species.

Zhu *et al.* (2008) investigated the very diverse microbial consortia associated with the introduced sponge *Suberites aurantiacus* in Pearl Harbor but demured from suggesting which if any of the species may not be native.

FUNGI

Introduced Marine Fungi

Species	Date	Vector	Native to
Cytospora rhizophorae	1902	R	Western Atlantic
Etheirophora blepharospora	1902	R	Western Atlantic

Cytospora rhizophorae Kohlmeyer & Kohlmeyer, 1971 **Introduced**

Kohlmeyer (1969, as *Cytospora* sp.) reported this Western Atlantic marine mangrove fungus from Pearl Harbor from *Rhizophora mangle*, based upon 1968 collections. In describing this as a new species, Kohlmeyer & Kohlmeyer (1971) noted further material from Coconut Island, also collected in 1968. The Kohlmeyers suggested that this host-specific fungus was introduced in 1902 with *Rhizophora* from Florida. *Cytospora rhizophorae* has been implicated in widespread dieback and mortality of *Rhizophora mangle* in Puerto Rico (Wier *et al.*, 2006).

Etheirophora blepharospora Kohlmeyer & Kohlmeyer, 1965 **Introduced**

= *Keissleriella blepharospora*

Kohlmeyer (1969) reported this host-specific fungus from the bark of seedlings and from proproots of the mangrove *Rhizophora mangle* based upon collections made in 1968 on Coconut Island and Anahulu River near Hale‘iwa, O‘ahu. Volkmann-Kohlmeyer & Kohlmeyer (1993) further discuss the manglicolous fungi of Hawai‘i.

PROTOCTISTA

Introduced and Cryptogenic Protozoa

Species	Date	Vector	Native to
Introduced Species			
Eufolliculina lignicola	1961	SB	Unknown
Mirofolliculina limnoriae	1961	SB	Indo-Pacific
Cephaloidophora communis	1949	SF	Unknown
Perkinsus marinus	1972	R	Western Atlantic
Cryptogenic Species			
Zoothamnium sp./spp.	1935	SF, BW, R	
Halofolliculina annulata	—	SF, R	
Parafolliculina violaceae	—	SF, R	
Metafolliculina nordgardi	—	SF, R	
Metafolliculina andrewsi	—	SF, R	
Lagotia viridis	—	SF, R	
Ascobius simplex	—	SF, R	

We discuss here examples of introduced and cryptogenic protists. A thorough exploration of the Hawaiian marine and estuarine protists will reveal many additional introduced and cryptogenic species. We focus here on ciliates, which we treat here in three ecological groups: fouling sessile taxa, ectocommensal taxa, and endocommensal taxa.

The absence of any foraminiferans (“forams”) from this list reflects a lack of biogeographic and systematic resolution, rather than the actual absence of nonnative forams in the Hawaiian near-shore and harbor environments. This is no more clearly illustrated by the resolution that 32 species of nonnative forams have been recognized recently in the eastern Mediterranean fauna (Meriç *et al.*, 2007). Forams are often common in fouling communities and on oysters and are easily transported by human activities. The lagoonal taxa noted by Resig (1974) from O‘ahu that are not in the Hawaiian fossil record would be candidates for further investigation as potential human-mediated invasions, particularly species such as *Trochammina inflata*, noted by Resig as having a “broad latitudinal distribution in bays, lagoons, and marshes of both hemispheres,” as well as *Haplophragmoides wilberti, H. manilaensis*, and *Lamellodiscorbis aguayoi*, three taxa originally described from the Gulf of Mexico and Caribbean.

DINOFLAGELLATA

Stat & Gates (2008) report the endosymbiotic dinoflagellate *Symbiodinium* A1 (*Symbiodinium microadriaticum*, Freudenthal *sensu stricto*) in the native coral *Acropora cytherea* from the French Frigate Shoals in the Northwestern Hawaiian Islands based upon collections made in May 2006. They suggested that *Symbiodinium* “has been vectored into Hawai‘i via *Cassiopea* sp. from the Red Sea and/or Atlantic Caribbean and has spread in its distribution and formed a symbiotic association with *A. cytherea.*“ LaJeunesse *et al.* (2009) argued that rather than being introduced, the association was more likely to be a natural one.

Parsons & Preskitt (2007) report upon a survey of the epiphytic dinoflagellates from coastal waters on the island of Hawai‘i. Twenty species were reported for the first time from the Islands, but biogeographic relationships of this microflora are insufficiently worked out to determine if any of these species have been introduced.

Class Dinophyceae
Perkinsidae
Perkinsus marinus (Mackin, Owen, & Collier, 1950) **Introduced**
= Dermocystidium marinum; *= Labyrinthomyxa marina*
Kern *et al.* (1973) reported this well-known endoparasite, popularly known as “Dermo” from Atlantic oysters (*Crassostrea virginica*) in Pearl Harbor, based upon collections made in July 1972 during and following a mass oyster mortality (see discussion at *C. virginica*). Ford & Tripp (1996) provide a review of the history and distribution of this lethal, disease-causing organism. It was presumably introduced with other imported oysters from the Atlantic coast of North America. We assume it is still present in the *C. virginica* population on O‘ahu.

CILIOPHORA

Vorticellidae
Zoothamnium sp. or spp. **Cryptogenic**
We interpret the record of Edmondson & Ingram (1939: 256) of unidentified “colonial forms of Infusoria ... [which] may add somewhat to the friction of [the bryozoan] *Bugula*, to the stems and branches of which they often thickly adhere,” from Kāne‘ohe Bay (1935) likely to be peritrichous ciliates in the genus *Zoothamnium*. Grovhoug & Rastetter (1980: 257) recorded *Zoothamnium* sp. from O‘ahu in fouling. Carr (1996) notes records of *Zoothamnium* sp. (and *Epistylis* sp.) as ectocommensals of cultured penaeid shrimp. Ship fouling and oyster culture have transported these protists around the world. We regard the one or more species of *Zoothamnium*, as they occur in harbor fouling communities in Hawai‘i, as cryptogenic.

Folliculinidae
A number of ”cosmopolitan” fouling taxa of these famous “bottle animacules” are recorded from Kāne‘ohe Bay [summary in Phillips, 1977; earlier works are those of Andrews (1944) and Matthews (1962, 1963, 1964)]. Many of the species with which these folliculinids are associated are recognized as introduced fouling organisms. We regard all of the following as cryptogenic in the Hawaiian biota, as it seems probable that a number of taxa may have found their way to the Islands on sailing vessels, with aquaculture products, and by other means. However, the global biogeography of marine folliculinids is poorly known and precludes any certain conclusions at this time:

Halofolliculina annulata (Andrews, 1944) **Cryptogenic**
Parafolliculina violaceae (Giard, 1888) **Cryptogenic**
Metafolliculina nordgardi (Dons, 1924) **Cryptogenic**
Metafolliculina andrewsi (Giard, 1883) **Cryptogenic**
Lagotia viridis Wright, 1858 **Cryptogenic**
Ascobius simplex (Dons, 1917) **Cryptogenic**
Grovhoug& Rastetter (1980) also recorded *Parafolliculina violaceae* and *Metafolliculina andrewsi* in 1976–1977 from fouling in Pearl Harbor and Kāne‘ohe Bay. Rastetter & Cooke (1979) recorded folliculinids from Kāne‘ohe Bay (1977–1978). Bailey-Brock (1989) recorded *Halofolliculina annulata, Lagotia viridis*, and *Ascobius simplex* on PVC settlement plates on an artificial reef in open waters at 20 m, 2.4 km off the southeast coast of O‘ahu.

Eufolliculina lignicola (Fauré-Fremiet, 1936) **Introduced**
Matthews (1963) found this wood-associated folliculinid in 1961, "abundant in tracheids [of wood] opened by burrowing gribbles" [limnoriid isopods], probably on Coconut Island in Kāneʻohe Bay. It likely occurs wherever harbor-dwelling limnoriids are found in Hawaiʻi and should be looked for in sites such as Pearl Harbor. Fauré-Fremiet (1936) described this species from the Breton coast of France, originally in the genus *Folliculinopsis*. A small species ("fully extended its length does not exceed 350 microns") with a pale blue color, it was associated with "*Limnoria lignorum*" (at the time the general name for most such wood-boring gribbles) and may be a microhabitat specialist. Fauré-Fremiet noted that "it builds its rudimentary shell in the pitted tracheids which are cut through by the hollowed galleries of these isopods in the pine wood of submerged wrecks" (translated from the French). We regard it as introduced based upon its association with introduced limnoriids. While first described from Europe, its biogeographic origin requires investigation, as it may of course have itself been introduced to the North Atlantic Ocean by shipping from elsewhere.

Ectocommensal Protists
Folliculinidae
Mirofolliculina limnoriae (Giard, 1883) **Introduced**
Matthews (1963) recorded this species on the pleotelson of the isopod (gribble) *Paralimnoria andrewsi* from samples collected in 1961 probably on Coconut Island in Kāneʻohe Bay. We regard it as introduced with limnoriids. Its known hosts (both *Paralimnoria* in Hawaiʻi and *Limnoria* elsewhere) appear to be rooted in the Indo-Pacific, where we regard this commensal to be native as well.

Endocommensal Protists
Cephaloidophoridae
Cephaloidophora communis Mavrodiadi, 1908 **Introduced**
Ball (1950) found this endoparasitic gregarine protozoan in the introduced barnacle *Amphibalanus eburneus*, presumably from Oʻahu, in 1949. It was found only in this barnacle and not in two other species of *Balanus*, nor in 30 species of decapods. Ball (1950) notes that this protozoan was previously known from both *B. eburneus* and other species of *Balanus*, and that "since *B. eburneus* has a very wide distribution over the world, the presence of *C. communis* is not surprising." We regard it as introduced with *A. eburneus.*

PORIFERA (sponges)

Introduced and Cryptogenic Porifera

Species	Date	Vector	Native to
Introduced Species			
Suberites aurantiacus	1902	SF	Unknown
Halichondria melanodocia	1960s [<1967]	SF	Western Atlantic
Halichondria coerulea	1960s [<1967]	SF	Unknown
Haliclona coerulea	1996	SF	Unknown
Gelliodes fibrosa	1996	SF	Philippines
Mycale cecilia	1947	SF	Caribbean
Mycale grandis	1996	SF	Indo-Pacific
Mycale parishii	1947	SF	Indo-Pacific
Monanchora sp.	1997	SF	Unknown
Cryptogenic Species			
Cliona sp./ *Pione* sp.	1947	SF, R	
Tethya ornata	1985	SF	
Oceanapia sp./*Halichondria* sp.	1948	SF	
Topsentia dura	1948	SF	
Topsentia sp.	1996	SF	

Introduced and Cryptogenic Porifera (continued)

Species	Date	Vector	Native to
Callyspongia diffusa	1945	SF	
Chalinid sp.	1997	SF	
Toxiclona sp.	1997	SF	
Biemna sp.	1996	SF	
Clathria procera	1960s [<1967]	SF	
Tedania reticulata	1947	SF	
Tedania sp.	1960s [<1967]	SF	
Echinodictyum asperum	1997	SF	
Dysidea sp.	1996	SF	
Dysidea sp. cf. *D. avara*	1948	SF	
Dysidea sp. cf. *D. arenaria*	1996	SF	
Hyattella intestinalis	1996	SF	
Heteropia glomerosa	1955	SF	

As with hydroids, bryozoans, ascidians, and other encrusting biota, the diversity of introduced sponges in the Hawaiian Islands has been and for some time will remain underestimated. Bergquist (1967) considered at least four species of sponges to have been introduced to Kāne‘ohe Bay, occurring together on the floating docks at Coconut Island (“It appears likely that this group of species has been transported artificially to Hawaii and that species which readily establish in fouling communities have been favored.”)

De Laubenfels (1957) had earlier speculated on the introduction of sponges to the Hawaiian Islands and specifically discussed sponge diversity in fouling communities in Honolulu Harbor and on vessel bottoms in Pearl Harbor. In noting that certain taxa, which he considered to also occur in the Northeastern Pacific Ocean also occurred in Hawai‘i, de Laubenfels wrote (1957, p. 249): “Could this American relationship be due to transport of sponges on ship bottoms? Sponges occur fairly commonly among the fouling organisms. With the possibility of transport in mind, studies were made of the bottoms of vessels in dry dock at Pearl Harbor. The results were inconclusive but not negative. It seems clear that on a long ocean voyage most of the sponges on the ship’s bottom perish, but a few might possibly survive.”

De Laubenfels (1957) did not, unfortunately, specify which vessels he had examined that had been on “long ocean voyage(s).” While he notes that he examined a number of “ship bottoms” in dry dock, some of these vessels may have also been in Pearl Harbor for some time, as were barges that de Laubenfels studied. He notes one barge “that had been long at Kwajalein in the Marshall Islands, and then for three months at Pearl Harbor,” which he sampled in 1948. This barge lacked calcisponges (present on Pearl Harbor barges) and had one sponge, *Tethya “diploderma,”* not found on the Pearl Harbor barges that de Laubenfels had sampled. The absence of the *Tethya* from local Pearl Harbor barges suggests that it had settled on the barge in question in the Marshall Islands before being brought to the Hawaiian Islands, although this sponge was apparently already known from the Harbor (see further discussion below, under *Tethya* sp.). Five additional species were found on the Marshall Islands barge that had arrived in Pearl Harbor, but de Laubenfels does not specifically identify which of seven species of sponges (other than *Tethya*) he lists were found on the Marshall Islands barge and which were found on *in situ* Pearl Harbor barges.

The Pacific island sponge fauna, in particular, and the Indo-Pacific sponge biota in general, are poorly known: there are a great many undescribed species, and many species that currently bear the names of taxa first described from the North Atlantic Ocean, the Mediterranean, and the Caribbean that require reevaluation (M. Kelly-Borges Shanks, pers. comm., 1996). The Hawaiian sponge biota further requires extensive reassessment, particularly for the presence of unrecognized endemic taxa and unrecognized introductions (M. Kelly-Borges Shanks, pers. comm., 1996; DeFelice, 2000; R. DeFelice, pers. comm., 2003).

In the following analysis, we treat as introduced or cryptogenic those taxa that appear to be either entirely restricted to, or primarily found in, the float-fouling communities of harbors, suggesting that they owe or may owe their presence in the islands to ship-borne introduction. For nomenclature and systematics, we follow the World Porifera Database at: http://www.vliz.be/Vmdcdata/porifera/ [accessed December 2007].

Class Demospongiae
Order Hadromerida
Clionidae

Cliona sp. or ***Pione*** sp. **Cryptogenic**

= *Cliona vastifica* of de Laubenfels, 1950 and of Bergquist, 1977

De Laubenfels (1950), under the name of the North Atlantic species *Cliona vastifica* Hancock, 1849 (now *Pione vastifica*) recorded this boring sponge, based on 1947 collections, from Waialua Bay (northwest of Kāneʻohe Bay) noting it was "common throughout the shallow waters of Hawaii but is always inconspicuous. If one breaks up almost any long-submerged calcareous material, such as shells or dead coral, one will find this boring sponge. It is very common throughout Kaneohe Bay." De Laubenfels further noted that "It is an abundant species throughout the Old World, but quite uncommon (although present) in the New World..... Is *vastifica* perhaps a recent immigrant to North America, carried by barnacles on ship bottoms? Did it reach Hawaii in that same way too?." Bergquist (1977) lists this as the only *Cliona* in Hawaiʻi. Coles *et al.* (1999a) report it in 1996 collections from Pearl Harbor.

It seems possible that the Clionidae in Hawaiʻi may include both indigenous open-coast and coral reef taxa, as well as introduced species brought to the Islands by ships (as de Laubenfels suggests) and through commercial oyster culture (as discussed for *Cliona* in general by Carlton, 1979a). We treat harbor- and bay-dwelling species as cryptogenic.

Tethyidae

Tethya ornata Sarà, Bavestrello & Calcinai, 2000 **Cryptogenic**

While we suspect that this species will eventually prove to be an introduction, we conservatively treat it here as cryptogenic, pending further knowledge of its distribution and phylogenetic relationships with other *Tethya* species. Sara *et al.* (2000) have described this sponge as a new species from a floating dock in Kāneʻohe Bay, at Coconut Island, collected in 1985 by Peter Karuso. It remains unknown from elsewhere, but we predict it will be found to be an Indo-Pacific species. We consider it a probable ship-fouling introduction. It may occur in Pearl Harbor, Keʻehi Lagoon (Honolulu Harbor), and similar locations as well.

Suberitidae

Suberites aurantiacus (Duchassaing & Michelotti, 1864) **Introduced**

= *Suberites zeteki* (de Laubenfels, 1936), described from Florida

= *Terpios zeteki*

This species appears in the Hawaiian literature as either *Terpios zeteki* or *Suberites zeteki*. De Laubenfels (1950,1951) recorded it from Kāneʻohe Bay on Oʻahu (1947) and from Kaʻalualu and Honaunau, Island of Hawaiʻi. De Laubefels (1954a) further recorded it growing in tanks in the Honolulu Aquarium, and in 1957 reported it from Waialua Bay (1947) and Ulumoku Pond in West Loch, Pearl Harbor (1947) and from boat fouling in Pearl Harbor. DeFelice *et al.* (2001) note that it is in all leeward harbors on Oʻahu and in Kāneʻohe Bay, and in Nawiliwili Boat Harbor on Kauaʻi, nothing that it is "common as fouling in harbors, especially those with some estuarine conditions, and in Kāneʻohe Bay, primarily on floating docks, dock pilings and mangrove roots, also on hulls of ships." Hoover (1998, 2006) illustrates a specimen from Pearl Harbor. Coles *et al.* (1999b) report it from Keʻehi Lagoon (1988), Honolulu Harbor, and Ala Wai Harbor.

De Laubenfels (1950, page 4) appears to refer to this species as one of the two Panamanian forms that "conceivably may have been brought to Hawaii on ship bottoms ... . Conversely, they may

have been taken to Panama from Hawaii"; de Laubenfels further states that of these two Panamanian species, "at least one of them is abundant on those that are dry-docked at Pearl Harbor." In his following text, the two Panamanian species referred to are *Mycale cecilia* and *Terpios zeteki* [*Suberites aurantiacus*].

Grovhoug & Rastetter (1980) recorded it from Pearl Harbor and Kāne‘ohe Bay (1976–1977). Coles *et al.* (1999a) report it from Pearl Harbor (1996 collections) and note that it (along with *Mycale celia*) was "so abundant at the power station outfall in East Loch that they form a virtual sponge reef." It was collected, interestingly enough, in 1902 during the *Albatross* surveys in Pearl Harbor (R.C. DeFelice, pers. comm., 1999, based on examination of Smithsonian Institution collections).

Suberites aurantiacus, first described from the Virgin Islands, occurs in both the Atlantic and Pacific. We regard it as introduced to the Hawaiian Islands. Zhu *et al.* (2008, as *S. zeteki*) report upon the microbial flora of *Suberites aurantiacus* at the Rainbow Marina, Pearl Harbor.

Order Halichondrida
Halichondriidae

Halichondria (Halichondria) melanodocia de Laubenfels, 1936 **Introduced**

Bergquist (1967) recorded this black western Atlantic tropical species on the floating pier at Coconut Island, based on material collected in the 1960s. It was previously known from the Caribbean (West Indies), Florida, and North Carolina (Hechtel, 1965). Bergquist considered it introduced. Coles *et al.* (1999a) report it from Pearl Harbor based on collections both in 1993 and 1996; it also occurs in Ala Wai Harbor (Coles *et al.*, 1999b) and Kāne‘ohe Bay (Coles *et al.*, 2002a). Hechtel (1965) noted its habitat in Jamaica as "abundant on pilings and mangrove roots." We consider float-fouling *Halichondria* in Hawai‘i, because of their habitat and their absence in the open marine biota, to be introduced.

Halichondria coerulea Bergquist, 1967 **Introduced**

Bergquist (1967) described this *Halichondria,* "a massive, spreading sponge ... found only on fouling surfaces" as a new species from the floating dock and stone pier at Coconut Is., Kāne‘ohe Bay (1960s collections). It has not been reported elsewhere (M. Kelly-Borges Shanks, pers. comm., 1996). It was not found in recent surveys of Pearl or Honolulu Harbors (R.C. DeFelice, pers. comm., 1999). We treat it here as introduced by ship fouling, and thus unknown in its area of its origin.

Oceanapia sp. or ***Halichondria*** sp. **Cryptogenic**

= *Pellina sitiens* of de Laubenfels (1957) [now *Halichondria sitiens*]
= *Pellina eusiphona* of Bergquist, 1977 [now *Oceanapia eusiphonia*]

De Laubenfels (1957) reported a single colony of a sponge under the name *Pellina sitiens* (Schmidt, 1870), now placed in *Halichondria*, "from a concrete dry dock at Pearl Harbor" (collected in 1948) an identification he called "dubious." *Halichondria sitiens* is a North Atlantic taxon, and thus a name applied with hesitation to Hawaiian material (M. Kelly-Borges Shanks, pers. comm., 1996). Another species, *Pellina eusiphona* Ridley, 1884, now placed in the genus *Oceanapia*, was described from the Indian Ocean and had been recorded by de Laubenfels from the Marshall Islands (de Laubenfels, 1954b). De Laubenfels (1957) noted that the specimen from Pearl Harbor was intermediate between the published descriptions of these two species; Bergquist (1977) placed de Laubenfels' use of the name (but not the actual species) "*sitiens*" in the synonymy of *P. eusiphona*. We consider it cryptogenic.

Topsentia dura (Lindgren, 1897) **Cryptogenic**

= *Halichondria dura*

De Laubenfels (1951) reported "with some hesitation" this Indo-Pacific species in 2 m of water in Hilo, based on specimens collected in 1948. R.C. DeFelice (pers. comm., February 1998) reports material collected since 1996 in Pearl Harbor and Hilo.

Topsentia sp. **Cryptogenic**

Coles *et al.* (1999a) report this species as a new record for Hawai‘i, based on collections in 1996 from Pearl Harbor. It may be Indo-Pacific in origin (R.C. DeFelice, pers. comm. February 1998). We regard it as cryptogenic.

Order Haplosclerida

Callyspongiidae

Callyspongia (Cladochalina) diffusa (Ridley, 1884) **Cryptogenic**

This Australasian and Indo-Pacific species was collected in 1947 on the dock of Coconut Island, Kāne‘ohe Bay, and also in Waialua Bay (de Laubenfels, 1950) and at Halapē in 1945 and Ka‘alualu in 1948 (de Laubenfels, 1951). Hildemann *et al.* (1980) noted that it “exists in abundance in large, ramose colonies” in Kāne‘ohe Bay, where it “thrives in shallow water (0.5 to 5 m) exposed to direct sunlight, and exhibits a uniform bright purple pigmentation throughout its soft tissues.” It still occurs in Kāne‘ohe Bay (Coles *et al.*, 2002a). It was collected in Pearl Harbor in 1996 [Coles *et al.,* 1999a; the record therein of a report from Pearl Harbor in 1947 by de Laubenfels (1957) is in error] and in Honolulu Harbor and Kewalo Basin (Coles *et al.,* 1999b) and in Waikīkī (Coles *et al.*, 2002b). Hoover (1998, 2006) illustrates a specimen from Coconut Island living in the coral *Montipora capitata.* We consider it cryptogenic.

Chalinidae

Haliclona* (*Soestella*) *coerulea (Hechtel, 1965) **Introduced**

= Sigmadocia coerulea

Coles *et al.* (1999a) reports this pale blue-green Caribbean species as a new record for Hawai‘i (and thus for the Pacific Ocean), based upon specimens collected in Pearl Harbor in 1996. They note that it “is common on artificial substrates of all harbors on the main Hawaiian Islands and Midway Atoll.” On O‘ahu it occurs in Kāne‘ohe Bay, Honolulu Harbor, Ke‘ehi Lagoon, Kewalo Basin, and Ala Wai Harbor; on Kaua‘i it occurs in Nawiliwili Harbor (DeFelice *et al.*, 2001). DeFelice *et al.* (2001) note that it is unlikely that de Laubenfels or Bergquist would have overlooked it in earlier surveys, given its abundance in such localities as the floating docks on Coconut Island. It now occurs on pier pilings, floating docks, mangrove roots, and patch reefs and in dredged channels in the Hawaiian Islands. We regard it as introduced. When a dry dock left Pearl Harbor in 1999 for Guam, it sailed with this sponge as well. Hoover (1998, 2006) illustrates a specimen from Pearl Harbor.

Hechtel (1965) reported it as “Common on pilings and mangrove roots on the outside of the Port Royal mangrove thicket,” and also from a “sandy turtle grass bed,” both in Jamaica. In addition to the Caribbean, *H. coerulea* is also known from the Pacific side of Panama; whether native to the Atlantic or Pacific Oceans remains unknown.

Undescribed chalinid **Cryptogenic**

Another cryptogenic chalinid sponge occurs in Ke‘ehi Lagoon (1997) and Ala Wai Harbor (1998) (Coles *et al.*, 1999b: 117), in Kāne‘ohe Bay (Coles *et al.*, 2002a) and in Waikīkī (Coles *et al.*, 2002b).

Toxiclona sp. **Cryptogenic**

An apparently cryptogenic species of *Toxiclona* occurs in Honolulu Harbor (Coles *et al.*, 1999b; collections of 1997), in Kāne‘ohe Bay (Coles *et al.*, 2002a), and at Waikīkī (Coles *et al.*, 2002b).

Niphatidae

Gelliodes fibrosa (Wilson, 1925) **Introduced**

Coles *et al.* (1999a) report this blue-gray Philippine species from Pearl Harbor (1996 collections), as a new state record for Hawai‘i, “abundant on the hull of a floating dry dock [the *Machinist*] brought from the Philippines in 1992.” It now occurs and is established in Pearl Harbor and Honolulu Harbor

on O‘ahu, apparently as a direct result of this introduction from the Philippines, on Maui (Kahului Harbor) and on Kaua‘i (Nawiliwili Harbor) (DeFelice *et al.*, 2001), as well as in Kāne‘ohe Bay (Coles *et al.*, 2002a) and Waikīkī (Coles *et al.*, 2002b). Coles *et al.* (1999b) also list it from Ke‘ehi Lagoon, Ala Wai Harbor, Barbers Point Harbor, and Kewalo Basin, while Coles *et al.* (2004) report it from Kawaihae and Hilo Harbors, Hawai‘i.

It is “mainly restricted to shallow-water fouling communities (i.e., pier pilings, floating docks) of the major harbors or associated disturbed habitats (i.e., dredged channels and artificial lagoons)... (and is) found on patch reefs… typically found encrusting the shaded underside of plate corals” in Kāne‘ohe Bay (DeFelice *et al.*, 2001).

Order Poecilosclerida
Desmacellidae
Biemna sp. **Cryptogenic**

Coles *et al.* (1997, 1999a) report this species (as *B. fistulosa* Topent, 1897) as a new record for Hawai‘i, based on collections in 1996 from Pearl Harbor. It is also found in Kāne‘ohe Bay (Coles *et al.*, 2002a). Hoover (1998, 2006) illustrates a specimen from Magic Island, O‘ahu, at 3 m depth. Coles *et al.* (1999b) report it from Honolulu Harbor, Ke‘ehi Lagoon, and Ala Wai Harbor.

It appears to be similar to a species known from Zanzibar and the west central Pacific (Coles *et al.*, 2002a; M. Kelly-Borges Shanks & R.C. DeFelice, pers. comm.). We regard it as cryptogenic.

Microcionidae
Clathria (Thalysias) procera of Bergquist, 1967 **Cryptogenic**

Bergquist (1967) recorded *Clathria procera* (Ridley, 1884), a widespread species occurring from the Red Sea to the Indo-Pacific (Hooper, 1996) from Kāne‘ohe Bay, based on material collected in the 1960s. We treat it as cryptogenic.

Mycalidae
Mycale (Carmia) cecilia de Laubenfels, 1936 **Introduced**

= *Mycale maunakea* de Laubenfels, 1951, synonymy *fide* Bergquist (1967, as *M. manaukea*).

De Laubenfels (1950) noted that this *Mycale* was “very common in Hawaii, widely scattered in shallow water locations. Its greatest abundance, however, seems to be in Honolulu Harbor and in Pearl Harbor” (collections of 1947). He further noted that it “... conceivably may have been brought to Hawaii on ship bottoms... Conversely, they may have been taken to Panama from Hawaii.” De Laubenfels offered reasons to doubt this initial identification, but it is accepted by Bergquist (1967), who found it at the floating pier at Coconut Island in Pearl Harbor and who considered it introduced. De Laubenfels (1957) noted that *Mycale cecilia* occurred in Honolulu Harbor in December 1947 “on nearly every piling;” he further recorded it from Ulumoku Pond in the West Loch of Pearl Harbor (1947), and from barge bottoms in Pearl Harbor. Evans *et al.* (1972) recorded a *Mycale* sp. from Pearl Harbor (1971). Coles *et al.* (1999a) report it from Pearl Harbor (1996 collections), and note that it (along with *Suberites aurantiacus*) was “so abundant at the power station outfall in East Loch that they form a virtual sponge reef.”

It also occurs in Kāne‘ohe Bay, Honolulu Harbor, Ke‘ehi Lagoon, Ala Wai Harbor, Barbers Point Harbor, Kewalo Basin, Kaua‘i, and Maui (Coles *et al.,* 1999b, 2002a, 2006). A Caribbean species (Coles *et al.*, 2002a), we regard it as introduced. Young (1967, as *Mycale maunakea*) noted that the native nudibranch *Chromodoris aspersa* feeds upon this species in Hawai‘i.

Mycale* (*Mycale*) *grandis Gray, 1867 **Introduced**

= *Mycale* (*Aegogropila*) *armata* Thiel, 1903

Coles *et al.* (1999a) report this bright red-orange species (as *M. armata*) as a new record for Hawai‘i, based on collections in 1996 from Pearl Harbor. It is now known from a number of stations around O‘ahu (Pearl Harbor, Honolulu Harbor, Ke‘ehi Lagoon, Barbers Point Harbor, and Kāne‘ohe Bay) and on Maui at Kahului Harbor (DeFelice *et al.*, 2001). It occurs on pier pilings, floating docks, dredged

channels, and lagoons, and on patch reefs in Kāneʻohe Bay. Coles *et al.* (1999b) report it on Oʻahu from Honolulu Harbor, Keʻehi Lagoon, Ala Wai Harbor, and Barbers Point Harbor. Coles *et al.* (2006) report it from Kauaʻi as well, based upon 2003 specimens. Coles & Bolick (2007) note that *M. grandis* has overgrown reef corals in Kāneʻohe Bay, where it was found to be smothering *Porites compressa* and *Montipora capitata* on back reef flats and slopes. Described originally from Ternate, an island in the Maluku Islands (Moluccas) in eastern Indonesia, it was previously known from Australia, Torres Straits, the Red Sea, and the general Indo-Malaysian region (DeFelice *et al.*, 2001).

Mycale (Zygomycale) parishii (Bowerbank, 1875) **Introduced**

De Laubenfels (1950) recorded material from Kāneʻohe Bay (1947) and further noted that "It is extremely abundant as a growth on vessels that remain for a year or so at harbor on the lee side of Oʻahu, as revealed by study of ship bottoms in the dry-docks at Pearl Harbor." Bergquist (1967) recorded it again at the floating pier at Coconut Island and considered it to be introduced, a determination with which M. Kelly-Borges Shanks concurs (pers. comm., 1996). McCain (1975) found it on fouling panels in Pearl Harbor (1973). Coles *et al.* (1999a) report it based on collections in 1996 from Pearl Harbor. Coles *et al.* (2002b) and DeFelice *et al.* (2001) record it on Oʻahu from Pearl Harbor, Honolulu Harbor, Keʻehi Lagoon, Kewalo Basin, Barbers Point, and Kāneʻohe Bay, and on Maui at Kahului Harbor. They note that "this sponge is mainly restricted to shallow-water fouling communities (i.e., pier pilings, floating docks) of the major harbors on Oʻahu or associated disturbed habitats (i.e., dredged channels and artificial lagoons). In Kāneʻohe Bay, it is found on patch reefs."

Mycale parishii is an Indo-Pacific species, previously known from the Indian Ocean, the East Indies (Indonesia), the Philippines, Australia, and the Pacific side of Panama. It has also been recorded from the Caribbean (West Indies [Jamaica]) and Brazil (Hechtel, 1965), to where (along with Pacific Panama) we regard it as introduced as well via ship fouling.

Banner & Banner (1966) [repeated by Castro (1971)] reported that in Hawaiʻi this sponge hosts in its spongocoel the alpheid shrimp *Synalpheus streptodactylus* Coutière, 1905. They provide no details in terms of location or exact collection date but note that it was between 1959 and 1963 (Banner & Banner, 1966, pp. 145 and 158). This shrimp occurs in other locations in the Pacific and Indian Oceans as well but not in association with this sponge. The shrimp is presumably native.

Crambeidae

Monanchora sp. **Introduced**

An encrusting sponge from the fouling community of Honolulu Harbor (1997) and Keʻehi Lagoon (1997) may be a species of the genus *Monanchora* [Coles *et al.*, 1999b, identified therein as *Neofolitispa unguiculata*, but probably not that species (R.C. DeFelice, pers. comm., 2001)]. We regard it as introduced by ship fouling.

Tedaniidae

Tedania (Tedania) reticulata Thiele, 1903 **Cryptogenic**

= *Tedania ignis* of de Laubenfels, 1950 and Bergquist, 1967

De Laubenfels (1950) provisionally identified a *Tedania*, described as "very common throughout the shallow waters of Hawaii including Kaneohe Bay" (1947) as the well-known West Indian fire sponge *T. ignis* (Duchassaing & Michelotti, 1864). De Laubenfels (1951) noted material collected in 1945 at Halape; under the name *T. ignis*, he further reported this species from shallow subtidal waters near Koko Head, near Hanauma Bay (1948) and in dredgings 2–3 km south of Pearl Harbor (1948). Bergquist (1967), in studying material from the floating pier at Coconut Island considered it to be introduced, and noted that of the species she considered introduced, only this species "is common elsewhere in Hawaii." While de Laubenfels tentatively identified this species as *T. ignis*, Bergquist uses this name without further comment. It appears to be *T. reticulata* of the Indo-Pacific (M. Kelly-Borges Shanks, pers. comm., 1998). We consider it cryptogenic.

Coles *et al.* (1999a) report it as *T. reticulata* from Pearl Harbor (1996 collections), and Coles *et al.* (1999b) report it from Keʻehi Lagoon, based on 1997 collections. Hoover (1998, 2006) illustrates a specimen from Coconut Island, Kāneʻohe Bay.

Sims & Irei (1979) report that this “fire sponge” occasionally causes severe human dermatitis in Hawai‘i, a phenomenon noted earlier by de Laubenfels in 1950.

Tedania sp. **Cryptogenic**

= *Tedania macrodactyla* of Bergquist, 1967

Bergquist (1967) recorded a *Tedania* species [as *T. macrodactyla* (Lamarck, 1813)] from the floating pier and stone pier on Coconut Island, Kāne‘ohe Bay (collections of the 1960s); the taxon *T. macrodactyla*, at the time, was previously otherwise known in the Pacific Ocean from the East Indies.

The applicability of this name to Indonesian or to Hawaiian material is questionable (M. Kelly-Borges Shanks, pers. comm., 1996). The identity of this fouling *Tedania* on O‘ahu thus remains to be determined. We regard it as cryptogenic.

Raspailiidae

Echinodictyum asperum Ridley & Dendy, 1886 **Cryptogenic**

Coles *et al.* (1999a, 1999b) report this species as a new record for Hawai‘i, based on collections in 1997 from Pearl Harbor. It is known from the Indo-Pacific (R.C. DeFelice, pers. comm. February 1998). We regard it as cryptogenic.

Order Dictyoceratida

Dysideidae

Dysidea sp. **Cryptogenic**

A sponge in the Pearl Harbor fouling community was collected in 1996 by M. Kelly-Borges Shanks and R.C. DeFelice that appears to be a new species of *Dysidea*, although similar to the well-known tropical western Atlantic “heavenly sponge” *Dysidea etheria* de Laubenfels, 1936. It is also found in Honolulu Harbor (Coles *et al.,* 1999b) and Kāne‘ohe Bay (Coles *et al.*, 2002a) and in Ke‘ehi Lagoon (Coles *et al.*, 2002a). We treat it here as cryptogenic.

Dysidea sp., cf. ***D. avara*** (Schmidt, 1862) **Cryptogenic**

De Laubenfels (1950) reported a single specimen collected at Coconut Island in Kāne‘ohe Bay in 1948 “on the east side of the dock, near the concrete bridge which connects the dock with the island,” in 2 m of water. It remains in Kāne‘ohe Bay (Coles *et al.*, 2002a). It is also found in Pearl Harbor (Coles *et al.*, 1999a; 1996 collections), Honolulu Harbor (Coles *et al.,* 1999b) and in Waīkikī (Coles *et al.*, 2002b). Hoover (1998, 2006) illustrated a specimen growing on a mangrove root on Coconut Island in one meter. Originally described from the Mediterranean, by the time of de Laubenfels’ (1950) report it had been reported from “throughout the Old World, Europe to Australia... even into the near Arctic,” which suggests either a species complex or a taxon widely distributed for centuries by ships. We regard it as cryptogenic.

Dysidea sp., cf. ***D. arenaria*** Bergquist, 1965 **Cryptogenic**

Coles *et al.* (1999a) report this sponge, previously known from Palau, as found in Pearl Harbor (1996) collections. It is also found in Honolulu Harbor (Coles *et al.,* 1999b), Kāne‘ohe Bay (Coles *et al.*, 2002a), and Waikīkī (Coles *et al.*, 2002b). We regard it as cryptogenic.

Spongiidae

Hyattella intestinalis (Lamarck, 1814) **Cryptogenic**

Coles *et al.* (1999a) report this Indo-Pacific sponge as found in Pearl Harbor (1996) collections; it is a new record for Hawai‘i. It was also collected on the hull of the floating dry dock the *Machinist* brought from the Philippines in 1992 (R.C. DeFelice, pers. comm., 2001). Coles *et al.* (1999b) report it from Honolulu Harbor, Ke‘ehi Lagoon, and Barbers Point Harbor. Although said to have been from the Mediterranean, the type locality was probably the Indian Ocean (Hooper & Wiedenmayer, 1994). We regard it as cryptogenic.

Class Calcarea
Order Leucosolenida
Heteropiidae
Heteropia glomerosa (Bowerbank, 1873) **Cryptogenic**
Coles *et al.* (1999a) report this cryptogenic species from Pearl Harbor (1996 collections). It also occurs in Kāneʻohe Bay (Coles *et al.*, 2002a). Coles *et al.* (1999b) report it from Honolulu Harbor, Keʻehi Lagoon, Ala Wai Harbor, and Kewalo Basin. Material was collected in 1955 on fouling test blocks in Honolulu Harbor by C.H. Edmondson (R.C. DeFelice, pers. comm., 1999). It was previously known from the Indian Ocean, South Africa, and Australia (M. Kelly-Borges Shanks & R.C. DeFelice, pers. comm., 1999).

CNIDARIA
Class Hydrozoa (hydroids)

Introduced and Cryptogenic Hydrozoa

Species	Date	Vector	Native to
Introduced Species			
Cordylophora caspia	1974	SF, BW	Ponto-Caspian
Turritopsis nutricula	1972	SF, BW	Atlantic?
Garveia sp.	1972	SF, BW	Unknown
Bougainvillia muscus	1967	SF, BW	Atlantic
Cladonema radiatum	1972	SF, BW	North Atlantic
Pennaria disticha	1928	SF, BW	Unknown
Obelia dichotoma	1972	SF, BW	Unknown
Obelia bidentata	1946	SF, BW	Unknown
Cryptogenic Species			
Moerisia horii	1972	SF, BW	
Eudendrium sp.	1972	SF, BW	
Halecium beanii	1943	SF, BW	
Halecium sibogae	2003	SF, BW	
Ventromma halecioides	1999	SF, BW	
Plumularia floridana	1999	SF, BW	
Plumularia strictocarpa	1999	SF, BW	
Plumularia setacea	1972	SF, BW	
Antennella secundaria	1999	SF, BW	
Halopteris diaphana	1970s	SF, BW	
Halopteris polymorpha	1999	SF, BW	
Lytocarpia phyteuma	2001	SF, BW	
Anthohebella parasitica	1999	SF, BW	
Clytia latitheca	1999	SF, BW	
Clytia hemisphaerica	1972	SF, BW	
Thyroscyphus fruticosus	1973	SF, BW	
Synthecium megathecum	1972	SF, BW	
Dynamena crisioides	1972	SF, BW	
Dynamena cornicina	1972	SF, BW	
Dynamena quadridentata	2001	SF, BW	
Sertularella areyi	1999	SF, BW	
Sertularella tongensis	1999	SF, BW	
Sertularella diaphana	1972	SF, BW	
Tridentata loculosa	1972	SF, BW	
Tridentata hupferi	1972	SF, BW	
Tridentata turbinata	2001	SF, BW	
Tridentata distans	2001	SF, BW	
Tridentata marginata	2001	SF, BW	

Additional Taxon Treated and Its Status

Sertularia subtilis Status: *Record doubtful; see discussion.*

As early as 1933, C.H. Edmondson speculated that some species of hydroids may have been transported to the islands in ship fouling (Edmondson, 1933). Cooke (1977a) remarked on the presence of many cosmopolitan species in the Hawaiian hydroid fauna, stating, “It should be noted ... that many of the forms reported were collected from artificial habitats such as floats, pilings, and so forth, or from disturbed areas such as Kāne‘ohe Bay. This would also tend to favor the establishment of colonizing (in the ecological, not morphological sense) species, which in general are quite widely distributed.” Cooke (1975) earlier noted, relative to the Enewetak hydroid biota, that the “many hundreds of ships and barges [that] visited Enewetak Atoll in the later part of World War II and during the period of atomic bomb testing” provided “a ready method ... for the introduction of so many cosmopolitan species.”

While occasionally recognizing ships as a transport mechanism for harbor-dwelling hydroids, the hydrozoan systematic and biogeographic literature, in general, does not attempt to identify or suggest which species in subtropical and tropical harbor biotas, or in adjacent habitats in the open ocean, may be introduced, presumably in deference to the largely undocumented (and often unlikely) possibility of natural dispersal as oceanic drifters.

We treat several species here as introduced, but most taxa are of necessity cryptogenic. Chu & Cutress (1955) reported *Syncoryne mirabilis* (Agassiz, 1862) (now known as *Sarsia tubulosa* [(M. Sars, 1835); Calder (1988)] as causing dermatitis in swimmers in Hawai‘i. There are no further reports of this or any similar hydroid from Hawai‘i, and D. Calder (pers. comm., July 2003) considers the report of Chu & Cutress to be a misidentification. We do not further consider it.

As with a number of other groups, we note that many more species of shallow-water hydroids from the islands could be considered cryptogenic. Thus, the species listed here are *examples* of cryptogens, and our treatment is not meant to imply that we consider all other hydroids known from the islands to be native.

Corydendriidae

Cordylophora caspia (Pallas, 1771) **Introduced**

= *Cordylophora lacustris* Allman, 1844

Cooke (1977a) reported this species in an anchialine (18 to 32 ‰) pond (Hālua Pond) at Cape Kinau, Maui, growing on the alga *Caulerpa serrulata*, collected by Diana Wong and John Maciolek. A Ponto-Caspian species native to the Black and Caspian Seas, *Cordylophora* has been widely distributed by ships in the Atlantic and Pacific Oceans. Wong (1975) notes the record; her material was collected in the summers of 1974 and 1975.

Turritopsis nutricula McCrady, 1857 **Introduced**

Cooke (1977a) found *Turritopsis* growing on the hydroid *Halocordyle* (= *Pennaria*) stems, “in harbors such as Ala Wai Yacht Harbor” in 1972 (BPBM-D456). Cooke further suggested that “it is likely that the medusa figured by Edmondson (1946a); [see Fig. 1b (*sic*, *lapsus* for 13b)] represents a maturing *T. nutricula* medusa.” Edmondson’s figure is of a medusa “occasionally taken in the tow net on Waikiki reef and in Pearl Harbor, Oahu” (Edmondson,1946a; the same figure and statement appears in Edmondson, 1933). However, Edmondson’s medusa is not *Turritopsis nutricula* (C. Mills, pers. comm., June 2003), and it may or may not be a campanulariid, as Edmondson suggested.

Grovhoug & Rastetter (1980) reported *T. nutricula* from 1976–1977 collections in Pearl Harbor and Kāne‘ohe Bay. It still occurs in Kāne‘ohe Bay (Coles *et al.*, 2002a) and doubtless still occurs in Pearl Harbor as well.

This species, possibly North Atlantic in origin, now also occurs on the Pacific coast of America, and in South Africa, Papua New Guinea, and New Zealand (Schuchert, 1996), which we suggest is due to ship-borne transport. We thus also consider it introduced to Hawai‘i.

It is often cited as being described in 1859 (e.g., Calder, 1988), but the date of publication was 1857 (D. Calder, pers. comm., June 2003).

Moerisiidae

Moerisia horii (Uchida & Uchida, 1929) **Cryptogenic**

=*Ostroumovia horii*

Cooke (1977a) reported this species, as *Ostroumovia horii*, otherwise known from Japan, from a brackish pond in a lava flow near Honokohau, island of Hawai‘i (collected in 1972; W. Cooke, pers. comm., July 1996). He noted that the "recording of this species from both Japan and Hawaii is quite interesting, since most species in this family have a severely restricted distribution, unless transported by human activity." We regard it as cryptogenic, pending further taxonomic work. No specimens from this collection in the Hawaiians Islands exist in the Bishop Museum collections, but Cooke (1977a, fig. 1) provides a figure of Hawaiian material.

Bougainvilliidae

Garveia sp. **Introduced**

We regard an unidentified *Garveia* found in O‘ahu fouling communities as introduced by ships. Cooke (1977a) reported it on the hydroid *Pennaria* at Ala Wai Yacht Harbor, based upon collections in 1972 (W. Cooke, pers. comm., July 1996). Grovhoug & Rastetter (1980) reported it as "*Garveia humilis* (Allman, 1877)" from Pearl Harbor and Kāne‘ohe Bay based on 1976–1977 collections, an identification we regard as requiring confirmation. We predict that once identified, it will be found to be a species with a disjunct, harbor-based distribution.

Bougainvillia muscus (Allman, 1863) **Introduced**

= *B. ramosa* (van Beneden, 1844), a junior homonym; see Calder, 1988 and Schuchert, 1996).

Tusov & Davis (1971) recorded a "*Bougainvillia* sp." from Kāne‘ohe Bay, O‘ahu in the summer of 1967. Cooke (1977a) reported *B. ramosa* from Kāne‘ohe Bay in the form of dense colonies growing on the stems of the hydroid *Pennaria* and noted that it was "more common in temperate waters, but known to penetrate subtropically to Brazil and Australia." Bishop Museum collections contain material from Kāne‘ohe Bay collected in October 1972 by T. Gosliner. We regard it as introduced by shipping, and, given the history and pattern of records of the species, as native to the Atlantic Ocean, and introduced to ports in the Pacific, such as in Australia, Papua New Guinea, and New Zealand (Schuchert, 1996).

Eudendriidae

Eudendrium sp. **Cryptogenic**

Cooke (1977a) reported a *Eudendrium* species (lacking gonophores and thus not resolvable to species) from Honolulu Harbor and Kāne‘ohe Bay based upon material collected 1972 (W. Cooke, pers. comm., July 1996). We regard it as cryptogenic, as *Eudendrium* species are also frequently found in natural communities worldwide.

Cladonematidae

Cladonema radiatum Dujardin, 1843 **Introduced**

This well-known North Atlantic hydroid (Calder, 1988) was first collected in the Pacific Ocean in 1949, when it was described as a new species from Wellington, New Zealand; it was later reported from Japan (Schuchert, 1996). W. Cooke collected it on O‘ahu in June, 1972 (BPBM-D461) who noted that "the medusae are often found on the alga *Ulva* in relatively quiet waters" (Cooke, 1977a). It has since been introduced to Puget Sound, Washington (Kozloff, 1996; Wrobel & Mills, 1998).

Pennariidae

Pennaria disticha Goldfuss, 1820 **Introduced**

= *Halocordyle disticha* (following Gibbons & Ryland, 1989)

= *Pennaria tiarella* Ayres, 1854 (following Vervoort, 1968)

= *Corydendrium splendidum* Boone, 1938 (following Cooke, 1977a)

Gibbons & Ryland (1989) have argued for the retention of the name *Pennaria*, with the genus *Halocordyle* as a junior synonym; Schuchert (1996) follows this usage. We regard this common foul-

ing hydroid as introduced with shipping. Paulay *et al.* (2002) treat this species as cryptogenic in Guam, while Cranfield *et al.* (1998) treat it as introduced to New Zealand, with a European origin. It is reported, with various synonyms, from warm-water seas worldwide (Vervoort, 1968; Cooke, 1975; Cutress, 1977; Gibbons & Ryland, 1989). Cooke (1975) noted that it “is a very cosmopolitan species found in temperate and tropical regions of all oceans. It is often found on man-made structures, although it is also common on marine angiosperms in temperate waters.” Its origin remains unknown.

The earliest identified Bishop Museum material is from 1929 from Pearl Harbor. Edmondson (1933: 23) reported it (as *Pennaria tiarella*) in Pearl Harbor and Kāne‘ohe Bay, “attached to stones, pilings of old wharves, buoys, and other floats.” He noted that it appeared to be identical to the Atlantic Ocean *P. tiarella* McCrady “and may have been transported to Hawaii on the bottoms of ships.”

Boone (1938) redescribed *P. disticha* as a new species, *Corydendrium splendidum*, from Kāne‘ohe Bay (synonymized by Cooke, 1977a), collected as a single large colony in 2 m (“1 fathom”) of water at low tide, in 1928. Edmondson & Ingram (1939) reported it (as *Pennaria tiarella*) in 1935 and subsequent years in fouling in Kāne‘ohe Bay. Hiatt (1954) noted that “there are certain areas (Pearl Harbor and Kaneohe Bay) where a species of *Pennaria* is found abundantly attached to almost any solid substrate.” It was further recorded by Evans *et al.* (1972) from Pearl Harbor (1971, as *Pennaria* sp.), by Long (1974) on offshore and Pearl Harbor panels (1968–1972), and by Brock (1995) from Pearl Harbor (1993). Cooke (1977a) reported it from Kāne‘ohe Bay, Ala Wai Yacht Harbor, Kewalo Basin, Honolulu Harbor, Ke‘ehi Marina, on pilings, submerged lines, and boat bottoms. Cooke noted that it is known to sting when handled. Coles *et al.* (1999a) record its continued presence in Pearl Harbor (1976 collections). DeFelice *et al.* (2001) note that it now occurs on all the main Hawaiian Islands. DeFelice *et al.* (1998) report it from Midway Atoll, and DeFelice *et al.* (2002) report it from French Frigate Shoals.

Studies of the feeding biology of *Pennaria* (as *P. tiarella*) by Pardy & Lenhoff (1968), and on the paths and rates of food distribution by Rees *et al.* (1970) were based upon specimens from floating docks at Coconut Island, Kāne‘ohe Bay.

Hoover (1998, 2006) illustrates specimens from Lāna‘i Lookout, O‘ahu, from approximately 7 m depth. He notes that *Pennaria disticha* is “the most common large hydroid in Hawai‘i” and that it grows to its largest size (about 30 cm height) in protected locations such as Kāne‘ohe Bay.

Haleciidae

Halecium beanii (Johnston, 1838) **Cryptogenic**

De Oreo (1946) reported this widespread tropical and temperate hydroid, whose origin is unknown, to cause human dermatitis in Hawai‘i, based upon a series of cases beginning in June 1943 in the vicinity of Honolulu, with details of further cases in 1945. It is tempting to interpret these first reports of *Halecium*-induced dermatitis as the timing of its introduction during World War II, but confirmation of this will await a more detailed study of the chronological appearance of this hydroid around the Pacific theater. Cooke (1977a) recorded it from “rubble at a depth of 30 feet in Maunalua Bay”, based upon material collected in 1972. He earlier recorded it at Enewetak on pier pilings and on rubble from a patch reef in shallow water (Cooke, 1975). The earliest Bishop Museum material is from 1945 (Coles *et al.*, 1999b) from Honolulu Harbor, on a wood block at 5 m depth (BPBM D260). It was also found in 1998 at Barbers Point Harbor, O‘ahu (Coles *et al.*, 1999b).

Halecium sibogae Billard, 1929 **Cryptogenic**

Specimens of this Indo-Pacific species were collected in 2003 on the *Mahi* wreck in O‘ahu in 20 to 30 m of water by Steve Coles and identified as this species by Dale Calder as a new record for Hawai‘i (S.L.Coles, pers. comm., February 2004).

Kirchenpaueriidae

Ventromma halecioides (Alder, 1859) **Cryptogenic**

This hydroid was first found in 1999 in Kāneʻohe Bay (Coles *et al.*, 2002a). It is circumglobal in tropical and warm temperate waters (D. Calder, identification and pers. comm. to S.L. Coles, 2001).

Plumulariidae

Plumularia floridana Nutting, 1900 **Cryptogenic**

This hydroid was first found in 1999 in Kāneʻohe Bay and in 2000 in Waikīkī (Coles *et al.*, 2002a, 2002b). Coles *et al.* (2006) report it from the island of Hawaiʻi, based upon 2003 collections. It is reported from all seas (Calder, 1997).

Plumularia strictocarpa Pictet, 1893 **Cryptogenic**

This hydroid was first found in 1999 in Kāneʻohe Bay and in 2000 in Waikīkī (Coles *et al.*, 2002a, 2002b). Coles *et al.* (2006) report it from Maui, based upon 2003 collections. It is reported from all seas (Calder, 1997).

Plumularia setacea (Linnaeus, 1758) **Cryptogenic**

= (?) *Plumularia milleri* Nutting, 1905, from Hawaiʻi (1902) (see Calder, 1991, and discussion below)

= (?) *Plumularia corrugata* Nutting, 1900 as reported by Nutting (1905) (see below)

Cooke (1977a) reported *P. setacea* from Kāneʻohe Bay, on a variety of substrates. He suggested that the material referred to by Edmondson (1946a, Fig. 13d) is "this species (or one similar)." Bailey-Brock (1989) recorded it on PVC settlement plates on an artificial reef in open waters at 20 m, 2.4 km off the southeast coast of Oʻahu. *Plumularia setacea* is regarded as a temperate and tropical cosmopolitan species (Calder, 1997). Cranfield *et al.* (1998) concluded that *P. setacea* was native to Europe and introduced to the Pacific Ocean, including New Zealand. We treat it as cryptogenic, whose origin remains unclear.

Calder (1997) concurred with earlier taxonomic conclusions that a hydroid described from Hawaiʻi, *Plumularia milleri*, by Nutting (1905) is one of many synonyms of *P. setacea*, and that *Plumularia corrugata* Nutting, 1900, was also a synonym. However, reminiscent of the situation with *Sertularella diaphana* and *S. torreyi*, we note that *P. milleri* was described from 173 m off the north coast of Maui, a habitat unusually deep for harbor-dwelling fouling hydroids. *Plumularia corrugata*, as reported by Nutting (1905), was from 223 m off the north coast of Maui, a habitat also deep for the *genre* of shallow-water fouling species considered here. Re-examination of this deeper-water material from Hawaiʻi would be of value.

Haloptericidae

Antennella secundaria (Gmelin, 1791) **Cryptogenic**

This hydroid was first found in 1999 in Kāneʻohe Bay and in 2000 in Waikīkī (Coles *et al.*, 2002a, 2002b); it also occurs in Kanunakakai Harbor, Molokaʻi (Coles *et al.*, 2004). It is circumglobal in tropical and warm temperate waters of the Atlantic, Pacific, and Indian Oceans (Calder, 1997).

Halopteris polymorpha (Billard, 1913) **Cryptogenic**

This hydroid was first found in 1999 in Kāneʻohe Bay and in 2000 in Waikīkī (Coles *et al.*, 2002a, 2002b); it also occurs in Kahului Harbor, Maui (Coles *et al.*, 2004). It was previously known from the Indo-West Pacific and Brazil (D. Calder, identification and pers. comm. to S.L. Coles, 2001).

Halopteris diaphana (Heller, 1868) **Cryptogenic**

Cooke (1977a) reported this hydroid, cosmopolitan in tropical seas, from a variety of substrates in Kāneʻohe Bay. In more recent years it has been found in Kahului Harbor, Maui (Coles *et al.*, 2004).

Aglaopheniidae

Lytocarpia phyteuma (Kirchenpauer, 1876) **Cryptogenic**

This species was first found in 2001 in Waikīkī (Coles, 2002b).

Lafoeidae

Anthohebella parasitica (Ciamician, 1880) **Cryptogenic**

This hydroid was first found in 1999 in Kāne‘ohe Bay and in 2000 in Waikīkī (Coles *et al.*, 2002a, 2002b). It was previously known from the eastern Atlantic Ocean and the Indo-West Pacific (D. Calder, identification and pers. comm. to S.L. Coles, 2001).

Campanulariidae

We regard several Hawaiian campanulariids found largely in fouling communities as introduced by ships. Edmondson & Ingram (1939) reported unidentified campanulariids in Kāne‘ohe Bay in 1935 and later years, doubtless representing one or more of the following species. Long (1974) reported an *Obelia* sp. found on fouling panels outside of Pearl Harbor.

Obelia dichotoma (Linnaeus, 1758) **Introduced**

This fouling hydroid, possibly of Atlantic origin, has been reported from Pearl Harbor and Kāne‘ohe Bay by several workers since the 1970s (Cooke, 1977a; Grovhoug, 1979; Grovhoug & Rastetter, 1980; Coles *et al.*, 2002a). Bishop Museum collections contain material (BPBM-D458) collected in October, 1972, in Kāne‘ohe Bay by T. Gosliner. It has likely been in the Islands for a great many years. Cornelius (1975) did not cite Hawaiian records.

Obelia bidentata Clark, 1875 **Introduced**

= *Laomedea bicuspidata*

This fouling hydroid, also possibly of Atlantic origin, was listed (as *Laomedea bicuspidata*) by Vervoort (1946) from Hawai‘i, with no further details [Cornelius (1975) repeated this citation]. Grovhoug (1979) recorded it from Pearl Harbor (1978 collections) as *Obelia bidentata* (?). It is not listed by Cooke (1977a). Coles *et al.* (2002a) list it for Kāne‘ohe Bay.

Clytia latitheca Millard & Bouillon, 1973 **Cryptogenic**

This hydroid was first found in 1999 in Kāne‘ohe Bay (Coles *et al.*, 2002a). It was previously known from the Indian Ocean and Bermuda (D. Calder, identification and pers. comm. to S.L. Coles, 2001).

Clytia hemisphaerica (Linnaeus, 1767) **Cryptogenic**

Cooke (1977a) recorded this fouling species from many different sites in Kāne‘ohe Bay, based upon collections made in 1972 (W. Cooke, pers. comm., July 1996). Grovhoug (1979) reported it from Pearl Harbor (1978) and Grovhoug & Rastetter (1980) recorded it from both Pearl Harbor and Kāne‘ohe Bay (1976–1977). It is to be expected in nonfouling facies in Hawai‘i, considering reports of it on sea grasses on intertidal sandflats and other habitats in Fiji (Gibbons & Ryland, 1989), if correctly identified there. Calder (1991) has provided a long list of synonyms and taxonomic discussion.

Thyroscyphidae

Thyroscyphus fruticosus (Esper, 1793) **Cryptogenic**

This Indo-Pacific species was first collected in 1973 by W. Cooke in Honolulu Harbor, at 0.3 m “on rubble”, where it still occurs (Coles *et al.*, 1999b, as *T. fructicosus*). It also occurs in Nawiliwili Harbor, Kaua‘i, and is very abundant in Hilo Harbor (Coles *et al.*, 2004).

Syntheciidae

Synthecium megathecum Billard, 1924 **Cryptogenic**

= *Synthecium tubithecum* of authors, not Allman, 1877

This cryptogenic species was reported by Cooke (1977a, as *Synthecium tubitheca*) from Kāne‘ohe Bay in 1–2 m of water as moderately common on coral rubble (based on collections made in 1972; W. Cooke, pers. comm., July 1996); it still occurs there (Coles *et al.*, 2002a). It also occurs at Waikīkī (Coles *et al.*, 2002b). Nutting (1905, as *Synthecium tubithecum*) much earlier reported this species

from Hawai‘i based upon collections made in 1902 by the R/V *Albatross*. These collections were off the south coast of Moloka‘i (in 128 m), and of the northeast coast of Hawai‘i (in 53 m). As with *Sertularella tongensis* and *Plumularia setacea*, the specimens upon which these deeper water records of *S. tubithecum* are based bear reexamination, and we use 1972, rather than 1902, as the first date of record.

Relative to the specific name, D. Calder (pers. comm., June 2003) advises using *S. megathecum* for Pacific populations, and reserving at this time the name *S. tubithecum* for Atlantic populations.

Sertulariidae

Dynamena crisioides Lamouroux, 1824 **Cryptogenic**

This cryptogenic species was reported by Cooke (1977a) from Kewalo Basin and Honolulu Harbor, O‘ahu, “where [it is] common on substrates of rock and rusting iron.” Bishop Museum collections contain material collected in October 1972 by W. Cooke in Honolulu Harbor. It also occurs in Ke‘ehi Lagoon and Barbers Point Harbor (Coles *et al.,* 1999b) and in Kāne‘ohe Bay (Coles *et al.*, 2002a). Coles *et al.* (2006) report it from Kaua‘i, based upon 2003 collections.

As with the previous species, it is widely recorded from the tropical Atlantic, Pacific, and Indian Oceans (Cooke, 1977a; Calder, 1991) and may also represent one or more species. This is primarily an intertidal species, apparently (Calder, 1991), and Gibbons & Ryland (1989) note that in Fiji it is “the only hydroid to occur on coral boulders that endure long emersion.” Cooke (1975) made similar remarks about this hydroid’s intertidal adaptations.

Dynamena cornicina McCrady, 1859 **Cryptogenic**

This cryptogenic species was reported by Cooke (1977a) from Coconut Island, Kāne‘ohe Bay, based upon material collected in 1972 (W. Cooke, pers. comm., July 1996). It is also recorded from the tropical Atlantic, Pacific, and Indian Oceans (Cooke, 1977a) and may represent one or more species. Gibbons & Ryland (1989) report this species as “widely distributed on sublittoral rock” in Fiji up to about the low water mark. However, Calder (1991) notes that this species may be synonymous with *Dynamena disticha* (Bosc, 1802). It is also reported from Nawiliwili and Port Allen Harbors, Kaua‘i, Kaunakakai Harbor, Moloka‘i, and Kahului Harbor, Maui (Coles *et al.*, 2004).

Dynamena quadridentata (Ellis & Solander, 1786) **Cryptogenic**

This hydroid was first found in 2001 in Waikīkī (Coles *et al.*, 2002b). It occurs widely in the Atlantic, Indian, and Pacific Oceans (Calder, 1991).

Sertularella areyi Nutting, 1900 **Cryptogenic**

This hydroid was first found in 1999 in Kāne‘ohe Bay and in 2000 in Waikīkī (Coles *et al.*, 2002b). It was previously known from the western Atlantic Ocean, Japan, and Korea (D. Calder, identification and pers. comm. to S. Coles, 2001).

Sertularella tongensis Stechow, 1919 **Cryptogenic**

This hydroid was first found in 1999 in Kāne‘ohe Bay (Coles *et al.*, 2002a, 2002b). It was previously known from the western Pacific Ocean (D. Calder, identification and pers. comm. to S.L. Coles, 2001).

Sertularella diaphana (Allman, 1885) **Cryptogenic**

= *Sertularella speciosa* Congdon, 1907

= (?) *Sertularella torreyi* Nutting, 1905, from Hawai‘i (1902) (see Calder, 1991, and discussion below)

Cooke [1977a, as *S. speciosa* (type locality, Bermuda) but noting the probable synonymy with *S.*

diaphana (type locality, Australia)] extended the range of this species to the Hawaiian Islands by reporting it from Kāne‘ohe Bay “from shallow water”, based upon material collected in 1972 (W. Cooke, pers. comm., July 1996). Hoover (1998, 2006) illustrates specimens from Palea Point, O‘ahu, in 7 m of water.

Based upon many synonyms, this is a cosmopolitan hydroid occurring in the Atlantic, Pacific, and Indian Oceans (Calder, 1991), or it is perhaps a species complex. Calder (1991) concurred with earlier taxonomic conclusions that a hydroid described from Hawai‘i, *Sertularella torreyi*, by Nutting (1905) is another synonym of *S. diaphana*. We note, however, that Nutting’s material was from deep water (128 m) off the south coast of Moloka‘i, as well as from between 742 and 1372 m off Kaua‘i, suggesting a re-evaluation of shallow-water and deep-water taxa may be of value.

Sertularia subtilis Fraser, 1937 **[See Discussion]**

Cooke (1977a) extended the range of this western tropical Atlantic Ocean (previously known from Puerto Rico) species into the Pacific Ocean by reporting it from Kahe Point, O‘ahu. However, *S. subtilis* is a poorly known species, and Cooke’s specimens are regarded as a misidentification of *Tridentata hupferi* (D. Calder, pers. comm., June 2003).

Tridentata loculosa Busk, 1852 **Cryptogenic**

= *Sertularia ligulata* Thornely, 1904

This widespread tropical Atlantic, Pacific, and Indian Ocean hydroid was reported by Cooke [as *Sertularia ligulata* (Lamouroux, 1816)], from the surface of *Porites lobata* in 2 m of water in Kāne‘ohe Bay (material collected in 1972; W. Cooke, pers. comm., July 1996). It was found again in 1999 in Kāne‘ohe Bay and in 2000 in Waikīkī (Coles *et al.*, 2002a, 2002b, the latter as *Tridentata ligulata*).

Tridentata hupferi (Broch, 1914) **Cryptogenic**

= *Sertularia subtilis* of Cooke (1977a), not Fraser, 1937

Cooke (1977a) reported this species (as *Sertularia subtilis*) from 2 m of water in coral rubble at Kahe Point reef, based upon material collected in 1972 (W. Cooke, pers. comm., July 1996). Cooke’s identification of *S. subtilis* is regarded as a misidentification of *Tridentata hupferi* by D. Calder (pers. comm., June 2003). It still occurs in Kāne‘ohe Bay, based on 1999 collections identified by D. Calder (Coles *et al.*, 2002a, as *T. humpferi*). It was previously known from West Africa, the Seychelles, and Fiji (D. Calder, identification and pers. comm. to S.L. Coles, 2001).

Tridentata turbinata (Lamouroux, 1816) **Cryptogenic**

This hydroid was first found in 2001 in Waikīkī (Coles *et al.*, 2002b). It is widely distributed in the Indian, Pacific, and Atlantic Oceans (Calder, 1991).

Tridentata distans (Lamouroux, 1816) **Cryptogenic**

This species was reported by Cooke (1977a, as *Sertularia distans gracilis*) from coral rubble at 2 m at Kahe Point Reef, O‘ahu (material collected in 1972; W. Cooke, pers. comm., July 1996). It was reported again in 2001 in Waikīkī (Coles *et al.*, 2002b). It is widely distributed in the Indian, Pacific, and Atlantic Oceans (Calder, 1991).

Tridentata marginata (Kirchenpauer, 1864) **Cryptogenic**

This hydroid was first found in 2001 in Waikīkī (D. Calder pers. comm. June 2002 to S.L. Coles). It is widely distributed in the Indian, Pacific, and Atlantic Oceans (Calder, 1991).

Class Anthozoa (corallimorpharians, corals and anemones)

Introduced and Cryptogenic Anthozoa

Species	Date	Vector	Native to
Introduced Species			
Culicia rachelfitzhardingeae	1983	SF, BW	Indo-Pacific
Carijoa riisei	1972	SF, BW	Indo-Pacific
Diadumene leucolena	1950s	SF, BW, R	Northwest Atlantic
Diadumene lineata	1999	SF, BW, R	Japan
Diadumene franciscana	1998	SF, BW	Unknown
Cryptogenic Species			
Sarcothelia sp.	2000	SF, BW	
Additional Taxa Treated and Their Status			
Discosoma nummiforme	1997	R	Indo-Pacific
Status: *Released not established*			
Dendronephthya sp.	1980s	BW?	Indo-Pacific
Status: *Failed*			
Montipora turgescens			
Status: *Native*			

Order Corallimorpharia (corallimorpharians)
Stichodactylinae
Discosoma nummiforme Leuckart *in* Rüppell, 1828 **Released**; **Not Established**
= *Actinodoscus nummiformis*

Coles *et al.* (1999b, p. 47) reported that this anthozoan was first found in the Ala Wai Yacht Harbor in December 1997 by Waikīkī Aquarium staff. The specimens "were artificially attached to a piece of coral rubble, indicating that the organisms had been discarded from a salt-water aquarium. Three small clumps were still growing at the site in April 1999, but the organism has not been observed elsewhere in or outside of the harbor." It is considered a private release (D. Gulko, pers. comm., 2003).

The colonies expanded despite a few attempts to remove them between 1999 and 2004, at which time a formal eradication was launched; no further colonies or individual polyps were detected as of fall 2006 (A. Montgomery & S. Pelleteri, pers. comm., February 2007).

Order Scleractinia (stony corals)

A thorough study of the pre- and post-World War II coral diversity in the Islands, and a comparison with the islands fossil record, remains to be undertaken. Grigg (1981) noted a hypothesis that *Acropora* species "may have been introduced by man via vessel traffic between Hawaii and other islands where *Acropora* exists" but concluded that "In light of the geological record, it is unlikely that *Acropora* was introduced to Hawaii by man. We know from the reef core at French Frigate Shoals that *Acropora* was in the Hawaiian Islands at least 100 years before Western contact. There is a remote possibility that *Acropora* could have been introduced by the early Polynesians on the bottoms of their canoes. However, if this were true, *Acropora* should be present in the high islands where the majority of the Hawaiians settled." Maragos *et al.* (2004) noted seven species of *Acropora* were present in the Northwestern Hawaiian Islands and were nearly absent from the main islands.

Specimens of living and dead corals from the Indo-Pacific and not otherwise known from Hawai'i occasionally are encountered in shallow waters of O'ahu and other islands. These are usually discarded specimens from aquaria, or may on occasion represent actual attempts to establish new colonies of "exotic" (in the aquarium trade sense) species.

Rhizangiidae

Culicia rachelfitzhardingeae Cairns, 2006 **Introduced**

= *Culicia* sp., cf. *C. tenella* of Fitzhardinge (1985, 1993) not of Dana, 1846

This small (4 mm in diameter and 1.5 mm in height) ahermatypic coral was first recorded in 1983 by Fitzhardinge (1985, 1993) from Kāne‘ohe Bay, where it exists both as solitary polyps and as “pseudocolonies” of asexually budded clones. Fitzhardinge recorded it on the underside of coral rubble and beneath coral colonies; *Culicia* also settled on experimental concrete blocks. Fitzhardinge & Bailey-Brock (1989) reported it settling on artificial reef materials in Kāne‘ohe Bay and noted that this coral recruited in all seasons.

In 2002–2003 Pakki Reath collected additional specimens in fouling communities on Kaua‘i (the main pier at Nawiliwili Harbor, 2002, and at the main docks at Port Allen, 2002) and on Moloka‘i (Kaunakakai Dock, 2003); it was also collected at Maui and Hawai‘i in 2002–2003 (Coles *et al.*, 2004; Cairns, 2006). It may have been overlooked in Pearl Harbor fouling surveys in 1996 because of its small size and cryptic nature (S.L. Coles, pers. comm., January 2004).

This fouling coral was described as a new species from Hawai‘i in 2006; it is known not from elsewhere. The last shallow-water endemic Hawaiian coral was described in 1907 (S. Cairns, pers. comm., November 2005). Although this is a small species, it is not likely to have been overlooked prior to the 1980s, as many of the same habitats and locations were well-collected and well-explored prior to this time. It is restricted to docks and harbors or to very shallow water in locations known to be highly invaded, such as Kāne‘ohe Bay.

Species of *Culicia* are widespread through the Indo-Pacific (Maragos, 1974; Maragos & Jokiel, 1978; Veron, 1986; Cairns *et al.*, 1999; Randall, 2003). We believe this coral was introduced to the Hawaiian Islands in ship hull fouling.

Acroporidae

Montipora turgescens Bernard, 1897 **Native**

Coles (1998) discovered this widespread Indo-Pacific coral in the Hawaiian archipelago in 1997 at the “Reef Hotel” in eastern Midway Atoll lagoon. Originally described from the Great Barrier Reef, it occurs from the Red Sea to the southern islands of Japan, and throughout the Indo-Pacific to the islands of French Polynesia and the Caroline and Phoenix Islands. Nonetheless, the closest populations to Midway are over 3500 km to the west and southwest in southern Japan (Coles, 1998). Coles thus noted that the “most likely origin by natural colonization is Japan, with planulae having been transported eastward on the North Pacific current”, but further commented that “as an alternative to natural transport by currents, *M. turgescens* may have been transported to Midway in the last century as hull fouling or in ballast water of ships utilizing the Midway harbor.” Maragos *et al.* (2004) found this coral more widely distributed in the Northwestern Hawaiian Islands, increasing in occurrence along the northwest half of the chain, and noted that the Hawaiian form of this species has not been observed outside Hawai‘i and does not conform to published photographs, suggesting that a cryptic endemic species may be involved.

Subclass Octocorallia

Order Alcyonacea (soft corals)

Nephtheidae

Dendronephthya sp. **Failed**

Gulko (1998) reproduced a photograph (derived from a video tape) of a colony of “*Dendronephthya* sp.”, a genus of soft coral previously unknown in the Hawaiian Islands, that was taken “a couple of years ago” in approximately 70 m of water [“a couple hundred feet’], “growing on the side of a sewage outfall off of O‘ahu.” Gulko further remarked that, “This probably represents an accidental introduction.” This appears to be the same colony tracked by Richard Brock “over an approximately 7 year period” (while he watched it grow in size) in the 1980s, but searches in the 1990s failed to find it, perhaps because of the impacts to the area where it occurred by Hurricane Iniki in September 1992 (R. Brock, pers. comm. March 2005 to S. Kahng). The colonies were located near Honolulu Harbor and may have been a ship-mediated introduction.

Xeniidae

Sarcothelia sp. **Cryptogenic**

Coles *et al.* (2002a) report this xeniid soft coral from Kāneʻohe Bay (2000) as a first record from Hawaiʻi and as a cryptogenic species. It is not the same as *Sarcothelia edmondsoni* (Verrill, 1928), a species known only from the Hawaiian Islands.

Clavulariidae

Carijoa riisei (Duchassaing & Michelotti, 1860) **Introduced**

= *Telesto riisei*

This "orange soft coral" (Henderson, 1990) or "snowflake coral" (Gulko, 1998; Hoover, 1998, 2006) was long thought to be native to the western Atlantic Ocean, from Florida to Brazil, but has now been shown to be native to the Indo-West Pacific (Kahng, 2005; S. Kahng, pers. comm., November 2005). It was first described from the Caribbean, presumably introduced there in the 19th century by shipping from the Pacific Ocean.

Carijoa riisei was first found in the Hawaiian Islands in 1972 by William J. Thomas in the fouling community in Pearl Harbor (Evans *et al.*, 1974; Thomas, 1978, 1979). Devaney (1977) noted that it was also in Honolulu Harbor and "several other areas along the leeward Oahu coast." Henderson (1990) reported it on the *USS Arizona* in Pearl Harbor (1986 collections); Brock (1995) again reported it from Pearl Harbor (1993); Coles *et al.* (1999a) record its continued presence there (1996 collections). It also occurs in Kāneʻohe Bay (Coles *et al.*, 2002a). Coles & Eldredge (2002) review its apparent spread from harbors to outer coast areas.

Additional records include Honolulu Harbor, Hawaiʻi Kai Marina, Port Allen Harbor, Kauaʻi, Kaunakakai Harbor, Molokaʻi, Kahului and Māʻalaea Harbors and Mala Wharf, Maui, and Hilo Harbor (Coles *et al.*, 1999b, 2002b, 2004, and 2006).

Bishop Museum collections include material collected on July 27, 1972 by Mike Lee, in about 7 m of water ("20 feet") in Pearl Harbor. Colonies can also be found in high energy subtidal sites around Oʻahu (C. Zabin, pers. comm., February 2000). Russo (1994) stated that it occurs to 50 m in the Hawaiian Islands; Grigg (2003) recorded it to 120 m in Hawaiʻi. DeFelice *et al.* (2001) note that it is now throughout the main Hawaiian Islands. Eldredge & Englund (2001) list Kauaʻi, Oʻahu, Molokaʻi, Maui, and Hawaiʻi. Kahng & Grigg (2005) note that it "is commonly observed on hard substrata in shaded habitat with moderate current flow. In the clear oceanic water surrounding Hawaiʻi, *C. riisei* is restricted to shaded habitat at depths shallower than 40 m", and was "not observed ... deeper than 115m."

Hoover (1998, 2006) illustrates specimens from Mākua, Oʻahu, in 6 m of water, noting that it "forms dense colonies in cavities along vertical walls or on the ceilings of caves and overhangs where current is strong, or under docks in harbors were plankton is plentiful. It is abundant on wrecks. It now occurs in all the main Hawaiian Islands and at Midway." Color photographs of this species are also in Gulko (1998) and Fenner (2005).

Grigg (2003) reported that in 2001 *C. riisei* was very abundant at depths of 75 to 100 m on the "Maui Black Coral Bed", where up to 90% of the black coral colonies of *Antipathes dichotoma* and *A. grandis* were dead, having been overgrown by *C. riisei.* Grigg (2004) further discussed the impact of *Carijoa* on the harvest of the black coral *Antipathe*s. Kahng & Grigg (2005) noted the extensive smothering of black coral at depths between 80 and 105 m, and found more than 60% of all black coral colonies "were at least partially overgrown."

Concepcion *et al.* (2008) report a possible second species of *Carijoa* in the Hawaiian Islands. The taxon in question is a transparent species, and a combination of ecological, morphological, and genetic data suggest that it may be a distinct species: these include the absence of green flourescent pigments, always present in *C. riisei*, and the presence of a "unique concatenated mtDNA haploytpe and a unique nDNA SRP54 allele."

Order Actiniaria (sea anemones)

As with many of the Hawaiian corals, several widespread Indo-Pacific sea anemones occur in the Hawaiian Islands. While some of these are potential candidates as introduced species, genetic work on possible source regions, an understanding of their potential (or lack thereof) for long-distance planktonic or drifting dispersal, as well as verification that some of these taxa could interface with human-mediated dispersal vectors (such as fouling or ballast) would be necessary before assigning taxa to a cryptogenic category. An example is the phymanthid anemone *Heteranthus verruculatus* Klunzinger, 1877, known in Kāne‘ohe Bay “on sills of concrete spillways between fish ponds” (Cutress, 1977), and otherwise known from the Red Sea and Eastern Australia. It was not recorded by Verrill (1928) but nor were other apparently native shallow-water actinians reported by Cutress (1977).

Another example is *Gyractis excavata* Bovieri, 1893 [=*Actinogeton sesere* (Haddon & Shackleton, 1893) *fide* England, 1987]. Dunn (1974), upon newly finding this anemone on O‘ahu (in 1973, *fide* England, 1987, p.255) asked “whether this actinian has arrived in the islands only recently, or whether it was overlooked or not recorded” in previous studies. It occurs in Kāne‘ohe Bay on “firm substrates, usually on pieces of dead coral, intertidally and in shallow water on sandy shores and reef flats” (Dunn, 1974) and also on “exposed coasts” at Manana Island, O‘ahu (Cutress, 1977). It is possible to visually lump this anemone in the field with the zoanthiniarian *Palythoa*, and this potential confusion may account for the lack of earlier records (D. Fautin, pers. comm., 18 February 1998). It is known from the Torres Strait (the type locality of *A. sesere*), and by synonymy with other species and by additional collections from Sri Lanka, Zanzibar, South Africa, Western Australia, Aden, Goa, Singapore, and Fiji (England, 1987). Fautin (pers. comm.,1998) notes that she has further collected it in Madang, Papua New Guinea. If the species England identified as synonyms do in fact encompass one biological species, then this is a widespread anemone of the South Atlantic and Indian Oceans.

If taxa such as *Heteranthus* and *Gyractis* are associated with ship-bottom fouling communities, or could be dispersed as planulae or as newly settled stages on floating debris in ballast water, then such distributions could have been achieved long ago, and they should be regarded as cryptogenic.

Diadumenidae

Diadumene leucolena (Verrill, 1866) **Introduced**

This small translucent anemone was probably collected as early as the 1950s in O‘ahu. Hiatt (1954) listed “*Diadumene (leucolena?)*” in his key to Hawaiian invertebrates. Hiatt would have been familiar with *D. leucolena* in his graduate student years at the University of California at Berkeley, as this anemone was used in zoology classes at the time and is common on the eastern shore of San Francisco Bay. He described his *D. leucolena* (1 cm x 4 cm) as having white catch tentacles, with a green-black column distinctly divided into regions and with green or white tentacles. *Diadumene leucolena*, as described by Cutress (1977) has the column distinctly divided into two regions, with a color varying from a dark, dirty green to greenish brown to dirty white. Hiatt’s tentacle description matches that of Hand (1956). Cutress (1977), definitely identifying this anemone, recorded it from Pearl Harbor, Honolulu Harbor, and the Ala Wai Canal. It also occurs in Honolulu Harbor (1997, Coles *et al.*, 1999b) and in Waikīkī (2000, Coles *et al.*, 2002b).

Diadumene leucolena is native to the Northwest Atlantic Ocean as far south as the West Indies and Caribbean (Cutress, 1977) and has also been introduced to the Pacific coast of America (Carlton, 1975, 1979b). Cutress suggested it could have been introduced with commercial oyster culture, although introduction by ships is possible as well. As warmer-adapted genotypes would fair better in Hawai‘i, it may be that this is another Caribbean element in the Hawaiian biota.

Godwin (2003b) notes that *D. leucolena* was present on a barge towed from San Diego to O‘ahu in 1999; *D. leucolena* is a nonnative species in California as well.

Diadumene lineata (Verrill, 1869) **Introduced**

= *Haliplanella luciae* (Verrill, 1898)

Chela Zabin discovered a population of this well-known orange-striped sea anemone on and among Pacific oysters (*Crassostrea gigas*) on intertidal pilings on the south shore of Kāneʻohe Bay on 15 February 1999 (Zabin *et al.*, 2004). In 2002 and 2003 additional specimens were found at Coconut Island in Kāneʻohe Bay in and around empty tests of the barnacle *Amphibalanus reticulatus* on intertidal fouling panels and under a pier on a piece of intertidal coral rock (Zabin *et al.*, 2004).

In November 2000, about 100 individuals of *D. lineata* were found by S. Godwin on a drift net in the lagoon at Pearl and Hermes Reef, Northwestern Hawaiian Islands (Zabin *et al.*, 2004). Whether this net drifted in from other Hawaiian Islands, or from elsewhere in the Pacific, is unknown, although if the latter, it would constitute the first evidence of transoceanic dispersal of a neritic sea anemone.

Native to Japan, it was introduced to the North Atlantic Ocean in the 1890s and to the Pacific coast of North America in the early 1900s (Carlton, 1979a). It has also been introduced to Indonesia, New Zealand, and Brazil (Zabin *et al.*, 2004). This anemone may have arrived in the Hawaiian Islands between the 1970s and late 1990s, as it would not likely have been overlooked by C.E. Cutress (Cutress, 1977), an experienced sea anemone field naturalist and systematist. Possible transport vectors include fouling on commercial or recreational vessels, ballast water, or with imported oysters.

Diadumene franciscana Hand, 1956 **Introduced**

Coles *et al.* (1999b) reported this anemone from Ala Wai Yacht Harbor in Honolulu based upon specimens collected in 1998. It was previously known from bays along the central California coast, to where it is also considered introduced (Carlton, 1979a). Specimens in Ala Wai were found near the Waikīkī Yacht Club and near the outflow into the harbor from Hilton Lagoon. A specimen of what was likely *D. franciscana* was found on the south shore of Kāneʻohe Bay in May 2001 by Chela Zabin and J.T. Carlton (Zabin *et al.*, 2004).

The origin of this anemone is not known, but it may be from the western or southwestern Pacific Ocean, Australasia, or the Indian Ocean (Carlton, 1979b). Shipping has likely led to its presence in the Hawaiian Islands, where it is doubtless more widespread than indicated here.

Classes Scyphozoa (jellyfish) and **Cubozoa** (cubomedusae)

Introduced Scyphozoa and Cubozoa

Species	Date	Vector	Native to
Scyphozoa			
Aurelia sp.	1953	SF, BW	Indo-Pacific
Cassiopea andromeda	1950	SF, BW	Indo-Pacific
Cassiopea sp.	2000	SF, BW	Indo-Pacific
Phyllorhiza punctata	1933	SF, BW	Indo-Pacific
Anomalorhiza shawi	1983	SF, BW	Philippines
Cubozoa			
Carybdea sivickisi	1996	BW	Indo-Pacific

Scyphozoa
Ulmaridae
Aurelia sp. **Introduced**

= *Aurelia labiata* of Hawaiian authors, not of Chamisso & Eysenhardt, 1821

This often abundant shallow-water moon jellyfish was unknown to C.H. Edmondson (1933, 1946a), the premier marine invertebrate zoologist of the Islands from the 1920s to the 1950s, and would not

have escaped his notice. It first came to general attention in the islands when Chu & Cutress (1954) reported it (as *Aurelia labiata*) to be “common the year round in bays and salt-water canals”, relative to reports of human dermatitis (“swimmer’s itch”) in Hawai‘i. Based upon Chu & Cutress’s report, presented at the 1953–1954 annual meeting of the Hawaiian Academy of Sciences, we interpret the first record to be in 1953. Devaney & Eldredge (1977), reporting it as “possibly *A. labiata*,” note that “it is seen, sometimes frequently, in harbors or inshore areas.”

Wrobel & Mills (1998) note it as *A. labiata* from Honolulu, and Gershwin (2001, p. 115) also provisionally assigned Hawaiian *Aurelia* to this species. Dawson *et al.* (2005), based upon genetic comparisons of world-wide *Aurelia* populations, assign Hawaiian populations to a probably unnamed *Aurelia* (“Aurelia species 4”) from the Indo-Pacific and specifically endemic to the region around eastern Borneo and Palau.

W. Cooke (pers. comm., July 1996) alerted us to this introduction, noting that given the biology and life history of both the adult and juvenile stages it could not survive transoceanic transport to the Islands naturally. We regard it as introduced, either as ship-fouling scyphistomae or as ephyrae in ballast water. Bishop Museum material includes 1963–1964 collections from Pearl Harbor, Kāne‘ohe Bay, and Kewalo Basin, all on O‘ahu. Hoover (1998, 2006) illustrates a specimen (as *Aurelia aurita*) from Ala Wai Boat Harbor, Honolulu, a location also noted by Coles *et al.* (1999b).

Cassiopeidae

Cassiopea andromeda (Forsskål, 1775) **Introduced**

Pacific basin *Cassiopea* have been reported from Hawai‘i under two separate names, *Cassiopea medusa* Light, 1914 and *Cassiopea mertensii* Brandt, 1835, both of which are synonyms of *C. andromeda* (reviewed in Holland *et al.*, 2004). Cooke (1984) noted that these *Cassiopea*, with “their pseudobenthic habits are the most improbable adult immigrants.” As *C. medusa*, Chu & Cutress (1954) noted that it was “common the year round in bays and salt-water canals.” Cutress (1961) considered it to be introduced from the Philippines by ships as hull-fouling scyphistomae to Pearl Harbor between 1941–1945. Carlton (1985) suggested that an alternative mechanism of introduction was as ephyrae in ballast water. It was restricted to Pearl Harbor until about 1950 when it appeared in Honolulu Harbor and Ala Wai Canal (Cutress, 1961). As *Cassiopea mertensii* Brandt, 1835, Uchida (1970) reported it from “the sandy bottom at a depth of 2 feet from Kaneche [Kāne‘ohe] Bay,” O‘ahu. This material was collected in February 1964 (Bishop Museum collections). *Cassiopea* were seen in the early 1990s in fishponds on Moloka‘i and in fishponds in Waikoloa area of the island of Hawai‘i (G. Crow, pers. comm., 2000). Hoover (1998, 2006) illustrates a specimen (as *C. medusa*) from the lagoon at Magic Island, O‘ahu. DeFelice *et al.* (2001) note that it now occurs “throughout main Hawaiian Islands.”

Holland *et al.* (2004) confirm the identity of *C. andromeda* based upon molecular evidence from the Hawaiian Islands. *Cassiopea andromeda* is widely distributed in the Indo-West Pacific; distant records are the Red Sea (from where it was described in the 18th century) and the western Atlantic Ocean (Florida Keys and Bermuda), to both of which regions it may be introduced.

Cassiopea sp. **Introduced**

Holland *et al.* (2004) report that a second genetically distinct species of introduced *Cassiopea* (“*Cassiopea* species 3”) also occurs in the Hawaiian Islands. This species of *Cassiopea* also occurs in the Papua New Guinea region. Hawaiian material was collected on windward O‘ahu from Kahuku fish pond, the Wedding Chapel, Mid Pacific Golf Course pond, and Kualoa Ranch. The date of collection of this material was 2000 (B.S. Holland, pers. comm., January 2007).

Magistiidae

Phyllorhiza punctata von Lendenfeld, 1884 **Introduced**

= *Cotylorhizoides pacificus* of Cutress in Doty, 1961 (see Devaney & Eldredge, 1977, p. 114, and Cooke, 1984, p. 587)

Under the name *Cotylorhizoides pacificus*, Cutress (1961) suggested that this Indo-Pacific jellyfish was introduced from the Philippine Islands, as ship-fouling scyphistomae, into Pearl Harbor between

1941–1945. It was, however, present in Pearl Harbor by 1933, as described and photographed by Edmondson (1933; see Devaney & Eldredge, 1977, who noted that the undetermined rhizostomid of Edmondson "certainly appears to be *P. punctata*"; Edmondson's species was also noted as being *P. punctata* by W.J. Cooke in an unpublished bibliography of Hawaiian coelenterates compiled in 1980 and on file in the Bishop Museum's Department of Invertebrate Zoology reprint library. Edmondson (1933) wrote a detailed description of the jellyfish along with a photograph, and noted that "At certain times of the year, usually during the winter months, a large undetermined species of jellyfish is abundant in Pearl Harbor, Oahu ... large specimens exceed 12 inches in diameter."

It may have been restricted to Pearl Harbor until about 1950; in 1953–1954 it appeared in Kāneʻohe Bay (Cutress, 1961). Carlton (1985) suggests that an alternative mode of introduction would be as ephyrae in ballast water. Cooke (1984) feels that the taxonomy of the Hawaiian population was unresolved, and that it should be referred to as a "mastigid," but that "any attempt at more precise identifications... would be unwise." We provisionally retain the name used in Devaney & Eldredge (1977).

Clarke & Abey (1998) note that in Kāneʻohe Bay on "several occasions during 1968–1970 .... approximately 20 [to] 40 cm [in diameter] medusae were visible roughly every 10 m across open areas of the bay, usually with a cluster of small yellowtail scad [*Atule mate*] associated with each one. The rather sudden disappearance of *P. punctata* from Kāneʻohe Bay in the early 1970s thus could have a major effect."

It was recorded again in Pearl Harbor in 1971–1973 (Evans *et al.*, 1974, as *P. punctata*). Devaney & Eldredge (1977, as *P. punctata*) noted that it "occurs, sometimes commonly, in Pearl Harbor, Honolulu Harbor, and Kaneohe Bay." They further note that the undetermined rhizostomid of Edmondson (1933, 1946a) abundant in Pearl Harbor during the winter "certainly appears to be *P. punctata*."

Hoover (1998, 2006) illustrates a specimen from the Waikīkī Aquarium, noting that "these impressive jellyfishes can be common in Honolulu Harbor, Pearl Harbor and Kāneʻohe Bay, Oʻahu, mainly during the winter months." DeFelice *et al.* (2001) listed Pearl and Honolulu Harbors, Ala Wai Canal and Yacht Harbor, and Kāneʻohe Bay as the known Oʻahu localities.

Graham *et al.* (2003) have reviewed the global invasion history of *P. punctata*, and taxonomic challenges associated with this jellyfish. It has also been introduced to California, the Mediterranean Sea, the southwest Atlantic Ocean, and the southern Caribbean Sea, and, since 2000, the Gulf of Mexico. Dense populations in the northern Gulf of Mexico in the summer of 2000 impacted shrimp fisheries.

Anomalorhiza shawi Light, 1921 **Introduced**

Cooke (1984) noted that this species, otherwise known from the Philippine Islands, was collected in 1983 and 1984 in Kāneʻohe Bay, Oʻahu. He suggested it was introduced as scyphistomae in ships' fouling communities. Carlton (1985) suggested it may also have been introduced as planktonic ephyrae in ships' ballast water. In February 2001 another specimen was collected in Kāneʻohe Bay, approximately 60 cm in diameter; a photograph appeared in *The Honolulu Advertiser* for February 16, 2001. This jellyfish remains unknown from any other locations in the Islands and is considered "extremely rare" (T. Theeger, pers. comm., February 1998).

Class Cubozoa (cubomedusae)

Carybdeidae

Carybdea sivickisi Stiasny, 1926 **Introduced**

This small (14 mm) but distinctive cubomedusa (box jellyfish) was first collected in 1996 at Waikīkī in Oʻahu (Matsumoto *et al.*, 2002). We suggest that it would not have been overlooked by Edmondson, who collected and noted gelatinous zooplankton between the 1920s and 1950s. Described from the Philippines, it has since been found in Thailand, Japan, New Zealand (Matsumoto *et al.*, 2002), Vietnam (Hartwick, 1991), Australia (Hartwick, 1991), and Guam (Gershwin, 2003). On Oʻahu it is found, curiously enough, in a saltwater swimming pool known as the Natatorium (opened in 1927), fed by ocean water. It has also been found outside of Yokohama

Bay on the west coast of O‘ahu (1998). Crow *et al.* (2006) report it from Mā‘alaea Boat Harbor, Maui, based upon night-lighting collections in 2005 and 2006.

Carybdea sivickisi, which can cause a painful sting, is benthic during the day and in the water column at night (Hartwick, 1991). We suggest ballast water transport, perhaps facilitated by the uptake of medusae during the periodic presence of breeding swarms (http: //www.ucmp.berkeley.edu/cnidaria/C_sivickisi.html).

CTENOPHORA (comb jellyfish)

Introduced Ctenophora

Species	Date	Vector	Native to
Vallicula multiformis	1992	BW	Caribbean

Coeloplanidae

Vallicula multiformis Rankin, 1956 **Introduced**

The report of Eldredge & Miller (1995) of a nonindigenous ctenophore in Hawaiian waters is based upon the collection in 1994 of this species in Hawai‘i by Charles Galt. He found this benthic, creeping platyctene comb jelly in Kāne‘ohe Bay, associated with the algae *Acanthophora, Bryopsis, Kappaphycus*, and *Caulerpa* (C. Galt, *in litt*., August 1994). In the summer of 1994, they reached densities of over 3,000 per square meter. It was present on the dock algae at Coconut Island at least by 1992 (C. Fiedler, pers. comm. to C. Galt; C. Galt, *in litt*., August 1996). *Vallicula* occurs both in shallow fouling communities and is known to be transported with algae in the aquarium trade. It also appeared in San Diego, California in 1997 (G. Matsumoto, pers. comm., 1997). *Vallicula multiformis* was originally described from the Caribbean, in Jamaica.

NEMATODA (roundworms)

Introduced and Cryptogenic Nematoda

Species	Date	Vector	Native to
Introduced Species			
Camallanus cotti	1993	R	Asia
Cryptogenic Species			
Spirocamallanus istiblenni	1962	R?	

Order Secernentea

Camallanidae

Camallanus cotti Fujita 1927 **Introduced**

This Asian nematode—a “pernicious helminth” (Font,1997a)—occurs in the introduced euryhaline mosquitofish *Gambusia affinis* and the introduced freshwater poecilid (swordtail) *Xiphophorus helleri* in Hawai‘i (Font, 1997a, 1997b; Font & Tate, 1994). Records include it occurring in *X. helleri* in June 1993 in Hakalau Stream, Hawai‘i. Englund *et al.* (2000a) reported it from additional fish hosts in Pearl Harbor, including brackish water sites.

Spirocamallanus istiblenni Nobel, 1966 **Cryptogenic**

Nobel (1966) described this nematode as a new species from the native zebra blenny (*pao‘o*), *Istiblennius zebra*, collected on O‘ahu in 1962 and 1963. It also occurs in the native sleeper *Eleotris*

sandwicensis (Font,1997a). While *S. istiblenni* was assumed to be native, Rigby & Font (1997) subsequently found it in Moorea and Fiji in marine fishes, including the bluestripe snapper (*ta'ape*) *Lutjanus kasmira*. Because *ta'ape* were introduced to Hawai'i, "it is problematic whether (this nematode) should be regarded as a native or exotic species" in the Hawaiian islands (Font, 1997a). Font (1997b) treated it as "native." Font & Rigby (2000) subsequently found this nematode in *Lutjanus kasmira* from Hilo Bay and conclude that it is cryptogenic. They suggest that examination of museum specimens of native freshwater fish from Hawai'i collected prior to the introduction of *ta'ape* in 1958 may be able to resolve whether this parasite is native or not.

ROTIFERA (rotifers)

Cryptogenic rotifers in brackish water of Maui
(data from Jersabek, 2003; designation as cryptogenic herein)

Species	Location*	Notes
Brachionus plicatilis (Müller, 1786)	CP, KeP, KaP	A probable species complex
Colurella adriatica Ehrenberg, 1831	CP KaP	
Hexarthra oxyuris (Sernov, 1903)	KeP	Previously recorded from an O'ahu brackish pool by Hauer, 1941, as *Pedalia fennica* (Levander, 1892) (Jersabek, 2003).
Lecane hastata (Murray, 1913)	CP	
Proalides sp., cf. *P. wulferti* Sudzuki 1959	CP, KaP	A Palaearctic (Europe, North Africa, and Asia north of the tropics) species.

* CP, Coot Pond; KeP, Kealia Pond; KaP, Kanahā Pond

Turner (1996) and Jersabek (2003) present lists of the rotifers of the Hawaiian Islands. Many of these are "cosmopolitan" taxa and bear European names. It seems probable that a number of these are introduced, but data remain too limited to make such determinations. We offer a table here of five brackish-water species (from Jersabek's work) that may be considered cryptogenic. All are considered "cosmopolitan" with the exception of *Proalides wulferti*, which was "previously known from the Palaearctic region only but may have been confused with *P. tentaculatus* de Beauchamp" (Jersabek, 2003). All but *Hexarthra oxyuris* were new records for the islands, based upon 2001 collections, but all of these species were doubtless present much earlier. As Jersabek notes, possible transport vectors include intentional releases of nonnative fish, clams, or ornamental plants, as well as the movement of resting stages with tourist luggage and clothing. To these vectors we add the usual shipping vectors for marine and brackish water species.

PLATYHELMINTHES (flat worms)

Introduced and Cryptogenic Platyhelminthes

Species	Date	Vector	Native to
Introduced Species			
"Turbellaria"			
Taenioplana teredini	1938	SB	Unknown
Trematoda			
Ascocotyle tenuicollis	1993	R	North America
Monogenea			
Salsuginus seculus	<1997	R	North America
Neobenedenia melleni	1981	R	North America
Cestoda			
Bothriocephalus acheilognathi	1993	R	Asia

Introduced and Cryptogenic Platyhelminthes (continued)

Species	Date	Vector	Native to
Cryptogenic Species			
"Turbellaria"			
Convolutriloba sp.	1970s	BW	

Additional Taxon Treated and Its Status

Trematoda
Centrocestus formosanus
Status: *Presence in brackish-marine waters in Hawai‘i not known; see discussion*

Class "Turbellaria" (flatworms)
Poulter (1987) lists several species of marine flatworms with "cosmopolitan" or disjunct distributions (for example, "Brazil and Hawaii", or "Red Sea and Hawaii"). Karling *et al.* (1972), for example, newly reported the microturbellarian *Gyratrix hermaphroditus* Ehrenberg, 1831, a "holeuryhaline (*sic*) cosmopolite and ubiquist" from the Pacific Ocean, from the American Pacific coast (as "Karling, unpublished'), and from Kāne‘ohe Bay, "on coral reefs and in sand in the tidal zone" at Coconut Island, based upon 1969 collections.

The distribution and systematics of most marine turbellarians are poorly known, and it is thus difficult to recognize either introduced or cryptogenic species in the Hawaiian fauna. That noted, there has been and remains striking potential for nonnative shallow water flatworms to be transported to the Hawaiian Islands in fouling, in ballast water, in ballast rock or sand, and with commercial oysters, as well as by other means, and careful attention needs to be paid to the probability of synanthropic dispersal for a great many species.

Order Acoela
Convolutidae
Convolutriloba sp. (?) **Cryptogenic**
Poulter (1987) noted the presence of "?*Convoluta* sp." in marine laboratory aquaria in Kewalo Basin, as well as in the laboratory aquaria at Coconut Island and in the wild in Kāne‘ohe Bay. Michael Hadfield first noted it between 1973 and 1978, but it may have been here much earlier (M. J. Hadfield, pers. comm., February 2000). This small (to 6 mm) green-brown-orange worm contains symbiotic algae. It is of interest to note that the acoel *Convolutriloba longifissura* was found in a seawater aquarium in Austria which had been set up with "material from the Pacific" (Gschwentner *et al.*, 1999).

Given the potential for convolutid acoel flatworms to be transported transoceanically (Rivest *et al.*, 1999) the human-mediated dispersal of this distinctive, sometimes abundant species is possible. Although this conspicuous flatworm was not likely to have been overlooked by C.H. Edmondson in his explorations of the fauna for many years between the 1920s and 1950s, we conservatively regard it as cryptogenic.

Order Polycladida
Euplanidae
Taenioplana teredini Hyman, 1944 **Introduced**
Hyman (1944) described this commensal flatworm as a new species from *Teredo* burrows (species not identified) from Honolulu Harbor. Edmondson (1945a) reported it as very abundant in Honolulu Harbor during 1943–1944, but "conspicuously absent during 1945." Edmondson (1945b) noted that it was first observed in 1938, being recovered from burrows of shipworms in test blocks in Honolulu Harbor; he provides a detailed description of the worm and some notes on its biology. Poulter (1987) reports it in burrows of *Teredo* (species not identified) in Honolulu Harbor, Waikīkī, and Kāne‘ohe Bay. Bishop Museum collections contain material collected by C.H. Edmondson between 1941 and 1944 (the latter being the date of the paratypes). Hyman (1944) noted that the entire life cycle of this

flatworm is completed inside the shipworm burrows, where the eggs are laid as well. She speculated that *Taenioplana*, as a shipworm predator, "may constitute an important enemy of this pest." It is likely found wherever shipworms are common and thus should be expected in Pearl Harbor as well. Now widely reported from the Atlantic and Pacific Oceans, its origin remains unknown.

Class Trematoda (flukes)
Martin (1958) reported the Asian heterophyid trematodes *Centrocestus formosanus* (Nishigori, 1924) and *Haplorchis taichui* (Nishigori, 1924) from freshwater snails in Hawai'i. Both may use poeciliid fish and snails as hosts in their life cycle. To our knowledge neither of these flukes has been reported in either brackish or freshwater introduced poeciliids in Hawai'i. *Centrocestus formosanus* specifically uses the mosquito fish *Gambusia affinis* and the snail *Melanoides tuberculata* as hosts (Mitchell *et al.*, 2005), both of which are found in brackish waters in Hawai'i.

Order Opisthorchiida
Heterophyidae
Ascocotyle tenuicollis Price, 1935 **Introduced**
Font (1997a, 1997b) reported this North American helminth parasite from the heart of the introduced mosquito fish *Gambusia affinis*, from specimens from the Island of Hawai'i, presumably based upon 1993 collections. This trematode uses introduced melanid snails as their first intermediate host, fishes as the second intermediate host, and birds as the definite hosts for the adult parasite. This parasite has been found in fish at Seaside, in Hilo, in salinities of 5 ‰ (W. Font, pers. comm., June 2003).

Class Monogenea (flukes)
Order Pseudophyllidea
Dactylogyridae
Salsuginus seculus (Mizelle & Arcadi, 1945) **Introduced**
Font (1997a) reported this North American parasite from the gill filaments of the introduced mosquito fish *Gambusia affinis*, from specimens from Hawai'i (no specific locality records or dates are given). This parasite infects mosquito fish in brackish estuaries in Louisiana (W. Font, pers. comm., June 2003), and since *Gambusia* occurs in both freshwater and brackish water in Hawai'i, we include this parasite here.

Capsalidae
Neobenedenia melleni (MacCallum, 1927) **Introduced**
This ectoparasite was reported from introduced tilapia (*Oreochromis mossambicus*) acclimated to full marine water and held in experimental cages in Kāne'ohe Bay, based upon specimens first noted in 1981 (Kaneko *et al.*, 1988). The original fish were collected from "fresh to brackish water" on O'ahu. Kaneko *et al.* (1988) considered that tilapia, "a euryhaline freshwater fish is not a normal host of *N. melleni*, which apparently maintains itself on natural hosts in Kaneohe Bay" (which have not been identified). Based upon the global distributions reported by Whittington & Horton (1996), which identify two geographic clusters for this species (the Western Atlantic and the Eastern Pacific), with outlier populations in the Red Sea and Hawai'i, we regard this fluke as not native.

Class Cestoda (tapeworms)
Bothriocephalidae
Bothriocephalus acheilognathi Yamaguti,1934 **Introduced**
The well-known Asian fish tapeworm has been moved around the world with carp (*Cyprinus carpio*) aquaculture and by the introduction of poeciliid fishes (*Gambusia*) for mosquito control (Dove *et al.*, 1997; Font, 1997a, 1997b; Font & Tate, 1994). It has been found on the island of Hawai'i in the introduced poeciliids *Xiphophorus helleri* (swordtail) and *Poecilia reticulata* (Font & Tate, 1994) based upon collections made in 1993. As *Poecilia reticulata* also occurs in brackish water, we include this parasite here.

ANNELIDA (true worms)

Introduced and Cryptogenic Annelida

Species	Date	Vector	Native to
Introduced Species			
Polychaeta			
Ophryotrocha adherens	1973	SF, BW	Europe
Neanthes arenaceodentata	1950s	SF, BW	Northwest Atlantic
Neanthes succinea	1941	SF, BW, R	Northwest Atlantic
Myrianida pachycera	1959	SF, BW	Indo-West Pacific
Eumida sanguinea	1966	SF, BW, R	Unknown
Polydora nuchalis	1988	FO	Northeast Pacific
Polydora websteri	1940s	FO	Northwest Atlantic
Streblospio benedicti	1977	SF, BW, R	Northwest Atlantic
Chaetopterus sp.	1960	SF, BW	Unknown
Branchiomma japonica	1946	SF, BW	Japan
Sabellastarte spectabilis	1946	SF, BW	Philippines
Ficopomatus enigmaticus	1937	SF, BW	Australia
Hydroides brachyacanthus	1939	SF, BW	Eastern Pacific
Hydroides cruciger	1936	SF, BW	Eastern Pacific
Hydroides diramphus	1900	SF, BW	Western Atlantic?
Hydroides elegans	1929	SF, BW	Indo-Pacific?
Pomatoleios kraussii	1967	SF, BW	Indo-Pacific
Salmacina tribranchiata	1935	SF, BW	Eastern Pacific
Serpula watsoni	1936	SF, BW	Indo-West Pacific
Janua pagenstecheri	1960s	SF, BW	Northeast Atlantic
Pileolaria militaris	1960s	SF, BW	Northeast Atlantic?
Cryptogenic Species			
Oligochaeta			
Bathydrilus adriaticus	1986	BW, SBA	
Pectinodrilus rectisetosus	1987	BW, SBA	
Pectinodrilus molestus	1986	BW, SBA	
Thalassodrilides gurwitschi	1987	BW, SBA	
Smithsonidrilus minusculus	1987	BW, SBA	
Limnodriloides rubicundus	1987	BW, SBA	
Tectidrilus bori	1986	BW, SBA	
Polychaeta			
Spinther japonicus	1976	SF, BW	
Lumbrineris sphaerocephala	1987	SF, BW	
Mesonerilla fagei	1997	BW, SBA	
Platynereis abnormis	1950s?	SF, BW	
Namalycastis abiuma	1995	BW, SBA	
Namalycastis hawaiiensis	1900	BW, SBA	
Namanereis amboinensis	1987	BW, SBA	
Namanereis littoralis	1970s	BW, SBA	
Capitella sp.	1975	SF, BW	
Malacoceros sp.	1978	SF, BW	
Minuspio sp.	1970s	BW	
Armandia intermedia	1979	SF, BW	
Eulaeospira orientalis	1960s	SF, BW	
Leodora knightjonesi	1960s	SF, BW	
Neodexiospira foraminosa	1960s	SF, BW	
Neodexiospira nipponica	1960s	SF, BW	
Neodexiospira pseudocorrugata	1960s	SF, BW	
Pileolaria pseudoclavus	1960s	SF, BW	
Simplicaria pseudomilitaris	1960s	SF, BW	
Spirorbis marioni	1960s	SF, BW	
Vinearia koehleri	1960s	SF, BW	

Additional Taxa Treated and Their Status

Species	Date	Vector	Native to
Polychaeta			
Namalycastis brevicornis Status: *Deleted*	1942	BW, SBA	Atlantic Ocean
Namalycastis senegalensis Status: *Deleted*	1942	BW, SBA	Atlantic Ocean
Boccardia proboscidea Status: *Intercept*	1990	R	Northeast Pacific
Clitellata: **Leeches**			
Myzobdella lugubris Status: *See discussion*			

Class Clitellata
Oligochaetes

Erséus & Davis (1989) were the first to suggest that certain members of the marine oligochaete fauna of the Hawaiian Islands may have been introduced by human activities, referring specifically to three species previously known largely from the warm waters of the Western Atlantic Ocean: *Smithsonidrilus minusculus* (treated in Erséus & Davis as *Limnodriloides claviger*), *L. rubicundus,* and *Tectidrilus bori*. However, Erséus & Davis also note the considerable uncertainty in the biogeography and systematics of these and other taxa. We thus consider these three, and several others, as cryptogenic species. Sand ballast may have been a particularly effective mechanism in the 19th and early 20th centuries for the introduction of some of these species. We follow here the updated nomenclature for Hawaiian oligochaetes in Erséus *et al.* (2005).

Tubificidae

Bathydrilus adriaticus (Hrabe, 1971) **Cryptogenic**

Erséus & Davis (1989) were the first to record this sand-dwelling species from Hawai‘i; it was previously known from the western Atlantic (Caribbean), Mediterranean, and Persian Gulf. Hawaiian records are from O‘ahu (Kāne‘ohe Bay, Mōkapu Point, Maunalua Beach) and Maui (Olowalu) all from intertidal sites or shallow subtidal (to 1.5 m), with the exception of a collection at 30 m from Mokapu Point. Erséus & Davis consider it “probably cosmopolitan.” The material was collected in 1986–1987.

Pectinodrilus rectisetosus Erséus, 1979 **Cryptogenic**

Erséus (1988) reported this species (as *Phallodrilus rectisetous*) from Paikō Beach, Maunalua Bay, O‘ahu (1987 material) from “barely subtidal mixed sand.” It was previously known from Italy, the Atlantic coast of France, and Saudi Arabia.

Pectinodrilus molestus Erséus, 1988 **Cryptogenic**

Erséus (1988) reported this species (as *Phallodrilus moletus*) from O‘ahu from three stations: Paikō Beach, Maunalua Bay (1987) from “barely subtidal mixed sand”, from off Ke‘ehi Lagoon, Honolulu, in about 70 m in medium sand (1986) and from Kawaiku‘i Beach Park, Maunalua Bay (1987). It was previously known from the Caribbean (Belize and Barbados), Florida, Bermuda, Great Barrier Reef, and Fiji.

Thalassodrilides gurwitschi (Hrabe, 1971) **Cryptogenic**

Erséus & Davis (1989) newly recorded this intertidal to shallow subtidal brackish water oligochaete, “known from heavily polluted situation(s)”, from O‘ahu (Maunalua Bay, 1987). It was previously known from the Black and Mediterranean Seas, the Caribbean, Persian Gulf, and southern China. Demopoulos *et al.* (2007) record it (as “cf. gurwitschi”) from Moloka‘i, as part of the mangrove infauna.

Smithsonidrilus minusculus (Erséus, 1983) **Cryptogenic**
This species was first recorded from Hawai‘i by Erséus & Davis (1989), as *Limnodriloides claviger*, based upon specimens “tentatively identified” as this species and discovered in shallow muddy sand in Maunalua Bay, O‘ahu (1987). It is also known from the Caribbean (Bermuda and Belize), Australia, and Hong Kong (C. Erséus, pers. comm., 4 January 2008).

Limnodriloides rubicundus Erséus, 1982 **Cryptogenic**
As with *S. minusculus,* Erséus & Davis (1989) tentatively extended the range of this western Atlantic species to Hawai‘i, based upon specimens from O‘ahu (intertidal and shallow waters at Maunalua Bay and Kāne‘ohe Bay, and from 70 m off Ke‘ehi Lagoon, Honolulu; material collected in 1987). *Limnodriloides rubicundus* was previously recorded from Delaware south to Venezuela and Bermuda, with another new record in Australia (Erséus & Davis, 1989, p.97).

Tectidrilus bori (Righi & Kanner, 1979) **Cryptogenic**
As with the group of species of *Limnodriloides,* Erséus & Davis (1989) report this western Atlantic species (Florida to the Caribbean, and Bermuda) in the Pacific Ocean based upon Hawaiian material collected in intertidal and shallow waters at Maunalua Bay and in 70 m off Ke‘ehi Lagoon, Honolulu, in 1986 and 1987. The identification of *T. bori* is considered to be less tentative than that of the other two species.

Leeches
Piscicolidae
Myzobdella lugubris Leidy, 1851 **[See Discussion]**
Font & Tate (1994) and Font (1997a, 1997b) reported the presence of this North American freshwater leech on introduced freshwater fish in Hawai‘i. We note it here because of their speculation that the private release of blue crabs, *Callinectes sapidus*, from the Gulf of Mexico, and on which the egg cocoons of this leech are found cemented to the carapace, may have led to the introduction of this leech (see also Font, 1997a). However, unless a large number of parasitized crabs have been released into Hawaiian waters, the number of *Callinectes* actually found in the wild in Hawai‘i would appear to be too few to support this means of introduction of *Myzobdella*.

Class Polychaeta (polychaetes)
The majority of Hawaiian intertidal and fouling polychaetes have not been previously analyzed in terms of potential candidates for introduced species, and we can present only a preliminary assessment here. Decades and centuries of ship movements can create distributions from the Red Sea and Africa to the Hawaiian Islands to South America and into the Atlantic Ocean that would appear to represent “natural” dispersal or ancient distributions. In short, a great many taxa must eventually be considered cryptogenic. We take a generally conservative view here. A large number of species, even those regarded as endemic and known only from the Hawaiian Islands, may also bear further consideration as cryptogens, especially for those taxa found in association largely with other introduced species. Many nonnative species around the world have first been described in the region to which they were introduced.

Bailey-Brock (1976) has noted that in the Hawaiian Islands, “boat harbors and lagoons have a typically rich fauna due to introduction of benthic invertebrates on the bottoms of boats. Such habitats remain reservoirs of introduced species, which are important in the geographical distribution of tube worms within the islands.” She further noted that in addition to the introduced tubeworm *Ficopomatus* (discussed as *Mercierella*), “the cosmopolitan fouler *Hydroides norvegica* has been dispersed by boats, and it is quite possible that *Hydroides lunulifera*, *Pileolaria militaris*, and others have been spread to and between the islands in the same manner.” We discuss these species below.

Poorly represented in our treatment here are species of Syllidae, Phyllodocidae, and Sabellidae, and not represented at all are species of Eunicidae and Cirratulidae. All five of these families are

often well-represented in ships' fouling communities and ballast water and on commercial oysters, making these families rich fields for exploration for cryptogenic and introduced species. Examples of genera that should be particularly examined for introduced and cryptogenic species are *Phyllodoce*, *Brania*, *Exogone*, *Typosyllis*, *Marphysa*, *Cirriformia*, and *Euchone*.

The Bishop Museum "Progress Report of the Marine Zoology Department" for 1965 stated that information was provided to the State Quarantine Station on the "potential harmfulness of *Nereis japonica* and *Lumbriconereis japonica* if established in Hawaii." The reason for this concern is not given, but it may be that these species were being imported, or were being considered for importation, as fish bait.

Spintheridae

Spinther japonicus Imajima & Hartman, 1964 **Cryptogenic**

This species was collected in 1976–1977 from sponges in Pearl Harbor and Kāneʻohe Bay (Grovhoug & Rastetter, 1980; Bailey-Brock & Hartman, 1987). Coles *et al.* (1999b) report it from Keʻehi Lagoon. It is otherwise known from Japan. We consider it cryptogenic.

Lumbrineridae

Lumbrineris sphaerocephala (Schmarda, 1861) **Cryptogenic**

Bailey-Brock & Hartman (1987) note that this Indo-Pacific species is "found commonly among fouling communities" in Kāneʻohe Bay. We consider it cryptogenic. Hawaiian material should also be compared to the Caribbean *Lumbrineris perkinsi* (L. Harris, pers. comm., January 2009).

Nerillidae

Mesonerilla fagei Swedmark, 1959 **Cryptogenic**

Bailey-Brock (1999) reported this tiny sand-dwelling species, previously known from the Northeast Atlantic Ocean (English Channel and Irish Sea) based upon numerous specimens collected in 1997 from coarse sand in 3 to 5 m in Honolulu Harbor. This remarkably disjunct distribution suggests possible human-mediated dispersal, perhaps with sand ballast of the 19th or early 20th centuries. Genetic comparisons with European material would be of value.

Dorvilleidae

Ophryotrocha adherens Paavo, Bailey-Brock & Åkesson, 2000 **Introduced**

Paavo *et al.* (2000) and Bailey-Brock *et al.* (2002) reported this species from Sand Island and Barbers Point sewage outfalls on Oʻahu (first collections 1973). It also occurs at the Hawaiʻi Kai Marina (B. Paavo, pers. comm., June 2003). This very small (1.2 mm) worm has likely been long overlooked because of its size and because of its potential to be mistaken for the juveniles of other dorvilleids. It is otherwise known from the Mediterranean (in the harbor of Kyrenai, Cyprus) and from the harbor of Las Palmas, in the Canary Islands. A protandric simultaneous hermaphrodite, it has a free-swimming larval stage lasting only up to five days in the water; this, combined with its close association with inshore, disturbed, and harbor habitats, suggests transport by shipping to the Hawaiian Islands. Populations from Oʻahu have been successfully interbred with European worms, indicating that they are the same species (Paavo *et al.*, 2000) further suggesting a lack of genetic divergence (as might be expected from natural colonization and genetic isolation) and thus modern-day human-mediated transport. Bailey-Brock *et al.* (2002) provide population data off Sand Island at 70 m for the period 1990–1998.

Nereididae

Neanthes arenaceodentata Moore, 1903 **Introduced**

= *Neanthes caudata* of authors

= *Neanthes arenaceodonta* of authors

This now widely distributed pileworm (Day, 1967) which may have originated in the North Atlantic Ocean, was reported by Hartman (1966) from coral sand in Kāneʻohe Bay. This material was likely

collected between 1946 and 1966. It was recorded in Pearl Harbor in 1971–1973 (Evans *et al.*, 1974). Bailey-Brock & Hartman (1987) note that it “may have been introduced.” Bailey-Brock *et al.* (2002) report it from off the Sand Island (O‘ahu) open ocean sewer outfall, from where it “virtually disappeared” after 1993.

Neanthes succinea Frey & Leuckart, 1847 **Introduced**
This is another Atlantic pile worm, which has been carried around the world with commercial oysters and in ship fouling and perhaps in more modern times in ballast water. Material from O‘ahu in the Bishop Museum dates from 1941 (O‘ahu), 1945 (off Waikīkī, in about 6 m) and 1944–1945 (Honolulu Harbor), but it was not reported in the literature until Bailey-Brock & Hartman (1987) reported it from the Ala Wai Canal, where it “is abundant in the mud along the banks.” We consider it introduced.

Platynereis abnormis (Horst, 1924) **Cryptogenic**
This species is known in sponge colonies and coral mud in Kāne‘ohe Bay, likely based upon material collected between 1946 and 1966 (Hartman, 1966). Coles *et al.* (2004) report it from 1997 collections by R.C. DeFelice in Mā‘alaea Harbor, and Coles *et al.* (2006) report it from the island of Hawai‘i, based upon 2003 collections. Bailey-Brock & Hartman (1987) note it otherwise “has a broad Indo-West Pacific distribution.” We consider it cryptogenic.

Subfamily Namanereidinae
Glasby *et al.* (1998) reported four species of supralittoral namanereids from Hawai‘i. We include them here because they may be found in brackish water, such as on mudflats in the mangrove zones of estuaries (Glasby, 1999). Because of their potential to have been carried in ship’s shore ballast or in modern ballast water on floating algae or bits of small debris, all four species are here considered cryptogenic (despite being widespread throughout the Pacific basin).

Namalycastis abiuma (Grube, 1872) **Cryptogenic**
Glasby *et al.* (1998) reports that this is a common species “of the supralittoral zone of mud flats in the tropics and subtropics around the world, often associated with mangroves and decaying vegetation such as *Nypa* palms, coconut husks and *Enteromorpha* (now called *Ulva*) overlying mud flats. On Moloka‘i the species was found [in 1995] in mixed gravel and detritus along the stream edge at 8–9 m elevation.” Glasby notes that this is the first actual record of this species in Hawai‘i, previous records of *N. albiuma* probably referring to *Namalycastis hawaiiensis* .

Namalycastis hawaiiensis (Johnson, 1903) **Cryptogenic**
Glasby *et al.* (1998) notes that this species is the “most abundant freshwater namanereid species” in the islands. Glasby *et al.* (1998) noted earlier records from a spring near Honolulu (Johnson, 1903; material probably collected about 1900) and, many years later, at the ‘Ewa Plantation on O‘ahu and on the Kona coast of Hawai‘i. Glasby *et al.* (1998) remark that in Hawai‘i “the species occurs in mud to muddy-sand sediments of streams, swamps, aquaculture ponds and on the Kona coast in closed coastal anchialine ponds; preferred salinities range from fresh to very slightly brackish water... (it) is often associated with leaf litter, under stones, coconut husks and under the bark of floating wood in areas of heavy nutrient load together with talitrid amphipods, the oligochaete *Branchiura sowerbyi* Beddard and other unidentified oligochaetes.” Whether *N. hawaiiensis* arrived in the Islands by natural drifting or by shipping is not yet known; if it is introduced, it is another example of a species first described from other than where it is native.

Namalycastis hawaiiensis is also known from eastern Asia (Hong Kong and Ryukyu Island), southeast Asia (Sumatra and Java) and the western Pacific Ocean (New Guinea; Palau Islands, Guam). Glasby *et al.* (1998) examined specimens from O‘ahu (1987), Kaua‘i (1995), Hawai‘i (1987, 1995), Moloka‘i (1994, 1995), and Maui (1995).

Namalycastis brevicornis (Audouin & Edwards, 1833) **Deleted**
Glasby (1999) notes that this Atlantic species, known from France, French Guiana, and Brazil, is represented by verified specimens in the Paris Museum from "Iles Sandwich" which had also been examined by Pierre Fauvel in 1942. Glasby noted that the record "probably refers to the Hawaiian Islands." If the record is a valid one, it would appear to be a case of an introduction, possibly by ship's shore ballast or in ballast water.

Namalycastis senegalensis (Saint-Joseph, 1900) **Deleted**
Glasby (1999) notes that this Atlantic species, known from West Africa and Brazil, is represented by verified specimens in the Paris Museum from "Îles Sandwich" which had also been examined by Pierre Fauvel, probably about 1942. Glasby notes that the record "probably refers to the Hawaiian Islands" (see Glasby, 1999, pp. 42 and 70). If the record is a valid one, it would appear to be another case of an introduction, possibly by ship's shore ballast or in ballast water.

Namanereis amboinensis (Plugfelder, 1933) **Cryptogenic**
This worm, already widely recorded from the upper littoral zone of the tropics and subtropics (Glasby *et al.*, 1998) was newly discovered in the Hawaiian archipelago with a collection in 1987 of specimens in He'eia Stream, O'ahu. It is "found in the upper littoral zone of mangroves (together with *Namanereis littoralis*) and under the bark of logs floating in fresh-brackish water (together with talitrid amphipods and *Namalycastis hawaiiensis*)" (Glasby *et al.*, 1998). The record is also noted by Glasby (1999).

Namanereis littoralis (Grube, 1872) **Cryptogenic**
Glasby *et al.* (1998) note that this "cosmopolitan" species was previously recorded from open ponds on the Kona coast of Hawai'i as *Namalycastis* sp., based upon material collected in the early 1970s. "The present material extends its Hawaiian distribution to O'ahu where it occurs behind the mangrove (*Rhizophora*) zone in muddy sand with surface detritus together with the more numerous species *Namanereis amboinensis* . On the Kona coast of Hawai'i the species occurs in anchialine ponds under stones at the water's edge." Glasby *et al.* (1998) reported specimens from near Anaeho'omalu Bay, 1987 (Anaeho'omalu Stream, pond) and from He'eia Stream, O'ahu, 1987. Glasby (1999) also notes this record.

Syllidae
Myrianida pachycera (Augener, 1913) **Introduced**
= *Myrianida crassicirrata* Hartmann-Schröder, 1965, described from O'ahu
Nygren (2004) has suggested, based upon molecular genetic data, that this spectacular Western and Indo-Pacific worm has been introduced to various harbors around the world (outlier sites include Hawai'i and Fort Pierce, Florida). It has been collected in ship's fouling in Los Angeles Harbor as well (Nygren, 2004). It was first collected in 1959 in Kāne'ohe Bay, where it is described as "common ... (in) coral rubble, mud, algae, and living sponges" (Friend, 1987). It is also known from Pearl Harbor (photograph by J. Grovhoug, "swimming over fouling community," on Plate 3 in Devaney & Eldredge, 1987), where it was first collected in 1976–1977 (Grovhoug & Rastetter, 1980). We regard it as a post-World War II invasion by ship fouling or ballast water.

Phyllodocidae
Eumida sanguinea (Oersted, 1843) **Introduced**
= *Eulalia sanguinea*
Hartman (1966) reported this species as being collected in June, 1966 in blisters in the introduced Atlantic oyster *Crassostrea virginica* in Pearl Harbor; the record is repeated by Bailey-Brock & Hartman (1987). Coles *et al.* (1999a) report it again from Pearl Harbor based on 1996 collections. Coles *et al.* (2002a) record it from Kāne'ohe Bay.

As this species appears to be harbor-restricted and occurs in a location heavily subjected histor-

ically to both the introduction of oysters and shipping, we consider it introduced. It is a very widely reported cosmopolitan species (Day, 1967), suggesting that more than one species is likely involved.

Capitellidae

Capitella sp. **Cryptogenic**

Ward (1978) first recorded *Capitella capitata* from Hawai‘i on the basis of larvae from the Ala Wai Canal and Kāne‘ohe Bay collected in 1975 or 1976. Bailey-Brock (1984) found it in densities up to 11,600 per square meter in the sand beds of the onuphid worm *Diopatra leuckarti* at Niu Valley on the south shore of O‘ahu. Bailey-Brock & Hartman (1987) noted that adult *Capitella capitata* have “been found in large numbers in sediments on fringing reefs near stream outlets in Kāne‘ohe Bay, at Niu near Aina Haina, in oyster culture ponds, and from other areas around O‘ahu.” Bailey-Brock (1990) reported it as co-occurring in Hawai‘i with *Polydora nuchalis* in oyster raceways and phytoplankton ponds at an oyster pond (“The capitellid is very hardy and survived in damp cracks and fissures in the floor of the ponds when they were drained and left to dry out.”). Coles *et al.* (2002b) report it from Waikīkī. Bailey-Brock *et al.* (2002) provide population data off Sand Island at 70 m for the period 1990–1998.

It is curious that there are no earlier records of this taxon in the Islands, especially from Pearl Harbor. *Capitella capitata* is now regarded as a species complex, and we use the designation *Capitella* sp. We consider it cryptogenic.

Spionidae

Polydora nuchalis Woodwick, 1953 **Introduced**

Bailey-Brock (1990) reports that this species, previously known from central California to the Gulf of California, was found in June 1988 at Kahuku, O‘ahu, in an Atlantic Oyster (*Crassostrea virginica*) farm. The oysters were being grown in the effluent water from a commercial shrimp (*Litopenaeus vannamei*) farm. The worms may have been introduced either with the oysters (both *C. virginica* and the Pacific oyster *C. gigas* having been imported from both the east and west coasts of North America, respectively) or with shrimp (from north of Guaymas in the Gulf of California and other locations in Central America and Asia).

Polydora websteri Hartman, 1943 **Introduced**

= *Polydora ciliata* of authors

This well-known Northwestern Atlantic “mudworm” was first found in the Hawaiian Islands by D.P. Abbott (1946) who reported it (as *Polydora ciliata*) from Wailupe Pond, O‘ahu; he also noted that it was very abundant at Kuapā Pond. No dates are given, but the material would have been collected in the 1940s. Hartman (1966) recorded it from mud blisters in shells of the Atlantic oyster *Crassostrea virginica* collected in 1966 in Pearl Harbor. Bailey-Brock & Hartman (1987), citing Smith *et al.* (1977) noted that large numbers of larvae were found in the stomach of the sergeant fish *Abudefduf* in Kāne‘ohe Bay.

Bailey-Brock & Ringwood (1982) reported that this worm periodically infested a land-locked intensive *Crassostrea gigas* oyster farm at Kahuku, O‘ahu where it “may have been inadvertently introduced to the Kahuku system with oysters transplanted from Kāne‘ohe Bay or with oyster spat imported from U.S. west coast hatcheries” The oyster farm eventually ceased operation (Eldredge, 1994). Ward (1987) reviewed these records, noting that it was “detrimental to the oyster mariculture industry in Hawaii”, and further reported it from coral rock in Kāne‘ohe Bay and Ala Wai Canal, as well as from mud in Nu‘upia Ponds, O‘ahu; planktonic larvae were found in both Kāne‘ohe Bay and the Ala Wai Canal.

Boccardia proboscidea Hartman, 1940 **Intercept**

This North Pacific worm was found in March 1990 in newly imported Atlantic Oysters (*Crassostrea virginica*) from Maine at an oyster culture facility in Keahole, Hawai‘i (Bailey-Brock, 2000). The oysters were held in open raceways with flowing seawater released to the sea, but the fate of these worms (which included egg capsules with larvae) is not known. Curiously, *B. proboscidea* was not

previously known from the Atlantic Ocean, and is thus likely an introduction to Maine as well. It is also introduced to Australia and possibly to Japan (records reviewed in Bailey-Brock, 2000).

Streblospio benedicti Webster, 1879 **Introduced**

This introduced species was found in 1977 (Ward, 1981) in mud in Hālawa Stream, draining into Pearl Harbor (Ward, 1981, 1987). Englund *et al.* (2000a) reports it from additional estuarine streams in Pearl Harbor. It may have been introduced from either the Atlantic coast of America or from the Pacific coast, to where it has also been introduced (Cohen & Carlton, 1995).

Malacoceros sp. **Cryptogenic**

Ward (1987) reports a *Malacoceros* species from estuarine mud banks in the Ala Wai Canal (collected in 1978, *fide* Bishop Museum collections). This location is characterized by numerous invasions. We regard it as a cryptogenic species.

Minuspio sp. **Cryptogenic**

Ward (1987) reports a species of *Minuspio* from Kāneʻohe Bay, Barbers Point, Pearl Harbor, and from sediment and coral rubble in experimental microcosm tanks at Mōkapu Peninsula. These are presumably based upon collections made in the mid- to late 1970s. Englund *et al.* (2000a, p. 109) report what is likely the same species from estuarine conditions in Pearl Harbor.

Opheliidae

Armandia intermedia Fauvel, 1902 **Cryptogenic**

We consider this opheliid to be cryptogenic, pending its resolution as conspecific with the Atlantic species. Bailey-Brock (1987) notes it from bottom samples in Honolulu Harbor and "among mangrove roots on a south shore fringing reef where densities reach 589/m^2" and in plankton in Kāneʻohe Bay. Englund *et al.* (2000a, p.109) record it from estuarine waters in Pearl Harbor. Coles *et al.* (2002b) report it from Waikīkī. It is considered to be widely distributed in the Indo-West Pacific and Atlantic (Bailey-Brock, 1987) and Australia (Hutchings, 2000).

Chaetopteridae

Chaetopterus sp. **Introduced**

= *Chaetopterus variopedatus* of Hawaiian authors

Bailey-Brock (1976) noted that *Chaetopterus* sp. was abundant in Kāneʻohe Bay on the alga *Dictyosphaeria cavernosa*. Bailey-Brock & Hartman (1987, as *C. variopedatus*) noted it was also "a frequent component of fouling communities." Grovhoug & Rastetter (1980) report it based on 1976–1977 collections from Pearl Harbor and Kāneʻohe Bay; Coles *et al.* (1999a) record its continued presence in Pearl Harbor (1996 collections). It also occurs in Honolulu Harbor, Keʻehi Lagoon, and Barbers Point Harbor (Coles *et al.,* 1999b). Hoover (1998, 2006) presents a color photograph of a population in Pearl Harbor at 3-m depth. The earliest specimen from the Islands appears to be that collected by L.G. Eldredge in May 1960 on Coconut Island, Kāneʻohe Bay (BPBM R-260).

Curiously, this large worm was not reported by Hartman (1966), or in the lengthy papers on Oʻahu fouling communities by C.H. Edmondson, or in Edmondson's several books on the Hawaiian marine fauna, the latter covering aspects of the biota of the Islands up to the 1940s. These lack of early reports of a relatively large (tubes up to 13 cm long), conspicuous, shallow-water invertebrate in easily-accessed habitats, combined with its presence in fouling communities, suggest to us that it is an introduction. Given the lack of historical records, it may have been introduced in ship fouling since World War II.

Sabellidae

Branchiomma japonica (McIntosh, 1883) **Introduced**

= *Branchiomma nigromaculata* of Bailey-Brock & Hartman, 1987, p. 411, not of Baird, 1865; not *Sabella havaica* Kinberg, 1867, and not *Branchiomma cingulata* (Grube, 1870) of Hartman, 1966, *fide* P. Knight-Jones, pers. comm., February 2000.

This medium-sized sabellid of Hawaiian fouling communities was long thought to be the same as *Sabella havaica* Kinberg, 1867, described from the Hawaiian Islands (and collected in 1852), which

would have made it one of the earlier records of an introduced marine invertebrate in the archipelago. However, while poorly known, *S. havaica* is a different species (per the above synonymy), and thus the first specimens of *B. japonica* in the Hawaiian Islands are likely those of D. P. Abbott, collected “from scrapings of bottom of naval vessel” in Pearl Harbor (Hartman, 1966, p. 235). No dates of collection are given, but Abbott was collecting in the islands from the early to mid 1940s (Abbott, 1941, 1946). Hartman (1966), under the name “?*Branchiomma cingulata*“, also noted material collected by R. W. Hiatt in 1946 from Halape “in holes, crevices and in matted algae at outer edge of rocky shore, 0.0 to 1.0’” (BPBM R504).

Bailey-Brock (1976) noted that it was only common in boat harbors and lagoons (“abundant on hard substrates, piers, buoys, and floating docks in relatively calm waters”) in the Hawaiian Islands, although, reminiscent of Hiatt’s record, it occurred at Kapoho, Hawai‘i, on a lava bench with living coral. Bailey-Brock (1976) further recorded it from a number of stations around O‘ahu, including the Ala Wai Canal. Grovhoug & Rastetter (1980, (as *B. cingulata*) collected it in 1976–1977 from Pearl Harbor and Kāne‘ohe Bay; Henderson (1990) records it in 1986 from the *USS Arizona* in Pearl Harbor, and Coles *et al.* (1999a) report its continued presence in Pearl Harbor (1996 collections). Phyllis Knight-Jones (pers. comm., February 2000) noted that “In Hawai‘i we found it at Koko and Coconut Harbors under pontoons, pipes, and fauna-covered ropes.” Coles *et al.* (1999b) report it as *B. nigromaculata* from Honolulu Harbor, Ke‘ehi Lagoon, Ala Wai Harbor, Ala Wai Harbor, Barbers Point Harbor, and Kewalo Basin, and Coles *et al.* (2002a) record it for Waikīkī. Coles *et al.* (2006) report it from Kaua‘i, based upon 2003 collections.

Branchiomma japonica is “abundant in Japan” (P. Knight-Jones, pers. comm., February 2000). We regard it as introduced, given its largely harbor and fouling habitat in the Islands and the highly disjunct distribution between Japan and Hawai‘i.

Sabellastarte spectabilis (Grube, 1878) **Introduced**

= *Sabellastarte sanctijosephi* of Hawaiian authors, not Gravier, 1906, *vide* Knight-Jones & Mackie, 2003.
= *Sabellastarte indica* Savigny,1822 (name pre-occupied, *vide* Knight-Jones & Mackie, 2003)

This large and distinctive fanworm (also known as a feather-duster worm) has had a complex taxonomic history. Curiously, it seems not to be mentioned in the Hawaiian biota until after World War II: there is no material in Bishop Museum collections prior to 1946, nor is there any mention of it in the literature until 1966. It does not appear (either by name or by description) in Edmondson’s books (1933, 1946a), nor is it mentioned in the early fouling studies of Pearl Harbor, an environment with which Edmondson was very familiar. On the assumption that such a large, colorful, and conspicuous fouling species would not be overlooked, we treat it here as introduced.

It has been treated in the Hawaiian literature as either *Sabellastarte indica* (in Hartman, 1966) or *Sabellastarte sanctijosephi* (in Bailey-Brock, 1987). Knight-Jones & Mackie (2003) reidentify Hawaiian material as *S. spectabilis*, a species from the Philippines. Hartman (1966) noted that R.W. Hiatt collected it in 1946 at Halapē, Hawai‘i, from a wide variety of coastal habitats (for example, “in holes, crevices, and in matted algae at outer edge of rocky shore;” from the interstices of the coral *Pocillopora meandrina*; from under boulders in quiet water, in crevices in lava in open coast tide pool, and even from a tidal channel exposed to heavy surf). Hartman (1966, p. 239, also as *S. indica*) referred material from “Puata Bay and Waialea (?) [*sic*], O‘ahu” collected in 1902 by the U.S.S. *Albatross*, but given the absence of any other records prior to 1946, as noted above, and its failure to be detected by Edmondson and others, we regard this material as requiring re-examination.

Bailey-Brock (1976) noted that it was “found in pockets and crevices in the reef flat. It is especially abundant along the edges of reefs that have been dredged to make small-boat harbors and swimming areas, as at Ala Moana and Fort Kamehameha, O‘ahu; it may be an indicator of waters with high sediment content.” She further characterized it (Bailey-Brock, 1976) as a species of “calm waters in harbors and marinas, along the edges of reef pockets, in dredged areas.” A specimen of this worm was found on the snail *Conus quercinus* collected in 2 m at Sand Island Reef, Kāne‘ohe (A. J. Kohn *in* Bailey-Brock, 1976).

Bailey-Brock & Hartman (1987, p. 220) repeats the fact that “the walls of dredged channels in

shallow or intertidal waters are frequently populated" by this worm, and noted (p. 416) that it was "abundant on Oahu's south shore reefs, and in Pearl Harbor and Kaneohe Bay at shallow depths, especially in dredged areas that receive silt-laden waters. They have also been found at depths of 25 to 30 m off Molokini Island, near Maui." Grovhoug & Rastetter (1980) record it from Pearl Harbor and Kāneʻohe Bay, based on 1976–1977 collections. Coles *et al.* (1999a) record it from Pearl Harbor as well. Coles *et al.* (1999b) report it from Honolulu Harbor, Keʻehi Lagoon, Ala Wai Harbor, Barbers Point Harbor, and Kewalo Basin. Coles *et al.* (2006) report it from Kauaʻi, based upon 2002 collections, and from 2003 collections in Kaunakakai Harbor, Molokaʻi, Kahului Harbor, Maui, and Kawaihae and Hilo Harbors, Hawaiʻi (Coles *et al.*, 2004).

Bybee *et al.* (2006a, b, 2007) describe the reproductive and larval biology of *Sabellastarte* in Kāneʻohe Bay, noting that it is a sequential protandrous hermaphrodite.

Walsh *et al.* (2003) noted that between 1976 and 2003, no fewer than 741,949 specimens of this brightly-colored worm were harvested for the aquarium trade, for a value of $860,362. Bybee *et al.* (2006b) remark that it "has become one of the most harvested marine ornamental species" in Hawaiʻi, and that "corals and other components of the reef community are often damaged by collectors."

Bailey-Brock & Hartman (1987, plate 3.II.4.b) present a color photo of the tentacular crown. Hoover (1998, 2006) also presents a color photograph of individuals amongst corals, at approximately 12 m at Kewalo Pipe, Oʻahu.

Serpulidae

Bastida-Zavala (2008) noted that additional species, which he formally recorded as now occurring in Hawaiʻi, were found on incoming vessels (Godwin, 2003a; Godwin *et al.*, 2004). These included *Pomatoceros minutus* Rioja, 1941 (Mexico to Peru) and *Protula atypha* Bush, 1905 (California to Mexico). These are intercepts, and we do not further treat them here.

Long (1974) reported *Hydroides sanctaecrucis* Kroyer in Morch, 1863, a Caribbean species, from panels deployed a short distance offshore from Oʻahu, in 15 m, between 1968 and 1972. Lewis *et al.* (2006) note that the introduction of *H. sanctaecrucis* to the Pacific coasts of Panama and Mexico, to Australia and to Singapore "adds some credibility" to Long's record. It has not been further reported in Hawaiʻi, despite extensive studies by M.G. Hadfield and his students on the serpulids of Pearl Harbor. We await further material, but at this time do not further consider it.

Ficopomatus enigmaticus (Fauvel, 1923) **Introduced**

= Mercierella enigmatica

This often abundant tubeworm first appeared in the northern hemisphere in the early 1920s in both San Francisco Bay, California, and in western France (Carlton, 1979a). It is thus of interest to note its establishment within about 15 years of these dates in Hawaiʻi. The Hawaiian populations may have been derived from San Francisco Bay; a genetic comparison of these two populations would be of interest. Straughan (1969a) noted records from Pearl Harbor in 1937, Kewalo Basin (1947), and Alai [Ala] Wai Canal (1947), based on Bishop Museum collections. Hartman (1952) had earlier reported it from the Ala Wai Canal based on 1948 collections, and later (Hartman, 1966) recorded again the 1947 material noted by Straughan from the Canal. Edmondson (1946a, p. 114) noted "an undetermined species of the genus *Mercierella* ... abundant on the bottom of a boat at Waikiki" (this statement does not appear in Edmondson's first edition in 1933). Edmondson's figure (p. 116, fig. 53d) shows a distally asymmetrical operculum with a ring of 22 short, straight spines around the outer edge. This compares reasonably well with the variable opercular spination of *Ficopomatus enigmaticus* and its characteristic operculum with a "distal eccentrically placed concavity" (ten Hove & Weerdenburg, 1978). Evans *et al.* (1972) also reported it from Pearl Harbor.

Bailey-Brock (1976) noted that *Ficopomatus* is present along the length of the Ala Wai Canal: "the most extensive population is seen in the section between the Manoa-Palolo channel and Kapahulu." She also reported *Ficopomatus* on Oʻahu at the beach park at Paiko, in canals of Hawaiʻi Kai, and in a drainage canal at Kahala. Bailey-Brock (1976) further reported that "On Maui, extensive masses of *Mercierella* were seen at a commercial fish farm located at Keālia Pond. It is believed

that *Mercierella* was introduced to Maui with oysters sent from Pearl Harbor to stock the pond. These serpulids may pose a threat to aquaculturists because they are so easily introduced and are able to withstand considerable exposure to freshwater. They frequently clog the pipes used for circulation between the holding ponds and cover settlement sites."

Hydroides brachyacanthus Rioja, 1941 **Introduced**

= *Hydroides brachyacantha*

This serpulid is known from Mexico to Ecuador and the Hawaiian Islands (Bastida-Zavala & ten Hove, 2003), and perhaps elsewhere, such as the Caribbean, Brazil, Australia, Chuuk, and other Indo-Pacific locations (Straughan, 1969a; Bailey-Brock & Hartman, 1987; H. ten Hove, pers. comm., 1996). Bastida-Zavala & ten Hove (2003) question its circumtropical and circumsubtropical status; a species complex may be involved.

Records are scattered and few in the Islands: 1939 (Black Point; Straughan, 1969a), Halapa (1946), and Kahulai, Maui (1973), all representing Bishop Museum material. Bailey-Brock (1976) notes that she did not encounter it and that it "is probably rare." Bastida-Zavala & ten Hove, 2003 examined Straughan's 1972 collections from O‘ahu. Coles *et al.* (1999b) record it from Honolulu Harbor, Coles *et al.* (2002a) from Kāne‘ohe Bay, and Coles *et al.* (2004) from Kahului Harbor, Maui.

We consider this species to be introduced by ship-fouling from the warm waters of the Eastern Pacific*;* it was found alive on a vessel arriving in Australia that had likely become fouled in Panama or Mexico (H. ten Hove, pers. comm., 1996). Bastida-Zavala & ten Hove (2003) note morphological differences from mainland populations. These differences could conceivably arise if *H. brachyacanthus* has been long isolated in the islands.

Hydroides cruciger (Mörch, 1863) **Introduced**

= *Hydroides crucigera*

A species otherwise known from Mexico to Colombia (Bastida-Zavala & ten Hove, 2003), we regard this as another of the introduced *Hydroides* "facies." Straughan (1969a) notes records from Pearl Harbor (1937, 1938), Kāne‘ohe Bay (1936, 1937, 1938) and Coconut Island (1968). Long (1974) found it on "offshore" and Pearl Harbor panels (1968–1972). Coles *et al.* (2002a) report it from Waikīkī. Coles *et al.* (2004, 2006) report it from Maui, based upon 2003 collections. Bastida-Zavala (2008) noted it as present on a vessel inbound from the American Pacific coast to Hawai‘i.

Bailey-Brock (1976) noted that it has been found as an epizoic on the native snail *Charonia tritonis* in 6 m of water off Waikīkī, O‘ahu, and that it was also found on rubble subtidally and was less common than *H. norvegica* and *H. lunulifera*.

Hydroides diramphus Mörch, 1863 **Introduced**

= *Hydroides lunulifera*, *H. lunifera,* and *H. lunifer* of Hawaiian authors; = *Eupomatus lunifer* (see Bailey-Brock & Hartman, 1987).

This is a species possibly of tropical American Atlantic origin (H. Zibrowius, pers. comm., 1996; see also Zibrowius, 1973); it now occurs world-wide circumtropically and circumsubtropically. In the islands, Edmondson & Ingram (1939) reported it from Kāne‘ohe Bay in fouling (1935, as *H. lunulifera*). Hartman (1966, as *Eupomatus lunifer*) reported a "new record" as follows: "Honolulu yacht harbor, May, 1900, collected by Dr. Loye Miller" (these specimens were examined again by Bastida-Zavala & ten Hove, 2003). Straughan (1969a, as *H. lunulifera*) reports records from Pearl Harbor (1929, 1937), Kāne‘ohe Bay (1936–1937), Kewalo Basin (1943) and Coconut Island (1968). Long (1974) found it on both "offshore" and Pearl Harbor panels (1968–1972); McCain (1975) further reported it on fouling panels in Pearl Harbor (1973), where it continues to be found (Coles *et al.*, 1999a). Additional Bishop Museum material includes specimens from the Ala Wai Canal (1968). Coles *et al.* (1999b) record it from Honolulu Harbor, Ke‘ehi Lagoon, Ala Wai Harbor, and Barbers Point Harbor, while Coles *et al.* (2004) record it from Nawiliwili Harbor, Kaua‘i and Hilo Harbor.

This serpulid has been found alive on a vessel after a sea voyage (H. ten Hove, pers. comm., 1996). Bailey-Brock (1976) notes that it is "quite possible" that it may "have been spread to and

between the islands" by ships. Bastida-Zavala (2008) reports it fouling on inter-island barges in Hawai'i.

Hydroides elegans (Haswell, 1883) **Introduced**

= *Hydroides norvegica* of authors, not of Gunnerus, 1768

Tubeworms under the name "*Hydroides norvegica*" were recorded around the world until the species-level taxonomy was first clarified by Zibrowius (1973). Edmondson & Ingram (1939) reported *H. elegans* (as *Hydroides norvegica*) from Kāne'ohe Bay (1935), and also noted its presence in vessel fouling. Straughan (1969a, as *H. norvegica*) reported collections from Pearl Harbor from 1929 to 1948, and from Coconut Island (1968). Bastida-Zavala & ten Hove (2003) examined material collected in 1936 in Kāne'ohe Bay. It remains common in Pearl Harbor and Kāne'ohe Bay (Long, 1974; Evans *et al.*, 1974; McCain, 1975; Grovhoug, 1979; Grovhoug & Rastetter, 1980; Rastetter & Cooke, 1979; Coles *et al.*, 1999a, 2002a). Bailey-Brock (1976) also reports it from the Ala Wai Canal and notes that in general it is a "dominant fouling organism" in Hawaiian harbors. Coles *et al.* (1999b) record it from Barbers Point Harbor.

Biological and ecological work on this species in Hawai'i has been conducted for many years in the laboratory of M.G. Hadfield and his students. In Pearl Harbor, submerged fouling panels "typically accumulated 100% cover of *H. elegans* within a few weeks, throughout the year" (Walters *et al.*, 1997). Walters *et al.* (1997) further note that these 75mm long worms in this habitat may reach reproductive maturity in 4 to 6 weeks. Hurlbut (1991c) reported on settlement and juvenile survival.

Almost all "Tall Ships" arriving in Sydney Harbour in Australia after the "Bicentennial Race" had this worm on their hulls. It may have originated in the Indo-Pacific if not specifically in Australia (H. ten Hove, pers. comm., 1996).

Pomatoleios kraussii (Baird, 1865) **Introduced**

We consider this tropical Indo-Pacific species (Straughan, 1969b) to be introduced, and in particular possibly a post-World War II invasion. It also occurs in South Africa and Japan and has been introduced to the Levant region in Israel and Lebanon (H. Zibrowius, pers. comm., 1996). There appear to be no records or museum material prior to the 1960s. Straughan (1969a: 235–236) collected it only in Kāne'ohe Bay at Coconut Island (1967–1968); Straughan (1969b) noted again that it was found only within Kāne'ohe Bay and speculated that it might be in Pearl Harbor. Grovhoug & Rastetter (1980) reported it from Pearl Harbor and Kāne'ohe Bay, based on 1976–1977 collections. Bailey-Brock (1976) noted that it was a "dominant" serpulid that "forms a distinct zone on the shoreward side of some leeward reefs and sea walls of Coconut Island" (citing Straughan), that it "occurs in the rocky intertidal and shallow subtidal on all the islands" (specific records are cited for O'ahu, Maui, and Hawai'i), and that it is a "dominant intertidal species not found below low tide." These records indicate an expansion beyond the harbors and shallow bays. Coles *et al.* (1999a) note its continued presence in Pearl Harbor. Coles *et al.* (1999b) report it from Honolulu Harbor, Ke'ehi Lagoon, and Barbers Point Harbor. Coles *et al.* (2006) report it from Kaua'i, based upon 2002 collections; it also occurs in Kahului Harbor from 2003 collections (Coles *et al*,. 2004). Alan Miller (*in* Straughan, 1969b) reported that the native gastropod *Morula granulata* will prey on it.

Salmacina tribranchiata (Moore, 1923) **Introduced**

= *Salmacina dysteri* of Hawaiian authors [in part], not of Huxley, 1855 [a European species].

Bastida-Zavala (2008) identified specimens of a *Salmacina* fouling an inter-island only cargo barge as this well-known Eastern Pacific (Alaska to Mexico) species. The material was collected in 2003 (Godwin *et al.*, 2004). Names of European species were first applied to many Pacific Ocean species, and this is such a case.

Edmondson & Ingram (1939) found it in fouling beginning in 1935 in Kāne'ohe Bay. Long (1974) reported it on "offshore" and Pearl Harbor fouling panels (1968), and Hartman (1966) noted that it occurred as "massed tubes fouling harbor installations during summer and fall months at Pearl Harbor and Kaneohe Bay." Henderson (1990) reported it on the *USS Arizona* in Pearl Harbor (1986).

Straughan (1969a) noted Bishop Museum records from Kāne‘ohe Bay (Coconut Island) from 1936 to 1966 and from Black Point in 1937. Bailey-Brock (1976) noted that it was also present in the Ala Wai Canal, with further stations on O‘ahu, Maui, and Hawai‘i. Grovhoug & Rastetter (1980, based upon 1976–1977 collections) and Coles *et al.* (1999a, based upon 1996 collections) note its continued presence in Pearl Harbor. Bailey-Brock & Hartman (1987) reported that it is “common on fouling panels and hard substrates in sheltered waters, e.g., Pearl Harbor and Kaneohe Bay, Oahu.” Bailey-Brock (1989) recorded it on PVC settlement plates on an artificial reef in open waters at 20 m, 2.4 km off the southeast coast of O‘ahu. Coles *et al.* (1999b) record it from Honolulu Harbor, Ke‘ehi Lagoon, Ala Wai Harbor, and Barbers Point Harbor. Coles *et al.* (2004, 2006) report it from Kaua‘i, based upon 2002 collections, and Coles *et al.* (2004, 2006) note 2003 collections from Maui and Hilo Harbor. We consider harbor and fouling populations of this *Salmacina* to be *S. tribranchiata*. Bailey-Brock (1976) reported its distribution in Hawaiian waters as “from shallow depths to 200–600 meters,” and as being found across a wide variety of habitat in the Islands (rocky intertidal, reef flats on algae, anchialine lava ponds, and reef slopes to depth). This range of habitats suggests that additional *Salmacina* species may occur here.

Bailey-Brock & Hartman (1987, plate 3.II.4.c) present a color photo of this species on a pier piling in Pearl Harbor. Hoover (1998, 2006) also gives a color photograph of specimens at 5 m at Kahe Point, O‘ahu.

Serpula watsoni Wiley, 1905 **Introduced**

= *Serpula vermicularis* of Hawaiian authors, not of Linnaeus, 1767

Bastida-Zavala (2008) reports this Indo-Pacific serpulid based upon specimens collected in 2003 (Godwin *et al.*, 2004) from an inter-island cargo barge operating solely in the Islands. We interpret this as the resolution of the identification of a common fouling *Serpula* recorded since 1936.

Straughan (1969a: 231) recorded a serpulid (as the North Atlantic Ocean *S. vermicularis* Linnaeus, 1767) from Kāne‘ohe Bay as early as 1936, and from Pearl Harbor from 1938 on, noting that of these and other specimens, “none ... were collected from natural substrates.” It is curiously not listed by Hartman (1966) in her review of previous and new Hawaiian collections of polychaetes, although a fair amount of harbor- and bay-material was available to her, suggesting that it has perhaps never been common. Bailey-Brock (1976, as *S. vermicularis*) noted that in the islands it is “subtidal (and) relatively uncommon” and was found at stations on O‘ahu and the island of Hawai‘i. Coles *et al.* (1999a) note (as *Serpula* sp.) its continued presence in Pearl Harbor; Coles *et al.* (1999b) record it from Honolulu Harbor, and Coles *et al.* (2004, 2006) report 2002 collections in Nawiliwili Harbor and 2003 collections in Kaua‘i and Hilo Harbors. *Serpula watsoni* occurs from the Indian Ocean to southern Japan, including Australia and Micronesia (Bastida-Zavala, 2008), all of which range may not be natural.

Spirorbid Tubeworms (Spirorbinae)

The tiny coiled tubeworms historically placed in the genus *Spirorbis*, but now assigned to many different genera, interface with a large number of human-mediated dispersal vectors: they may occur in ship fouling, on commercial oyster shells, as juveniles or adults on small pieces of seagrass or floating debris taken into ballast tanks, on semisubmersible exploratory oil platforms, and so forth. In turn, many species of spirorbids are reported as occurring in harbors worldwide. Vine *et al.* (1972, p. 177), for example, note that the spirorbids *Simplicaria pseudomilitaris* and *Neodexiospira pseudocorrugata* settled abundantly on fouling panels in Kāne‘ohe Bay and that within about 30 days “had many fully mature adults of these two species, with well-developed embryos in their opercula.” Such reproductive strategies are particularly conducive to weedy dispersal. A number of authors have noted that ship dispersal may have been integral to the modern-day distribution of spirorbids (Knight-Jones *et al.*, 1975; Bailey-Brock, 1976, p. 72). Bailey (1969) noted that no less than four species of spirorbids, *Simplicaria pseudomilitaris, Pileolaria heteropoma, Janua pagenstecheri,* and *Neodexiospira pseudocorrugata* (as *Spirorbis corrugatus*) occurred on the hull of a local fishing vessel on the island of Chios in the Aegean Sea.

"Early" records of spirorbids in Hawai'i include the report of Edmondson & Ingram (1939) of unidentified spirorbids from fouling in Kāne'ohe Bay (1935 and later years). However, if spirorbids have been introduced here by ship fouling, such species likely arrived decades or centuries ago. Examination of historical materials (such as oyster shells from Hawaiian estuaries) for spirorbids with dried tissue in the shells, may prove fruitful in establishing earlier records. Thus, for example, dried specimens of Pearl Harbor spirorbids (some with their spiny opercula visible) are found on oyster shells (*Ostrea sandvicensis*) collected as early as 1919 in the mollusk collections of the Bishop Museum. Rehydration or genetic examination of this material should be possible.

Bailey-Brock (1976) noted that "floating mangrove fruits, coconuts, driftwood, and other debris are often encrusted with spirorbines in Hawaiian waters, such debris providing an efficient dispersal mechanism for these gregarious worms." Vine *et al.* (1972, pp. 178–179) also noted "the ease with which many adult Spirorbinae species may be transported on floating algae and the stones or shell fragments associated with these, and on crustacean carapaces, turtle shells, driftwood, ships' bottoms, and perhaps on algae or barnacles attached to cetaceans." Noting the few examples of endemism in the spirorbid fauna of the islands, they suggest that "Evidently there have been continuous invasions of species from other regions" (we interpret this to mean largely natural invasions, that is, range expansions) and conclude that "the widespread distribution of species can perhaps be explained by the ease with which adults may be transported." We note that there appear to be no records of shallow-water spirorbids collected on drift material on the high seas.

Knight-Jones *et al.* (1975) have gone into some detail on the evolutionary origin of different spirorbid clades and their means of dispersal. They suggest, based on diversity and climatic adaptations, that *Janua pagenstecheri* for example is native to the northeast Atlantic Ocean, whereas *Neodexiospira brasiliensis* (= *Janua brasiliensis*) [not yet recorded from Hawai'i], *Neodexiospira foraminosa* (= *Janua steueri*), and *Neodexiospira pseudocorrugata* are native to the Indo-West Pacific or West Pacific. Regarding the now-widespread distribution of *J. pagenstecheri* and *N. pseudocorrugata*, they wrote:

> "As for methods of dispersal, most *Janua* may attach themselves to algae, including some of those algae which float when detached. In Europe *pseudocorrugata* is often found on *Cystoseira*, whilst *pagenstecheri* sometimes occurs sparsely on *Fucus vesiculosus*, but we have seen that these two most widely distributed of Spirorbinae are never found on algae in tropical waters. Probably their wide distribution has been brought about by long distance transport of shells lodged in the holdfasts of large floating algae such as *Ecklonia* and *Macrocystis*. Near Sydney (Australia) *pseudocorrugata* is often found on the algal part of such holdfasts. Self-fertilisation is possible, in *pagenstecheri* at least... so even a single adult thus transported to a littoral pool may establish this species in a new locality."

While there is no question that *within* northern or southern ocean basins dispersal of spirorbids on seaweeds must occur, little is known of the potential for such dispersal *between* oceans or across the equator; in particular, discovery of living spirorbids of any of the species treated below on drift material in mid-ocean (although such occur commonly near islands) would be of great interest. Regardless, as most of these species also occur in ship fouling, no presumption can be made as to the probability that drifting algae play or played a greater role. As a result, many spirorbids must now be considered cryptogenic. Spirorbid pelagic larval life is a few hours long (Bailey-Brock & Hartman, 1987), and thus larval transport to the islands is not possible. We conservatively treat only three species as introduced, in one case because of primary association with harbors and fouling communities, and in two cases because of a possible or presumed center of origin in the Atlantic Ocean. Other species in the Hawaiian Islands that occur on open reefs or even in deeper waters may of course also be cryptogenic or introduced, but we present a conservative list here. We treat one species, *Vinearia koehleri*, as a cryptogenic example based upon a potential dispersal vector, as discussed below.

Eulaeospira orientalis (Pillai, 1960) **Cryptogenic**

Bailey-Brock (1976) first reported this species from the Hawaiian Islands, based on collections made in the 1960s–1970s. The species was found on the green alga *Dictyosphaeria cavernosa* in Kāne‘ohe Bay (O‘ahu), as was *Chaetopterus* sp., and on rocks in Honokohau Harbor (Hawai‘i) (Bailey-Brock & Hartman, 1987). It appears to otherwise be known from the Red Sea, Madagascar, and Indian Ocean (Sri Lanka), as well as the Pacific Island groups of Fiji and Tonga (Bailey-Brock, 1985; Bailey-Brock, 1987). We regard it as cryptogenic.

Janua pagenstecheri (Quatrefages, 1865) **Introduced**

Vine *et al.* (1972) recorded material from intertidal stones on Sand Island (Kāne‘ohe Bay), based on collections made in the 1960s or 1970 and noted it has been recorded from many locations in the Mediterranean, Atlantic, and Pacific. Indeed, it is one of the most widely distributed of all spirorbids: “It is found in all oceans and extends from the equator to (in Norway) latitude 70°” (Knight-Jones *et al.*, 1975). Knight-Jones *et al.* (1975) regard it as of European origin because of the breadth of its physiological and ecological adaptations to the climatic conditions of the northeast Atlantic Ocean. They also suggest (as noted above) that it may have gained entry to the Pacific Ocean by means of floating algae or other floating materials. However, the lack of physiological breadth noted by Knight-Jones *et al.* (1975) for Pacific populations would argue for relatively recent transport, and there is no reason to believe that this would be the case for natural drift algae. Considering the proposed European origin, we thus suggest that it has most likely been introduced by ships to the Pacific Ocean: Knight-Jones *et al.* (1975, pp. 123–124) noted that it occurs in ship fouling but does not survive on algae in tropical waters. Thus its long dispersal at sea on floating algae through the tropics—as opposed to quicker ship passages—would appear not to be likely (see earlier discussion, above).

Leodora knightjonesi (de Silva, 1965) **Cryptogenic**

= *Janua knightjonesi*

One of a number of spirorbids reported by Vine *et al.* (1972) originally from Sand Island (Kāne‘ohe Bay) on intertidal stones but now more widely recognized around the islands (Bailey-Brock & Hartman, 1987) thus note that it is “very common on basalt rocks of the intertidal region of the Kona, Hawaii coast.” First Hawaiian records were in the 1960s or 1970s. Bailey-Brock (1976) reported that “an abundance [of this species] forms white encrustations on the lava rocks at Waiulua Bay, Anaehoomalu, Hawaii.” First described from the Indian Ocean (Sri Lanka), its origin is unclear, as there are isolated records in the Atlantic (West Indies) and the Indian and Pacific Oceans (Sri Lanka, Australia, Tonga, Hawaiian Islands) (Bailey, 1970; Vine *et al.*, 1972; Knight-Jones *et al.*, 1975; Bailey-Brock, 1987). We suggest it may be native to the Indo-Pacific and introduced to the West Indies and Hawaiian Islands. We treat it conservatively, however, as cryptogenic; it may have been introduced with ship rock ballast or in ship fouling.

Neodexiospira foraminosa (Moore & Bush, 1904) **Cryptogenic**

= *Janua steueri* Sterzinger, 1909

Vine *et al.* (1972) reported specimens from 8 m depth on algae at Ma‘ili Point (O‘ahu) based upon material collected in the 1960s or 1970s. It was also noted by Grovhoug & Rastetter (1980) for Kāne‘ohe Bay and Pearl Harbor (1976–1977 collections. Bailey-Brock & Hartman (1987) noted that it “occurs in bays and harbors, often on algae attached to floating docks.” Bailey-Brock (1989) recorded it on PVC settlement plates on an artificial reef in open waters at 20 m, 2.4 km off the southeast coast of O‘ahu; *N. foraminosa* was one of the dominant colonists. Coles *et al.* (2006) report it from Kaua‘i and Maui, based upon 2003 collections.

Neodexiospira foraminosa, first described from Japan (Honshu on red algae at 62 m; Knight-Jones *et al.*, 1975) “has a Pacific distribution and has been collected at Johnston Atoll, Fiji, and Tonga” (Bailey-Brock & Hartman (1987). It is also reliably known from the Red Sea, Sri Lanka, and Florida (Knight-Jones *et al.*, 1975) and New South Wales, Australia (Hutchings & Rainer, 1979). Knight-Jones *et al.* (1975) do not repeat or map the early record of it (as *J. steueri*) from the

Caribbean (Bailey, 1970; Vine *et al.*, 1972). Knight-Jones *et al.* (1975) consider it a species originating in the Western Pacific. Knight-Jones & Knight-Jones (1984) note the possibility that this species could be distributed in ship fouling (where it is often found), and that it has been found in fouling assemblages on test plates. We consider it cryptogenic in the Hawaiian biota.

Neodexiospira nipponica (Okuda, 1934) **Cryptogenic**

= *Janua nipponica*

We consider this species cryptogenic based upon its disjunct distribution between Japan and Hawai‘i (Vine *et al.*, 1972; Knight-Jones *et al.*, 1975 (who note that South African material formerly assigned to this species is *Janua brasiliensis*) (Bailey-Brock & Hartman, 1987). It was collected, in the 1960s or 1970s from intertidal red algae at Nanakuli (O‘ahu). Coles *et al.* (2006) report it from Kaua‘i and Maui, based upon 2003 collections.

It may have been introduced with ship fouling. Knight-Jones *et al.* (1975) suggest that *N. nipponica* may prove to be *Neodexiospira brasiliensis* (Grube, 1872).

Neodexiospira pseudocorrugata (Bush, 1905) **Cryptogenic**

= *Janua pseudocorrugata; = Spirorbis corrugata* of authors

Vine *et al.* (1972) reported this spirorbid from intertidal stones at Sand Island and on fouling panels on Coconut Island (Kāne‘ohe Bay). Vine *et al.* (1972, p. 177) further noted that it was particularly abundant on the fouling plates at Coconut Island and that, along with *Spirorbis marioni*, is one of the few species able to tolerate upper shore conditions. Straughan (1977) documented its occurrence in upper intertidal rock pools on O‘ahu, where it is abundant on live and hermit crab-occupied snail shells. It was also noted by Grovhoug & Rastetter (1980) for Kāne‘ohe Bay and Pearl Harbor (1976–1977 collections).

Although with a type locality in northwest France, and with a broad range from the British Isles to the Mediterranean, Knight-Jones *et al.* (1975) argued for an Indo-West Pacific origin and noted that it also occurs in ship fouling; we suggest here it may have been brought to Europe from the Pacific by the earliest sailing vessels. In the Pacific-Indian Ocean theaters it is also known from Australia, Mozambique, Sri Lanka, Tonga, Japan, and Catalina Island (California) (Knight-Jones *et al.*, 1975; Bailey-Brock, 1987). The date of collection at O‘ahu is apparently in the 1960s or in 1970s. Bailey-Brock & Hartman (1987) noted that it “is cosmopolitan in temperate and warm seas and is very common in shallow waters of Hawaii and at Johnston Atoll.” We regard it as cryptogenic.

Pileolaria militaris (Claparède, 1868) **Introduced**

Vine *et al.* (1972) noted this species on an oyster shell (= *Isognomon* sp.?, *fide* Vine *et al.*, 1972, p. 176) intertidally at Coconut Island, Kāne‘ohe Bay. Bailey-Brock & Hartman (1987) note that it is “found commonly in harbors and protected bays in Hawaii, and less frequently on exposed shores.” Bailey-Brock (1976, p.72) noted that it was “quite possible” that *P. militaris* may “have been spread to and between the islands” by ships. Vine *et al.* (1972, p. 176) also describe it as a species that “settles on a calcareous red alga which encrusts the undersides of platelike coral structures.” The date of first collection in the Hawaiian Islands is apparently in the 1960s or 1970s. It was also noted by Grovhoug & Rastetter (1980) for Kāne‘ohe Bay and Pearl Harbor (1976–1977 collections).

It is widespread in the North Atlantic Ocean and the Mediterranean (Vine *et al.*, 1972; Bailey, 1969). If this is its area of origin, it is introduced to regions such as Mexico, and to the Pacific Ocean, where it is known from Hawai‘i, Australia, Tonga, and other regions (Vine *et al.*, 1972; Bailey-Brock, 1987; Bailey-Brock & Hartman, 1987). We regard it as introduced.

Pileolaria pseudoclavus Vine, 1972 **Cryptogenic**

= *Pileolaria semimilitaris* Vine, 1972

This species was described from fringing reefs in the Red Sea and in the same year from fouling plates in “shallow” water at Coconut Island, Kāne‘ohe Bay (Vine, 1972; Bailey-Brock & Hartman, 1987). The date of collection is apparently in the 1960s or in 1970 (Vine, 1972, p. 140). We regard it as cryptogenic; it may have been introduced with ship fouling.

Simplicaria pseudomilitaris (Thiriot-Quiévreux, 1965) **Cryptogenic**

= Pileolaria pseudomilitaris

Vine *et al.* (1972) reported this species, originally described from the Mediterranean Sea, from stones and fouling panels on Sand Island (Kāne‘ohe Bay) and Koko Head from the intertidal to 3 m. The date of collection is apparently in the 1960s or in 1970. Grovhoug & Rastetter (1980) reported it from Pearl Harbor and Kāne‘ohe Bay (1976–1977). Bailey-Brock & Hartman (1987) note that it is “very common in harbors and shallow reefs of the Hawaiian Islands and at Johnston Atoll.” Vine *et al.* (1972, p. 176) note that it is “an abundant intertidal species usually found on the undersides of stones on the lower shore and in the shallow sublittoral zone.” Knight-Jones & Knight-Jones (1984) note that this species may owe its distribution “to transport on ships’ hulls” from which it has been recorded. Vine *et al.* (1972, p. 177) further note that it was particularly abundant on fouling plates at Coconut Island. It is now known from widespread stations in the Mediterranean and Atlantic (including the Aegean Sea and West Indies) and Pacific (Galapagos Islands, Australia, and New Zealand). We consider it cryptogenic.

Spirorbis marioni (Caullery & Mesnil, 1897) **Cryptogenic**

This species has been reported on Nanakuli, O‘ahu (at Mokoli‘i Islet) and Hawai‘i, on intertidal igneous rocks (Vine *et al.*, 1972; Bailey-Brock, 1976; Bailey-Brock & Hartman, 1987), based upon specimens collected in the 1960s or 1970. It also occurs in Panama (the type locality), Mexico, the Galapagos Islands, Easter Island, and southern California (Vine *et al.*, 1972; Bailey-Brock & Hartman, 1987). It is often “associated with harbours and thus ship transport” (Phyllis Knight-Jones, pers. comm., August 1996). Vine *et al.* (1972, p. 176) further note that it is a species of the “shallow rock pools in the upper shore and splash zone…(where)... it is presumably better adapted to avoid desiccation and salinity fluctuations than are most of the opercular-brooding species.” This would also suggest the potential to colonize ship hulls at the waterline. We consider it cryptogenic.

Vinearia koehleri (Caullery & Mesnil, 1897) **Cryptogenic**

= Pileolaria koehleri

Vine *et al.* (1972) reported this species, described from the Mediterranean, from Mā‘ili Point (O‘ahu) and Hilo (Hawai‘i). On O‘ahu they were found at 8 m on stones; on Hawai‘i they were abundant intertidally and in shallow water on lava rocks. The date of first collection is apparently in the 1960s or in 1970s. Bailey-Brock (1989) recorded it on PVC settlement plates on an artificial reef in open waters at 20 m, 2.4 km off the southeast coast of O‘ahu. Vine *et al.* (1972, p. 176) note that it was “found intertidally on stones in rock pools but appears to favor settlement below tidemarks and can live in the intertidal zone only when it is permanently covered by water.” It has since been recorded from the West Indies, the Red Sea, New Zealand, and Australia, as well as at Johnston Atoll, Fiji, and Tonga (Vine *et al.*, 1972; Bailey-Brock & Hartman, 1987).

MOLLUSCA
Class Gastropoda (snails)

Introduced and Cryptogenic Gastropoda

Species	Date	Vector	Native to
Introduced Species			
Diodora ruppelli	1962	SF, BW	Indo-Pacific
Tarebia granifera	1856	R	Indo-Pacific
Melanoides tuberculata	1994	R?	Asia-Africa
Pyrgophorus coronatus	1998	BW?	Caribbean
Vermetus alii	<1972	SF	Unknown
Thylaeodus (?) sp.	1970	SF, BW	Atlantic?
Bostrycapulus calyptraeformis	1913	SF	Eastern Pacific
Crucibulum spinosum	1946	SF, BW	Northeast Pacific
Cuthona perca	1972	SF, BW	Northwest Atlantic
Caloria indica	1968	SF, BW	Indo-Pacific
Okenia pellucida	1972	SF, BW	Indo-West Pacific
Phyllodesmium poindimieri	1995	SF, BW	Indo-West Pacific
Cryptogenic Species			
Hipponix australis	1850s	SF	
Cypraea kuroharai	1971	SF, BW	
Hinemoa indica	<1907	SF, BW	
Pyrgulina oodes	<1979	SF, BW	
Additional Taxa Treated and Their Status			
Haliotis spp.	1927-	R	Northeast Pacific
Status: *Released not established*			
Trochus niloticus	1952, 1963	R	Indo-Pacific
Status: *Released not established*			
Amphithalamus inclusus	1981	SF, BW	Northeast Pacific
Boonea cincta	1981	SF, BW	Northeast Pacific
Ividella navisa	1981	SF, BW	Northeast Pacific
Peristichia pedroana	1981	SF, BW	Northeast Pacific
Evalea sp., cf. *E. americana*	1981	SF, BW	Northeast Pacific
Chrysallida trachis	1981	SF, BW	Northeast Pacific
Iolaea eucosmia	1981	SF, BW	Northeast Pacific
Status (above seven species): *Establishment unknown*			
Vitularia miliaris			
Status: *Native*			
Conus capitaneus			
Status: *Natural waif? See discussion*			
Bulla adamsi	1946	BW	Northeast Pacific
Status: *Failed*			
Bulla vernicosa			
Status: *Native*			

Subclass Prosobranchia
Order Vetigastropoda
Haliotidae

Haliotis spp. **Released**; **Not Established**

In 1905, J.J. Cobb suggested the introduction of the famous edible Pacific coast abalones to Hawai‘i when he wrote, “An attempt should be made to introduce the abalone, as it would probably thrive

well on the rocky reefs and sea walls.” Between 1927 and 1959, several attempts were made to plant California abalone, particularly the black abalone *Haliotis cracherodii*, on O‘ahu, as summarized below. Coles *et al.* (2002a) note that in 1968–1969 two additional species of California abalone, *Haliotis fulgens* and *H. corrugata*, were brought to Coconut Island in Kāne‘ohe Bay, but whether these were released in open water is not clear. Eldredge (1994) and Olin (1994) also note the occasional importation since 1989 of *H. fulgens* and the Asian abalone “*Haliotis diversicolor supertexta”* for closed-system research. No abalones are known to have survived in the wild in Hawai‘i.

Releases of the California Abalone *Haliotis* spp. on O‘ahu

Date	Where	Number	Reference/Source
1927	Kāne‘ohe Bay	—	Edmondson & Wilson, 1940 (“where they seemed to do well at first but eventually disappeared”)
1927–1928	Mokapu Point	5, 30	Brock, 1952 (two separate releases: *Haliotis rufescens* or *H. cracherodii* ?)
1958	off Rabbit Island	167	Brock, 1960 (*Haliotis cracherodii*)
1959	off Pyramid Rock	728	Brock, 1960 (*Haliotis cracherodii*, as two separate plantings, of 2.5-7.5 cm individuals from “southern or Lower California”)

Fissurellidae

Diodora ruppelli (Sowerby, 1834) **Introduced**

Kay (1979, page 42) noted that this keyhole limpet was “... first reported on O‘ahu in 1962 from the reef near the entrance to the Pearl Harbor channel; specimens have since been recorded at depths to 15 m ... described from the Red Sea and apparently occurs throughout the Indo-West Pacific.” It was recollected in Pearl Harbor in 1996 (Coles *et al.*, 1997). Coles *et al.* (2002a) report it from Kāne‘ohe Bay based upon collections in 2000; Coles *et al.* (2002b) record it at Waikīkī, also based upon collections made in 2000.

As it is unlikely that this species was previously overlooked in the molluscan fauna, and given that the first populations were discovered adjacent to a major harbor, we regard it as introduced, either in ship fouling or by ballast water.

Trochidae

Trochus niloticus Linnaeus, 1758 **Released**; **Not Established**

This famous large edible snail, native to Indo-Malayasia, Melanesia, and parts of Micronesia, has been widely released in the Pacific Ocean to establish new fisheries resources (Eldredge, 1987; Bour, 1990). It has been released three times on O‘ahu, twice in 1952 and again in 1963, as shown in the following table.

Releases of the Top Shell *Trochus niloticus* on O‘ahu

Date	Where	Number	Reference/Source
1952	in Coconut Island ponds, Kāne‘ohe Bay	27	Brock, 1952, from Guam, as *T. obelisus*
1952	in Coconut Island ponds, Kāne‘ohe Bay	2	Brock, 1952, from Fiji (12 imported, only 2 alive at time of release); Bour (1990) reports the 1952 release as a total of 39 specimens.
1963	Kāne‘ohe Bay	750	Bour, 1990; Eldredge, 1994; from Guam; no evidence of subsequent reproduction, although specimens found over the years until 1978.

Cross (1968) noted that divers had reported seeing *T. niloticus* in depths up to 27 m in Kāne‘ohe Bay. While Kay (1979, p. 20) and Kay & Schoenberg-Dole, (1991, p. 4) indicated that this snail has become established, there are no known reproducing populations. Specimens from the 1963 planting continued to appear until 1978, in keeping with age distributions for this snail (Bour, 1990, figure 5, page 12).

Wes M. Thorsson reports to us (June, 2003) that he saw a “few” specimens in about 20 m of water off Makapu‘u (south of Kāne‘ohe Bay), of uncertain dates. One “fresh-dead specimen”, encrusted with coralline and brown algae, and approximately 100 mm in diameter, was collected in January 1993 off Rabbit Island, Makapu‘u Point, at 8 m by C. Takahashi (C. Takahashi, pers. comm., June 2003). The latter specimen would be too young to be linked to the 1963 releases in Kāne‘ohe Bay, suggesting that later importations or releases, intentional or accidental, have occurred.

Order Caenogastropoda
Thiaridae

Tarebia granifera (Lamarck, 1816) **Introduced**

= *Melania mauiensis* Lea, 1856, described from Maui (Cowie, 1997)

The natural range of this snail is unclear, but it probably is the Indo-Pacific region (Abbott, 1952). The first record in the Islands is based on the description of *Melania mauiensis* in 1856, although it may have been introduced prehistorically (Cowie, 1998), such as in the roots of wetland plants (for example, taro) brought with the Polynesians (Englund *et al.*, 2000a). We include *T. granifera* here because of its occurrence in brackish and marine waters in Hawai‘i, such as at Kalauao in 3 ‰ in Pearl Harbor (Englund *et al.*, 2000a), at Moanalua Stream in 15 ‰, and in Wai‘alaenui Stream in 30 ‰ (Englund *et al.*, 2000b).

Melanoides tuberculata (Müller, 1774) **Introduced**

For the first record in the islands of this well-known snail in 1994, the native range is unclear but has been suggested to be either Asia, the Middle East, and Africa, but it has “probably been in the islands for many years” (Cowie, 1997). Indeed, it may have been introduced prehistorically (Cowie, 1998) by the Polynesians. Cowie (2007) suggests that “earlier Bishop Museum material will probably result in much earlier dates for the presence of this species on these [O‘ahu and Maui] and the other main Hawaiian Islands.” *Melanoides tuberculata* occurs in brackish and marine waters on O‘ahu—in 15–23 ‰ in Moanalua Stream and to 31 ‰ in Kapalama Stream and to tidal areas of lower Mānoa-Palolo Stream, ranging from 14 to 33 ‰ (Englund *et al.*, 2000b).

Barleeiidae

Amphithalamus inclusus Carpenter,1864 **Establishment Unknown**

We discuss this tiny Californian barley snail below along with species of pyramidellids. Whether it is established is not known. It was found in 1981 in Kawaihae Harbor, on the northwest coast of the island of Hawai‘i by B. Draper (*in litt.*, 9 June 1986), and again in 1985 near the Navy Pier on the northeast side of Sand Island, Midway Islands, by D. Shasky.

Hydrobiidae

Pyrgophorus coronatus (Pfeiffer, 1840) **Introduced**

Cowie (1999) has provisionally identified a brackish water snail from Pearl Harbor, first collected in 1998, as this species, which was previously known from the Caribbean islands and from continental areas bordering the Caribbean. Populations were found in the Waiawa Wildlife Refuge, Pouhala Marsh, and Waiawa Springs. Englund (2002) notes that "densities of this newly introduced species were high with up to several thousand incidentally captured in a single seine haul."

Pearl Harbor specimens exhibited morphological variation in the extent of shell spination and relative height and width (Cowie, 1999). Although it does not have planktonic larvae, Cowie suggests that introduction via ballast water cannot be excluded. Snails entrained on bits of floating debris could be taken up in ballast water.

Vermetidae

Thylaeodus (?) sp. **Introduced**

Strathmann & Strathmann (2006) report a small (up to 7.7 mm diameter) vermetid snail ("Hadfield's vermetid", named after Michael G. Hadfield, its discoverer in Hawai‘i) from the Hawaiian Archipelago and Guam. We hypothesize that it was introduced from the Atlantic Ocean. While best known from O‘ahu, specimens are reported from Kure, Midway, Pearl and Hermes, Lisianski, Maro, French Frigate Shoals, and Necker, as well as from Luminao Reef in Guam. It appears to be indistinguishable (in terms of shell morphology) from a species known from Florida, the Azores, and the Mediterranean, which may be *Thylaeodus rugulosus* (Monterosato, 1878), described from the latter sea. Of particular interest is that specimens from O‘ahu and Florida differed by only 20 of 1,745 base pairs (in various sequences of rRNA and tRNA).

Thylaeodus (?) sp. occurs on O‘ahu in harbor fouling communities, and on intertidal and shallow subtidal shells and coral rubble. It was first noted in 1970 on the walls of the outdoor aquaria at the Kewalo Marine Laboratory in Honolulu. Its occurrence on oyster valves suggests that examination of museum material would be of interest to establish earlier records, if any. In Pearl Harbor, it occurs with other vermetids, bryozoans, and sponges, in a classic fouling facies.

The genetic identity of Hawaiian material with an Atlantic population suggests recent gene flow, which while unlikely to be maintained naturally by floating debris between the Atlantic and the Hawaiian Islands, would be expected of ship-mediated transport. Its widespread distribution across the Atlantic-Mediterranean offers the hypothesis that it may be native to that ocean. If introduced initially to O‘ahu by shipping, downstream dispersal [such as by rafting, to which it would be well adapted (Strathmann & Strathmann, 2006)] across the Hawaiian Island chain would be expected, while ship traffic would take a fouling species to Guam.

Vermetus alii Hadfield & Kay *in* Hadfield *et al.,* 1972 **Introduced**

Michael G. Hadfield (pers. comm. May 1991 and December 1995) informs us that what he and Alison Kay described as *V. alii* he had also seen in Miami, Florida, and he felt that it was a probable introduction to Hawai‘i. We concur, and regard it as a species introduced with ship fouling.

Evans *et al.* (1972) reported it (as *Vermetus* sp. n.) from Pearl Harbor. Hadfield *et al.* (1972) described *V. alii* with a type locality at Mokuloe (Coconut Is.), Kāne‘ohe Bay, O‘ahu, on subtidal coral, noting that it was "the largest species of Hawaiian vermetid, occurring intertidally and subtidally cemented to coral heads and concrete sea walls such as those in the docks at Mokuoloe Island" (*alii* is an Hawaiian word for chief or royalty, in reference to the snail's large size and purple and

yellow color). Kay (1979) noted that it occurs "intertidally and subtidally cemented to coral heads and concrete sea walls in bays such as Kaneohe Bay and Pearl Harbor, Oahu." Grovhoug & Rastetter (1980) also reports it from Pearl Harbor and Kāneʻohe Bay (1976–1977) as does Henderson (1990; Pearl Harbor, 1986). It still occurs in Pearl Harbor (Coles *et al.*, 1999a). Additonal records include Honolulu Harbor, and other south and west shore harbors and marinas on Oʻahu; Kāneʻohe Bay, Waikīkī and Koko Marina, and in harbors and on some nearby coral reefs on Kauaʻi, Molokaʻi, Maui, and Hawaiʻi (Coles *et al.*,1999b, 2002a, b, 2004, 2006). Carlton (1999) lists it as tentatively originating from the Caribbean (the subtropical Western Atlantic Ocean), although alternatively it may originate from the subtropical mainland Eastern Pacific. Kay & Switzer (1974) reported it from Fanning Island (as *Serpulorbis alii*) based on 1972 collections.

Rudiger Bieler informs us (pers. comm., 9 August 1996) that he believes that *Vermetus alii* is a junior synonym of *Eualetes tulipa* (Chenu, 1843), a species of the western Atlantic and Eastern Pacific. Coles & Eldredge (2002) and the various Coles *et al.* reports used the latter name (*Eulates tulipa*) to refer to this species.

Hipponicidae

Hipponix australis Lamarck, 1819 **Cryptogenic**

= *Sabia conica* of authors

= *Hipponix minor* Garrett, 1857 *vide* Kay, 1979 (as "1853")

Kay (1979, as *Sabia conica*) notes that this Indo-West Pacific hoofsnail, which lives attached to other snails such as *Turbo, Terebra, and Conus* occurs in "all islands in the Hawaiian chain"; she illustrates a specimen on *Nassarius papillosus.* As it is capable of being transported either in ship fouling or by ballast water [and has thus been introduced to British Columbia (Carlton, 1992b)], and as there appear to be no fossil records of it on the Islands—although snails of similar structure, morphology and size are represented in the Oʻahu fossil record, such as *Cheilea* and *Crepidula* (Kosuge, 1969)—we consider it cryptogenic. It was first collected in the 1850s in the Islands. Hoover (1998, 2006) provides a color illustration of specimens attached to a *Terebra* shell at Lānaʻi Lookout, Oʻahu, in shallow water.

Calyptraeidae

Bostrycapulus calyptraeformis (Deshayes, 1830) **Introduced**

= *Crepidula aculeata* of Hawaiian authors, not of Gmelin, 1791 (see Collin, 2005).

= *Crepidula aculeata hawaiiensis* Dall, 1922 [a "manuscript" name on specimen labels in the Bishop Museum with the note, "identified by author" (William Healey Dall)].

Small spinous crepidulas around the world have often been identified as the "cosmopolitan" species *Crepidula aculeata*, departing strikingly from the general observation that shallow-water marine gastropod mollusks are not globally distributed. Collin (2005) has identified the Hawaiian stocks of this slipper limpet as *Bostrycapulus calyptraeformis*.

Bishop Museum collections contain one lot of *Bostrycapulus calyptraeformis* collected by W.A. Bryan at Paumalu, Oʻahu in 1913, and a number of lots from Pearl Harbor and Honolulu Harbor from 1915 and later. Bryan (1915) listed and illustrated "*C. aculeata*" from Hawaiʻi without a specific location. Edmondson (1933) referred to it as "about the shores." Edmondson & Ingram (1939) reported it from fouling communities in 1935 and later years from Kāneʻohe Bay. Evans *et al.* (1972) reported it from Pearl Harbor (1971), as did Long (1974, who also found it settling on nearshore panels, collections of 1968–1972) and Grovhoug & Rastetter (1980, Pearl Harbor and Kāneʻohe Bay, collections of 1976–1977). Kay (1979) noted it commonly occurs "... on boat bottoms, pilings, and rocks, especially near harbors." It occurs in harbors, marinas, and some coral reef sites throughout the Islands.

B. Draper (*in litt.*, 9 June 1986) regarded it as an introduction to the Hawaiian Islands; his 1984 specimens came from Pohoiki Bay near an old Sugar Cane barge dock. Draper also reported that D. Shasky's collection included specimens from Hilo and Kawaihae, Hawaiʻi as well as Midway Island near the Navy piers. Burgess (1995) noted specimens collected in 1959 in the Ala Wai Boat Harbor.

Bostrycapulus calyptraeformis is native to the warmer waters of the Eastern Pacific, from Panama to Peru [Collin (2005), who noted that Reeve (1859) listed "*Crepidula aculeata*" from the

“Sandwich Islands” (Reeve’s record may, in turn, have been the basis of Sowerby’s (1883) listing it from the “Sandwich Islands” as well, rather than the listing by Sowerby representing an independent record)]. No further 19th century reports of *C. aculeata* from Hawai‘i were forthcoming; in the nineteenth century many shells were erroneously reported from the “Sandwich Islands”.

Collin (2005) also noted that there are specimens of an unidentified “Pleistocene” calyptraeid from Hawai‘i “possibly attributable to *Bostrycapulus*” in the Academy of Natural Sciences of Philadelphia collections (ANSP 116536). However, the material is in very poor condition, consisting of several broken shells (Collin, 2005, and pers. comm.) and the specimens are not verified as fossil (R. Collin, pers. comm.). Spiny crepidulas are otherwise unreported as fossils from the Hawaiian Islands.

Collin (2005) found that Hawaiian populations were a close genetic match to populations in Panama. We regard *B. calyptraeformis* has a ship-fouling introduction in the late 19th or early 20th century from Panama to Hawai‘i.

Crucibulum spinosum (Sowerby, 1824) **Introduced**

This “spiny cup-and-saucer shell” appeared—as did a number of other species—in the Hawaiian fauna during or soon after World War II. Keen (1971) noted an Eastern Pacific distribution from “California and southward through the Gulf [of California] to Tomé, Chile, on stones and dead shells, intertidally, and offshore in depths to 55 m.” Kay (1979) referred to it as “circumglobal in distribution,” perhaps with *Crepidula aculeata* in mind; *C. spinosum* is classically restricted to the warm Eastern Pacific Ocean and is not listed in molluscan works for Australasia, the Indo-Pacific, the Western Pacific, or the Atlantic Ocean. However, Springsteen & Leobrera (1986) report it as introduced to Palawan in the Philippines as a new record (although the first date of collection is not given); they note that it has been introduced to Hawai‘i and that the Philippine record represents a “considerable westward expansion of the known range.” Given the volume of commercial ship traffic between Pearl and Honolulu Harbors and the Philippines, as well as the number of ocean-going yachts that visit both Hawai‘i and Palawan, the appearance of *C. spinosum* in the Philippines is not a surprise—indeed, it probably now already occurs in other Pacific harbors but goes unreported.

Edmondson (1946d) was the first to remark on its presence in Hawai‘i, noting that “One interesting gastropod has recently appeared in Honolulu Harbor. It apparently is a species of *Crucibulum*, closely related to *Cheilea dillwyni*, except that the internal cup of the shell is entire instead of crescent shaped.” Edmondson (1948) identified the Honolulu Harbor population as *Crucibulum spinosum*; in 1949, he added Pearl Harbor (Edmondson, 1949), noting that “This species described from the west American coast, has apparently become widely established in Hawaii within recent years.” Edmondson (1952a) referred to some “fine specimens” obtained at Pier 27, Honolulu Harbor.

Tinker (1958, as *Calyptraea spinosum*) and Burgess (1959) further referred to its introduction, Burgess noting that it was by then widespread around O‘ahu. Ulbrick (1969) reported that it occurred on pieces of dead coral or basalt rocks dredged from sand and rock bottom at 5 to 8 m in Kāne‘ohe Bay and that it was also found on sea walls and experimental trays put out for oyster spat. Long (1974) reported it from fouling panels in Pearl Harbor (1968–1972); Grovhoug & Rastetter (1980) also reported it from Pearl Harbor and Kāne‘ohe Bay (1976–1977). Coles *et al.* (1999a) report it from Pearl Harbor in 1996, Honolulu Harbor, Ke‘ehi Lagoon and Barbers Point Deep Draft Harbor in 1997 (Coles *et al.,* 1999b) Kāne‘ohe Bay (Coles *et al.* 2002a) in 2000, and Moloka‘i, Kawaihae and Hilo Harbors based upon 2003 collections (Coles *et al*. 2004, 2006).

Kay (1979) noted that it “... may have been introduced in Hawaii during World War II.” Burgess (1995) remarked that it “became abundant on flat submerged objects in about 1950. Perfect specimens were collected [from a refloated boat] in 1959 from Ala Wai Boat Harbor. The probable source was some port in Southern California.”

Cypraeidae

Tinker (1958) listed three species of Indo-Pacific cowries, *Cypraea cylindrica* Born, 1778, *Cypraea cribraria* Linnaeus, 1758, and *Cypraea staphylaea* Linnaeus, 1758, each with the following comment but without further explanation: “It has been brought into the Hawaiian Islands on the hulls of

ships." Burgess (1959) noted that the source of these records were collections made off the USN concrete barge *YON-146*, which had arrived in Pearl Harbor from Guam, by S. Tinker, C.M. Burgess, and others in 1950 (although neither Tinker nor Burgess mention the date of sampling). Burgess added that four additional species of cowries had also been found on the barge: *Cypraea clandestina* Linnaeus, 1767, *Cypraea carneola* Linnaeus, 1758, *Cypraea helvola* Linnaeus, 1758, and *Cypraea poraria* Linnaeus, 1758. *Cypraea carneola, C. helvola,* and *C. poraria* were all already known from and are considered native to Hawai'i, the first two being known from fossils as well. *Cypraea cylindrica* and *C. cribraria* are not further known from the Hawaiian biota. *Cypraea staphylaea* is known from a few living specimens in Hawai'i. The discovery of such a diverse array of cowries in hull fouling from a vessel that had traversed the ocean is notable and suggests that the original distribution of cowries throughout the Indo-Pacific may have been altered by shipping over the past 500 years, although little to no reference is made to this vector in discussions of cowrie biogeography. Eyerdam (1959) had earlier reported on the discovery of *Cypraea tigris* on an army transport vessel travelling from the Marshall Islands to Puget Sound (see Carlton, 1987, Table 1, p. 454).

The late C.M. Burgess, a well-known cowry expert, in a paper entitled "Strangers in Hawaii" (1995), argued that several cowry species were probable introductions to the Hawaiian Islands. That cowries can be transported in hull fouling is demonstrated above, and Burgess, a seasoned observer of the Hawaiian fauna, took note of unusual records. We tentatively admit one species, otherwise known from Japan, as cryptogenic. We note that the islands are naturally bathed with planktotrophic, teleplanic larvae from distant locations, and volunteer species in open deeper waters may be expected, and, indeed, these would be most likely recognized among the mollusks. Burgess listed *Cypraea gaspardi* Biraghi & Nicolay, 1993 [type locality: Kwajalein; collected in 1993 and 1994 (alive?) off Pearl Harbor in 12 m of water; "this recent finding proves that introduction of exotic mollusks is still occurring, as can be expected," *Cypraea arabica* (Linnaeus, 1767); *Cypraea depressa* Grey, 1824; *Cypraea pallida* Gray, 1824 ["probably", collected in 1969 (1, alive, 50', off Molokini islet near Maui; previous known distribution was Bay of Bengal and Sri Lanka)]; *Cypraea labrolineata* Gaskoin, 1849; *Cypraea hirundo* Linnaeus, 1758; *Cypraea gracilis* Gaskoin, 1849; and *Cypraea staphylaea* Linnaeus, 1758. We do not further treat any of these species here.

Cypraea kuroharai Habe, 1961 **Cryptogenic**

Of the many cowry species discussed by Burgess (1995), one species, *Cypraea kuroharai*, is compelling as a possible ballast-water or ship fouling introduction. The only records appear to be Japan and Hawai'i. Burgess notes that it was first found in 1971 in O'ahu in 20 m by John Earle and that a total of about 14 collections have been made since then, "spread over most of Leeward O'ahu." Burgess (1995) felt that the resolution that *Cypraea kuroharai* as a distinct species "verifies the introduction of this species to Hawai'i from Japan, its type locality." Burgess further considered this the only introduced cowry that could be considered as established.

Muricidae

Vitularia miliaris (Gmelin, 1791) **Native**

= *Vitularia sandwicensis* Pease, 1861, *fide* Kay (1979)

Burgess (1963) offered a case for the introduction of this "murex" in the Hawaiian Islands, stating that the first live specimens of this Indo-Pacific species in Hawaiian waters were not collected until 1962 (or 1959, a date Burgess later gives in the same paper). Burgess (1963) noted that live specimens were found on Barge *YON-146* in 1950 in Pearl Harbor, thus leading him to suggest that "World War II vessels docking in Hawaiian harbors" had introduced it. Burgess's records included collections made in April, 1959 [36 m, off Kewalo Basin, O'ahu (*fide* caption)], May 1962 (at 27 m, *vide* text; at 36 m, *vide* caption, in sand and coral off Kewalo Basin) and February 1963 (Mā'alaea Bay, Maui, dredged). Subsequently, however, Rehder (1964) noted that there were specimens in the Smithsonian Institution from Hawai'i collected in 1902 (*Albatross* dredging, one specimen off O'ahu, 26 - 51 m), 1915 (Thaanum and Langford collectors, at entrance to Honolulu Harbor), 1916 (off Waikīkī), and 1918 (off Launiupoko Camp, Maui). Kay (1979) lists *Vitularia sandwicensis*

Pease, 1861, described from Hawai‘i, as a synonym of *V. miliaris*. James (1989) notes Pleistocene material of *Vitularia sandwicensis* from the Mokapu Peninsula, O‘ahu.

While Kay (1979) did not mention Burgess's 1963 paper, the apparent absence of collections from between 1918 and 1959 is curious and it would be of interest to find similar cases of such hiatuses among other Hawaiian mollusks. Burgess noted, as did Kay, that the species is found in shallower waters elsewhere: "On Guam the shell is found in very shallow water or even exposed on the reef at low tide." Burgess provided a photograph of a specimen collected by Thaanum "at intertidal zone on the reef" on Guam. Kay (1979) stated that in Hawai‘i it occurs "at depths of 30 to 60 m; elsewhere in the Indo-West Pacific *V. miliaris* occurs in shallow water or even exposed on reefs at low tide", quoting Cernohorsky (1967). Kay (1967) noted that many prosobranchs "which are widely distributed in the Indo-West-Pacific live in deeper water in the Hawaiian Islands than they do elsewhere."

Montgomery & Montgomery (1963) reported that in seven years of collecting on Guam, they had only encountered (or heard of) *Vitularia miliaris* on pilings, usually on the oyster *Dendostrea hyotis* on pilings in Apra Harbor (*V. miliaris*, if it is not in the fossil record in Guam, is thus perhaps a candidate for consideration as an introduction to Guam). Burgess (1995), not considering Rehder's (1964) note or Kay's (1979) synonymy, repeated his view that *Vitularia miliaris* was introduced, linking its occurrence again in O‘ahu to Barge *YON-146*: "This mollusk has become firmly established in deeper (10–20 fathoms) leeward Oahu waters. The *Pele* dredged many in all stages of growth at nearly all stations in this area in 1960." Burgess continued, "That this mollusk would thrive in rather deep Hawaiian waters is an ecological mystery when its 'normal' habitat is shallow or even intertidal water" (but note Kay, 1967, above).

While the inevitable conclusion is that this species is native, it may be that it is a waif in the islands, going through periods of recruitment from the Indo-Pacific. Finding it in fouling on a barge arriving in Hawai‘i, combined with a perhaps coincidental mid-20th century natural colonization or a resurgence episode in the decade thereafter, would have lead Burgess to the possible conclusion that it was introduced. There remains the possibility that vessel fouling could also have transported to the islands novel genotypes that would have lead to its increased abundance by 1960. We consider it to be native.

Conidae

Conus capitaneus Linnaeus, 1758 **[See Discussion]**

Burgess (1959) proposed that this Indo-Pacific cone snail was introduced to Hawai‘i in World War II, based upon collections of unspecified date "by the Harrisons", who were local shell collectors. Kohn (1959) stated that, "This species was not known to occur in the Hawaiian area until the collection of a living specimen by Mrs. A.M. Harrison... ," noting two specimens: one, collected alive, by Mrs. Harrison, at a depth of 5.4 m off Nanakuli, O‘ahu (April 1958), and a second, by Mr. A.M. Harrison, at a depth of 10.7 m near Ka‘ena Point, O‘ahu (August 1958). Kohn & Weaver (1962), however, re-identified the Ka‘ena Point specimen as *Conus vexillum* Gmelin, 1791.

Kay (1979) noted it is rare, found at depths of 20 m. Alan J. Kohn (pers. comm., July 1996) felt that the records represented the "arrival of larvae spawned elsewhere, and that the species (like several others that have been collected once or twice in Hawai‘i), do not maintain breeding populations there." We do not further consider it here.

Subclass Heterobranchia
Superorder Pyramidellidacea
Pyramidellidae

The late B. Draper (Draper, 1986) records seven species of small California snails in Kawaihae Harbor, on the northwest coast of the island of Hawai‘i, which "proved to be identical to species described from Southern California." He suggested that these species were "accidentally imported on U.S.Marine Corps landing craft during practice landings at the Kawaihae Harbor", some of which craft came from Long Beach, California. Draper (*in litt*, 9 June 1986) provides to us the names of these species, further detailed information, and photographs. One of these seven species, *Amphi-*

thalamus inclusus, is a barleeiid, but it is listed here (as well as above) because of the nature of the dispersal phenomenon. We treat all of these species as of unknown establishment:

Amphithalamus inclusus Carpenter, 1864 **Establishment Unknown**
Boonea cincta (Carpenter, 1864) **Establishment Unknown**
[identified as *Chrysallida vicola* (Dall & Bartsch, 1909) by Draper; now regarded as a synonym of *B. cincta* (Turgeon *et al.*, 1998)]
Ividella navisa (Dall & Bartsch, 1907) **Establishment Unknown**
Peristichia pedroana (Dall & Bartsch, 1909) **Establishment Unknown**
Evalea sp., cf. ***E. americana*** (Dall & Bartsch, 1904) **Establishment Unknown**
Chrysallida trachis (Dall & Bartsch, 1909) **Establishment Unknown**
Iolaea eucosmia Dall & Bartsch, 1909 **Establishment Unknown**

The specimens were collected from screenings from bottom dredgings by a U.S.Government scoop dredge, during deepening of the harbor from 12 to 15 m, in October 1981. Kawaihae Harbor served ships operating for C&H Sugar Co. and Chevron Oil, and was used by U.S.Marine Corps amphibious landing craft for practice. Landing craft were reported to be from Long Beach, California, according to a resident of Kawaihae and were brought over two or three times a year.

Draper's photograph of one species, *Ividella navisa*, bears the inscription, "dark material in early whorls may be dead body material", implying that Draper felt it was possible the specimens were collected alive. All the photographs uniformly show very fresh, well-sculptured shells, not suggestive of worn (dead or beach) material. Draper subsequently sampled a similar habitat (dredgings under a docking pier used by naval vessels and oil tankers) on Midway Island and did not find any of the above species. He felt that this supported his hypothesis that these southern California species were brought over to Hawai'i by these landing craft.

It remains to be determined if any of these species are established in Hawaiian waters. Draper felt that pyramidellids, in particular, could be introduced to one locality and remain in one site for many years because of their habitat specificity. Eldredge (1994, p. 10) noted that an unidentified species of pyramidellid was reported to have been on giant clams (*Tridacna* spp.) imported to Hawai'i in the 1980s.

Hinemoa indica (Melville, 1896) **Cryptogenic**
= *Odostomia pupu* Pilsbry, 1918 *fide* Kay, 1979

We regard this species, because of its disjunct distribution and its habitat in Hawai'i, as cryptogenic. According to Kay (1979) this species is "common in tide pools and on fringing reefs, and abundant in shallow, nutrient rich waters such as Pearl Harbor and south Kaneohe Bay, Oahu...." It was originally described from the Indian Ocean and is also known from Sri Lanka and "Indo-China" (Kay, 1979). Coles *et al.* (1999b) record it from Pearl Harbor in 1996 (Coles *et al.,* 1999a), Honolulu Harbor in 1997 and Barbers Point Deep Draft Harbor in 1998 Coles *et al.* 1999b), Kāne'ohe Bay in 1999 and 2000 (Coles *et al.,* 2002a) Waikīkī in 2001 and Hawai'i Kai in 2002 (Coles *et al*., 2002b), and Maui (Coles *et al.* (2004, 2006), based upon 2003 collections.

It has been present in the islands for many years, having been described as *Odostomia pupu* by Pilsbry (1918). Pilsbry's material came from "Waikiki beach, near Honolulu." Gary Rosenberg of the Academy of Natural Sciences of Philadelphia informs us (pers. comm., January 2000) that the type lot of *Odostomia pupu* lists Frederick Stearns as the collector. Pilsbry noted that some of his specimens were "minutiae picked out of shell-sand sent many years ago by Mr. Frederick Stearns." Stearns died in 1907, the same year the material was cataloged at ANSP.

Pyrgulina oodes (Watson, 1886) **Cryptogenic**

Reminiscent of *Hinemoa indica*, this snail, "common in tide pools and on reefs and in sediments to depths of 65 meters" is also "the dominant pyramidellid in micromolluscan assemblages from nutrient-rich waters such as Pearl Harbor and south Kaneohe Bay, Oahu" (Kay, 1979). Described from Flinders Passage, northwestern Australia, it has otherwise been reported from Enewetak (Kay, 1979).

We regard it as cryptogenic. It remains to be determined when specimens were first collected in the Islands.

Superorder Opisthobranchia
Order Cephalaspidea
Bullidae

Bulla adamsi (Menke, 1850) **Failed**

Tinker (1958) stated that this Eastern Pacific snail had been “recently introduced into the Hawaiian Islands.” Burgess (1959) believed it to have been introduced during World War II and noted that it was “now” widespread around O‘ahu. Burgess (1995), noting that specimens were first found in 1946, stated that *Bulla adamsi* “were abundant in the muddy silt at night across the Ala Wai Channel from the Honolulu Yacht Club in 1949.... They continued to be collected until about 1956. The construction of Magic Island obliterated this area” (a figured specimen was collected in 1949 at night at Ala Moana Reef, opposite the Honolulu Yacht Club). It is not mentioned by Kay (1979). We consider it a failed invasion, possibly destroyed by shoreline destruction.

Bulla vernicosa Gould, 1859 **Native**

= *Bulla marmorea* Pease, 1861 (type locality Hawai‘i)
= *Bulla peasiana* Pilsbry, 1893 (type locality Hawai‘i)

Burgess (1959) considered this (as *Bullaria vermicosa* [*sic*]) to be a World War II-era introduction. However, Kay (1979) noted that the species had long been known in Hawai‘i under other names (see above) and further notes its sporadic appearances. *Bulla vernicosa* is “widespread in the Pacific” (Kay, 1979). Burgess (1995) noted that this species was “abundant on an exposed (at low tide) sand islet in mid Kāne‘ohe Bay in 1954. This large *Bulla* probably came from Guam. Whether these mollusks are still present there is unknown to the author who has not collected the area in over forty years. Chris Takahashi collected this species in 100 feet buried in sand at Kōloa, Kaua‘i in 1981. I have no record of other findings. This large handsome shell would be difficult to overlook.” Burgess’s figured specimen is from Kāne‘ohe Bay collected in 1954. We regard this as a native species, with its aperiodic appearances having been mistaken for an invasion. Cephalaspideans are particularly well known for their sporadic blooms in shallow water.

Order Nudibranchia

Cuthona perca (Marcus, 1958) **Introduced**

Gosliner (1980) reported this western Atlantic species [Brazil, its type locality, as well as Florida and the Caribbean (Jamaica, Barbados)] from the floating docks in association with the sea anemone *Aiptasia* sp. at Coconut Island, Kāne‘ohe Bay, based upon specimens collected in 1972 and 1973. The only *Aiptasia* reported from Hawai‘i is *A. pulchella* Carlgren, 1943 (Cutress,1977). This nudibranch is also known from New Zealand (Gosliner, 1980). Terrence Gosliner (pers. comm. July 1996) feels that it is ”highly likely to be introduced. [The] only known collections that I have seen are from Kaneohe Bay.”

Caloria indica (Bergh, 1896) **Introduced**

= *Learchis indica*
= *Caloria militaris* (Alder & Hancock, 1866)

Gosliner (1980) reported this species, found preying on the hydroid *Pennaria tiarella*, as common in Kāne‘ohe Bay on patch reefs and on floating docks of Coconut Island; single specimens were also collected from Ala Moana Beach Park and from 12 m off Pokai Bay, based upon specimens collected in 1972–1973. Earlier reports include those of Baba (1969), based upon material collected in 1968 by G. Robilliard from “Hawaii”; Baba noted that Robilliard reported that “his specimens were found feeding exclusively on ... *Pennaria* growing in shallow water.” Burn & Narayanan (1970) recorded specimens also collected in 1968 by Robilliard from Kāne‘ohe Bay, on *Pennaria* hydranths. Bertsch & Johnson (1981) illustrate a 22 mm specimen from Magic Island. Hoover (1998, 2006) provides a color photograph of a specimen at Kahe Point, O‘ahu, in 6 m.

Described from India, it is regarded as being widespread throughout the Indo-Pacific, including India, Sri Lanka, Australia, New Zealand, Japan, and New Caledonia. Bertsch & Johnson (1981) noted it as "a common subtidal species that eats the hydroid *Halocordyle* [= *Pennaria*]." We regard both it, and its prey, as introduced.

Okenia pellucida Burn, 1967 **Introduced**

This nudibranch, first described from Australia, was collected in 1972 on the introduced bryozoan *Zoobotryon* on floating docks on Coconut Island in Kāneʻohe Bay; it was also found in the Ala Wai Canal next to Magic Island, Oʻahu (Gosliner *et al.*, 1986). Gosliner (2004) reports further specimens from Māʻalaea Bay, Maui, in 1991. It is now known from Australia, New Zealand, Japan, Palmyra Atoll, and Malaysia (Rudman, 2004; Gosliner, 2004). Outlier popuations are those in Hawaiʻi and in Dubai, United Arab Emirates (Rudman, 2004). Burn (1967) noted that it occurred in Sydney Harbour (specimens collected in 1956) on the bryozoan *Zoobotryo*n (as *Z. pellucidus = Z. verticillatum* of current literature and as cited in this monograph), growing on wharf piles, floating pontoons, and small boats. Willan & Coleman (1984) report it from Queensland (Moreton Bay), Western Australia (Fremantle Harbour), and New Zealand (Waitemata Harbour), confined to harbors where *Zoobotryon* occurs in shallow water. Rudman (2004) suggested "that its wide distribution has probably been aided by shipping." Larval dispersal and floating *Zoobotryon* no doubt play a regional role in the dispersal, although we know of no reports of *Zoobotryon* being dispersed by ocean currents.

Phyllodesmium poindimieri (Risbec, 1928) **Introduced**

Wagner *et al.* (2007) report this Western Pacific and Indo-Pacific nudibranch (Rudman, 1991; S. Kahng, pers. comm., September, 2005), a known predator specialist of *Carijoa*, from Hawaiʻi. It was first found in October 1995 on Maui (at Māʻalaea) by C. Pittman and remains present at the site, where the nudibranchs usually remain concealed during the day near the base of the *Carijoa* colonies but move to the tips of the colonies at night, "looking like little iridescent pom-poms" (C. Pittman, pers. comm., September, 2005). They are also known from Oʻahu as of the late 1990s as well, based upon a photograph by J. Hoover (C. Pittman, pers. comm., September 2005) and are still found at various sites on Oʻahu (S. Kahng, pers. comm.).

Class Bivalvia (mussels, oysters, scallops, clams, and shipworms)

Introduced Bivalvia

Species	Date	Vector	Native to
Anomia nobilis	<1859	SF	Indo-Pacific
Crassostrea virginica	1895	R	Western Atlantic
Crassostrea gigas	1939	R	Japan
Saccostrea "cucullata"	1996	SF	Indo-Pacific
Chama fibula	<1915	SF	Indo-Pacific
Chama macerophylla	1996	SF	NW Atlantic, Caribbean
Chama lazarus	1996	SF	Indo-West Pacific
Chama pacifica	1996	SF	Indo-West Pacific
Sphenia coreanica	1968	SF	Japan
Abra sp.	1996	SF, BW	Unknown
Venerupis philippinarum	1918	R	Japan
Lioconcha fastigiata	1985	BW	Northwest Pacific
Hiatella arctica	<1920	SF	Unknown
Martesia striata	1915	SF, SB	Southern hemisphere
Bankia bipalmulata	1939	SB	Southern hemisphere
Lyrodus affinis	1923	SB	Southern hemisphere
Lyrodus pedicellatus	1902	SB	Southern hemisphere
Teredo bartschi	1935	SB	Southern hemisphere
Teredo clappi	1922	SB	Southern hemisphere
Teredo fulleri	1935	SB	Southern hemisphere
Teredo furcifera	<1921	SB	Southern hemisphere

Additional Taxa Treated and Their Status

Species	Date	Vector	Native to
Mytilus galloprovincialis	1998	SF	Mediterranean Sea
Status: *Failed*			
Pinctada fucata martensi	1956	R	Japan
Tridacna crocea	1951	R	American Samoa
Tridacna squamosa	1983	R	Palau
Meretrix meretrix	1926	R	Japan
Mya arenaria	1923	R	California
Tivela stultorum	1924	R	California
Pustulostrea tuberculata	1956	R	Australia
Ostrea conchaphila	1893	R	California
Mercenaria mercenaria	1930s; 1967–1968	R	Connecticut
Status (above nine species): *Released not established*			

Mytilidae

Mytilus galloprovincialis Lamarck, 1819 **Failed**

A naturally settled population of this originally Mediterranean mussel was discovered in the ballast tank of a resident submarine in September 1998 in Pearl Harbor, having been derived from larvae spawned by adult mussels arriving on the bottom of the *USS Missouri* in June of that year from Puget Sound in the state of Washington (Apte *et al.*, 2000). No further specimens have been found in the fouling communities in Pearl Harbor or elsewhere. As Apte *et al.* (2000) note, *M. galloprovincialis* is established in other subtropical environments, such as Hong Kong, and it thus not impossible that a warmer-adapted genetic strain of this mussel (such as those in southern California, or in Hong Kong) could become established in Pearl Harbor or elsewhere on the islands.

Anomiidae

Anomia nobilis Reeve, 1859 **Introduced**

We suggest that this brackish-water jingle shell, although described from the Hawaiian Islands, is an early ship-fouling introduction from the Indo-West Pacific Ocean. Its specific geographic origin remains unknown at this time. It has not yet apparently been reported as a fossil in the Islands. It is unlikely to have been missed in collections of some two or three decades prior to the 1850s [for example, Conrad's (1837), description of shallow-water endemic Hawaiian brackish water mytilids]. It may thus be another example of a species being first described from the site of introduction. Genetic studies of this species would be especially compelling.

Anomia nobilis was described by Reeve (1859) from the "Sandwich Islands" as the "noble anomia" from the Cuming Museum collections but with no further data. Bryan (1915) recorded it from "Ford's Island, Pearl City." Edmondson (1933) noted that it was "under surface of stones in shallow water"; Dall *et al.* (1938) recorded it on waterlogged boards in Honolulu Harbor, from Pearl Harbor, and from off Honolulu in 31 to 60 m. Edmondson & Ingram (1939) found a naval vessel at anchor for 3 months in Pearl Harbor to be heavily fouled with *Anomia nobilis*. Edmondson (1944a) commented that "*Anomia* is seen on the hulls of boats more frequently than is *Ostrea*, and this fact may be accounted for by its mode of life and rapid development." Long (1974), Grovhoug (1979), and Henderson (1990) reported it from Pearl Harbor, on settlement panels both inside and outside of the Harbor. Kay (1979) commented that it was one of the "characteristic fouling organism in Hawaiian waters and numerous specimens may be piled one on top of the other on waterlogged boards and pilings in Pearl Harbor and Kāne‘ohe Bay." Hurlbut (1991c) reported on settlement and juvenile survival in Pearl Harbor. It was more recently reported in Pearl Harbor in 1996 (Coles *et al*., 1999a), Honolulu Harbor in 1997 and Barbers Point Deep Draft Harbor in 1998 Coles *et al.,* 1999b), Kāne‘ohe Bay in 1999 (Coles *et al.* 2002a), Waikīkī in 2001 and Hawai‘i Kai in 2002 (Coles *et al*. 2002b), Kaua‘i in 2002 and Maui in 2003(Coles *et al.* (2004, 2006).

Ostreidae

Crassostrea virginica (Gmelin, 1791) **Introduced**

The Eastern, Virginia, or Atlantic oyster, *Crassostrea virginica* remains established in Pearl Harbor (Coles *et al.*, 1999a), as a result of what is widely regarded as large plantings made in 1895 by J.F. Colburn of Honolulu. Colburn provided a detailed history of his attempts in 1893 and 1895 to D.S. Jordan and B.W. Evermann, who published Colburn's account in 1905. In 1895 Colburn imported over 38,000 oysters from San Francisco Bay by means of five voyages of the steamship *Australia*. About two-thirds of the oysters were transported in boxes on the open deck and washed down each morning with seawater; the remainder were carried in a refrigerated compartment: "With the former way my loss was more in number, but the latter way was the most expensive" Colburn wrote, noting that the deck oysters could be transported for $10 per ton, whereas the refrigerated oysters cost five cents per pound for freight.

Pilsbry (1918) noted that, "Professor Bryan [1915] has recorded the unsuccessful attempts to introduce eastern and California oysters. It could not reasonably be expected that oysters from waters so much colder would thrive, and so far as is known, they have died out completely. There is a large valve of the Virginia oyster in the Bryan collection, picked out of material dredged in Honolulu Harbor, probably a ballast shell." This "ballast" shell, dated 1917, is now in the Bishop Museum collections; rather than being from ballast, it probably represents a shell from the Pearl Harbor plantings in 1895.

The history of plantings of this oyster in Hawai'i is given by Jordan & Evermann (1905), Bryan (1915), McClellan (1938), Anonymous (1940), Brock (1952, 1960), and Kay (1979). These are summarized in the table below. Carlton & Mann (1996, Table 1) give these Hawaiian records as "1866; 1883 to 1949 and perhaps later years"; however, their table should read, "1866; 1883 to 1929", as later releases (see below) were only movements within the islands. A transport event of 1871 noted by Bryan (1915) and McClellan (1938) refers only to live oysters received for consumption from California and not an outplanting into O'ahu waters (Cobb, 1902).

Plantings of the Atlantic Oyster *Crassostrea virginica* on O'ahu

Date	Where	Number	Reference/Source
1866	Pearl Harbor	"cans"	McClellan, 1938 (aboard the *Comet*, Captain John Paty; oysters "handed over to J. H. Coney, Honolulu")
1877	Honouliuli	?	Kay, 1979: 19, by James Campbell
1883	Kalihi Bay	300	Jordan & Evermann, 1905; Bryan, 1915; McClellan, 1938; oysters from San Francisco planted by Allan Herbert; heavy freshets from stream covered them with mud.
1890	Moanalua fishpond	ca. 100	McClellan, 1938: plantings by S. M. Damon from San Francisco; in April 1892 "three young oysters had grown" [= settled?] on the coral slab where oysters had been planted.
1893	Manana, Ewa, Pearl Harbor	1,000	Jordan & Evermann, 1905; Brock, 1952; McClellan, 1938; plantings from California made by J. F. Colburn
1895	Manana, 'Ewa, Pearl Harbor	38,614	Jordan & Evermann, 1905; Bryan, 1915; Brock, 1952; from California made by J. F. Colburn.
1921	'Aiea Bay, Pearl Harbor	2,000 seed	Coleman, 1923 and McClellan, 1938 (5 barrels, from Great South Bay, Long Island, that had been replanted in Tomales Bay, California).
	Kāne'ohe Bay	3,000 seed	McClellan, 1938; Brock (1952, as Coral Garden, He'eia)
1922	Kāne'ohe Bay	a shipment	McClellan, 1938
1922	?	?	Coleman, 1923
1923	Kāne'ohe Bay	?	Brock, 1952: 118
1923	Pearl Harbor	?	Anonymous, 1940 (*in error?*)
1924	Kāne'ohe Bay	?	Brock, 1952: 118
1924	Pearl Harbor	?	Anonymous, 1940 (*in error?*)
1926	Kāne'ohe Bay	"small shipment"	Anonymous, 1940
1929	Hanaloa Pond	2 barrels	Brock, 1952: 118
1929	Mokapu	2 barrels	Brock, 1952: 118

Edmondson (1933) noted that while the Atlantic oyster was growing in Kāne‘ohe Bay, “there is no conclusive proof that it spawns in these waters.” Anonymous (1940), noting the 1920s plantings in Kāne‘ohe Bay and Pearl Harbor, reported that “Those planted in Kaneohe Bay did not thrive but those sown in Pearl Harbor did well for a time. At present one can find them in scattered places, but not enough for commercial purposes.” However, at the same time, Edmondson & Wilson (1940) reported that the plantings in Pearl Harbor “were quite successful and there is evidence that spawning and setting of spat occurred.” Edmondson (1949a) noted that “Several examples of shells of *Ostrea virginica* were presented by Spencer Tinker. This large oyster has now become quite well established in certain areas of Pearl Harbor, from plantings of many years ago. However, there is a closed season throughout the year against taking the oyster which will continue until productivity reaches a higher level.” Sakuda (1966) studied the reproduction cycle in West Loch, Pearl Harbor. Hartman (1966) recorded the spionid worm *Polydora websteri* and the phyllodocid worm *Eumida sanguinea* from mud blisters in shells of *C. virginica* collected in June 1966 in Pearl Harbor. Preston (1971) used material from the West Loch, Pearl Harbor, in studying chromium-51 accumulation. Evans *et al.* (1972) again report it from Pearl Harbor based upon 1971 specimens. Sparks (1962) reported that there were 150,000 square yards (125,415 m^2) of *C. virginica* in Pearl Harbor, representing over 35,600,000 oysters ranging in density from 67 to 406 per square yard (56 to 339 per square meter), with spawning probably occurring in late spring or summer.

In July 1996 we examined an exposed bed of *Crassostrea virginica* at low tide in the upper part of the West Loch, Pearl Harbor. A predator (likely a crab) had created a series of distinctively broken shells throughout the oyster reef. Outside of Pearl Harbor, Kay (1979) reported *C. virginica* from Kāne‘ohe Bay and from fishponds on Moloka‘i. Bailey-Brock (1990) reported that the spionid worm *Polydora nuchalis* was found in June 1988 at Kahuku, O‘ahu, in a *Crassostrea virginica* farm. The oysters were being grown in the effluent water from a commercial shrimp (*Litopenaeus vannamei*) farm. There is a small record of interisland movements, doubtless more frequent than recorded. Brock (1952) noted such movements in 1940 and 1949, and Kay (1979) reported that in 1939, 2.5 tons of oysters were removed from Kāne‘ohe Bay and distributed to other localities [citing Brock, 1960; however, that information is not in Brock (1960) nor in Brock (1952)]. In the early 1970s *C. virginica* was recorded as having suffered extensive mortalities in Pearl Harbor. The fact that the population survived has not been clear in the literature since that time. In July, 1972 it was reported that “some 34 million oysters” were killed in West Loch, Pearl Harbor (Anonymous, 1972). Three reasons for this mortality have been suggested:

(1) Disease: Kern *et al.* (1973) reported that “dermo”, the lethal, disease-causing dinophyceaen *Perkinsus marinus*, was found in the oysters in Pearl Harbor during and following the mass mortality.
(2) Water quality/trophic conditions: A. Kay (pers. comm., 31 May 1991) noted that “most of the oysters died out when the sewage was diverted out of Pearl Harbor”, indicating a potential change in trophic conditions.
(3) Increased sedimentation: Anonymous (1972) reported that while oysters had been sent off for pathological testing, in addition “a large number of oysters were buried during the past three years as a result of mud runoff from land cleared for development but not yet built on. In West Loch, a new storm drain empties silt into the oyster beds with every rain.” Increased sedimentation has also been cited as a possible cause by M. Hadfield (pers. comm., 1995).

Crassostrea virginica apparently recovered over the next quarter century and remains in Pearl Harbor. Coles *et al.* (1999a) reported that “West Loch areas receiving highly turbid runoff and sedimentation were dominated by *Crassostrea virginica* wherever hard substrata were available for settlement and growth.”

Crassostrea gigas (Thunberg, 1793) **Introduced**

The Pacific or Japanese oyster is well established at least in Kāne‘ohe Bay. Records of known plantings are as follows:

Plantings of the Pacific Oyster *Crassostrea gigas* in the Hawaiian Islands

Date	Where	Number	Reference
1926	Kalihi, Kāneʻohe Bay	"a small shipment"	Anonymous, 1940 (all died within 2 years); Brock, 1952
1935	Mōkapu	two boxes	McClellan, 1938
1938	Pearl Harbor	2,000	Brock, 1952
	Mōkapu	500	
1939	Kāneʻohe Bay: Coconut Island, Mōkapu	210 cases	Anonymous, 1940 (210 cases containing ca. 2.5 million oyster spat); Brock (1952, as 203 cases with 2,150,000 oysters); see text

Anonymous (1940) reported that over 2.5 million spat released in 1939 (see table above) thrived and did well, until dredging in Kāneʻohe Bay for the Marine Corps Base commenced, causing the resulting sedimentation to smother a large number of the oysters; a flatworm (*Stylochus*) was said to have preyed on the remaining oysters.

Edmondson & Wilson (1940) noted that in March 1939 more than one million spat were planted in Kāneʻohe Bay: "Exceptionally rapid growth has taken place during the past four months and it is hoped that this species may become permanently established in Hawaii." Brock (1952, 1960) thought it had not established, but Kay (1979) noted that it was abundant in Kāneʻohe Bay, attached to pilings, cement walls, and coral heads in the intertidal zone. Bailey-Brock & Ringwood (1982) noted "natural populations" in "Kaneohe Bay and Pearl Harbor, Oahu." It remains abundant in Kāneʻohe Bay, especially along the south shore, in 2003.

Saccostrea "cucullata" (Born, 1778) **Introduced**

= *Ostrea cucullata*

Early, relatively small, plantings of this species, from Australian sources, on Oʻahu (Kāneʻohe Bay, Kalihi Basin, Mōkapu, West Lock, and Sand Island) in 1928–1929 [Anonymous, 1940; Edmondson & Wilson, 1940; Brock, 1952; and perhaps as early as 1925 (Galtsoff, 1964)] failed to result in permanent populations at the time. Paul Galtsoff examined specimens in 1930 in Kāneʻohe Bay and found them to be "ripe and spawning" but noted that "During World War II the small population of this species was destroyed by dredging operations."

However, *S. cucullata* was detected to have colonized Pearl Harbor in 1996 surveys (Coles *et al.*, 1999a). We interpret it as a hull-fouling ship introduction; when this invasion occurred is uncertain but is likely to have been in the last quarter-century. *Saccostrea cucullata* is described as a widespread oyster, occurring from West Africa around the Cape of Good Hope into the Indo-West Pacific to southern Japan, Australasia, China, and the Philippines (Carriker & Gaffney, 1996). However, genetic analyses (Lam & Morton, 2006) reveal a complex of species under the morphoname "*cucullata*", which we thus place in quotation marks here, pending resolution as to which clade the introduced Hawaiian stock represents.

Gryphaeidae

Hyotissa hyotis (Linnaeus, 1758) **Intercept**

Paulay (1996) reported this well-known Indo-Pacific oyster-like bivalve as a "new state record" for the Islands. However, the specimens represent shells taken from vessel hulls in Pearl Harbor circa 1950–1951, both of which ships were almost certainly recently arrived from the South Pacific. We do not further consider it here. It is of interest to note that it has recently become established in the Florida Keys (Bieler *et al.*, 2004), and it would not be surprising if it does eventually find its way to the Islands.

Chamidae

Paulay (1996) reported *Chama lazarus* Linnaeus, 1758 and *Chama pacifica* Broderip 1835 from Pearl Harbor as “new state records” for Hawai‘i, based upon specimens collected in 1950–1951. U.S.Navy Lieutenant Commander H. Ryder sampled vessel bottoms in Pearl Harbor in 1950 and 1951 and either presented the material to, or it came into the hands of, the shell collector A.E. Mehring. Because these species had not been collected before 1950–1951, because there are references to a “South Pacific” ship bottom, and because no other fouling studies (such as those of C.H. Edmondson) from the 1930s through the 1970s reported these bivalves, we conclude that Lt. Commander Ryder sampled vessels that had become fouled in foreign ports, and that these 1950–1951 specimens do not represent actual Hawaiian populations.

However, both species were subsequently collected in Pearl Harbor surveys in 1996 (Coles *et al.*, 1999a). We suggest that these modern populations are not linked to the intercepts of Lt. Commander Ryder some 50 years earlier.

Chama fibula Reeve, 1846 **Introduced**

= *Chama hendersoni* Dall, Bartsch, & Rehder, 1938

This small South Pacific bivalve (described from the Philippines) was present by 1915 in the Islands (Bryan, 1915, plate 104, figure 21, this species, *fide* Dall *et al.*, 1938). It was described as a new species, *Chama hendersoni* by Dall *et al.* (1938) from specimens from Pearl Harbor. Dall *et al.* (1938) noted additional material from Honolulu Harbor, including a valve dredged off the entrance of Honolulu Harbor in shallow water. Kay (1979) noted that *C. hendersoni* was a synonym of *C. fibula*, known from the Philippines and recorded from Sydney Harbour, Australia, and noted that it was known only from Pearl Harbor and Honolulu Harbor, although it was “very common in beach drift at Midway.” Coles *et al.* (1999a) record it from Pearl Harbor, Honolulu Harbor, and Barbers Point Harbor(1999a); Coles *et al.* (2000a) report it in Kāne‘ohe Bay based upon collections in 2000, at Waikīkī in 2001 (Coles *et al.* (2002b), at Nawiliwili Harbor in 2002 and in Hilo Harbor in 2003 (Coles *et al.* 2004).

Its absence from the fossil record of the Islands, its restriction to primarily harbor waters in O‘ahu, and its natural absence from Micronesia (Paulay *et al.*, 2002) leads us to suggest that this species was introduced by ship fouling to O‘ahu, and perhaps from there to Midway.

Chama macerophylla Gmelin, 1791 **Introduced**

Coles *et al.* (1999a, as *Chama elatensis* Delsaerdt, 1986) reported this species as established in Pearl Harbor, based on 1996 collections. Coles *et al.* (2002a) also report it (as *C. macerophylla*) from Kāne‘ohe Bay based upon collections in 1999. DeFelice *et al.* (2001) note that the *Chama* under consideration has been tentatively identified as the warm-water Western Atlantic species *C. macerophylla*, on the authority of G. Paulay. *Chama macerophylla* is known from North Carolina to Brazil, including the Caribbean and Bermuda (Abbott, 1974; DeFelice *et al.*, 2001; Mikkelsen & Bieler, 2007).

Chama lazarus Linnaeus, 1758 **Introduced**

This southern hemisphere chamid was first collected in 1996 in Pearl Harbor (Coles *et al.,* 1999a), and was also found in Honolulu Harbor in 1997 (Coles *et al.*, 1999b). Paulay (1996) gives the range as East Africa to Tonga, in Western Polynesia; Matsukuma (2000) as Amami Islands to northern Australia and the Indian Ocean, living on rocks in the lower intertidal zone to 20 m. As discussed above, we take 1996, and not 1950, as the date of first collection.

Chama pacifica Broderip, 1835 **Introduced**

This southern hemisphere chamid was first collected in 1996 in Pearl Harbor (Coles *et al.,* 1999a). Paulay (1996) gives the range as Thailand to the Line Islands. Matsukuma (2000) as the Kii Peninsula southward to Southeast Asia and the Indian Ocean, living, as does *C. lazarus*, on rocks in the lower intertidal zone to 20 m. As discussed above, we take 1996, and not 1950, as the date of first collection.

Myidae

Sphenia coreanica Habe, 1951 **Introduced**

Coles *et al.* (1999a) and Coan (1999) report the establishment of this Japanese species in Pearl Harbor. The name is tentative, awaiting further study of more mature material from Asia. It was first reported from Pearl Harbor (1968–1972) by Long (1974) as *Sphenia* cf. *fragilis* (H. & A. Adams, 1854) in fouling assemblages at 9 m depth. *Sphenia fragilis* is a closely related species from the warm Eastern Pacific which could easily be confused with *S. coreanica*.

Semelidae

Abra sp. **Introduced**

Coles *et al.* (1999a) record this semelid as introduced to the Pearl Harbor, based on 1996 collections.

Veneridae

Venerupis philippinarum (A. Adams & Reeve, 1850) **Introduced**

= *Tapes philippinarum*
= *Tapes semidecussata* Reeve, 1864
= *Tapes japonica* Deshayes, 1853
= *Tapes philippinarum okupi* Bryan, 1919 (described from Hawai‘i)
= *Paphia philippinarum* (as used by Edmondson & Wilson, 1940).

This species is often placed in the genus or subgenus *Ruditapes*; see Carlton (1992) and Paulay (1996) for taxonomic notes. The Japanese littleneck clam *Venerupis philippinarum* was apparently intentionally introduced at least twice to the Islands. Bryan (1919) reported that populations existed at ‘Ewa and Pearl Harbor between the late 1880s and about 1890. They reappeared about 1918–1919 and became abundant at Kalihi and Moanalua on the mudflats (Bishop Museum collections contain a large suite of shells collected by Bryan in 1918 in Kalihi Harbor). Thaanum (1921) noted that, “A Japanese now living in Honolulu has twice planted this bivalve on the mud flats at Moanalua on Oahu” in apparent reference to the failed first and the successful second plantings. Thaanum noted that the clams “are frequently imported from Japan to Honolulu by the barrel for sale among the Japanese”; it is likely that some of these were released alive. Edmondson (1933) noted that “since its introduction it has multiplied rapidly in shallow bays about Oahu and is now used extensively as food.” Dall *et al.* (1938) noted material collected by Thaanum. They quote Thaanum as follows:

> “Bought in fish markets in Honolulu in 1918, collected by vendor at Maunalua [*sic*], Oahu. Inquiry brought information that a certain Japanese had planted them there. This man was located in Honolulu by Langford who was told by him that he had made several attempts at planting shells imported alive from Japan as the Japanese are fond of the clam, but only recently plantings had succeeded, and the shells seemed to be now well established. Barrels of live shells frequently shipped from Japan are inspected by Mr. Langford before being released. [some of these specimens] are samples from these importations. Japanese emigrants also frequently bring live shells in their baggage of this species, and also of species of *Tivela* and a large univalve (*Rapana thomasi* Crosse).”

Of specimens from Kēōkea, Hilo, Thaanum (1921) wrote, “After visiting this pond at least once a month for over twenty years without ever seeing this species, I suddenly found them one day in considerable numbers — all dead, but with valves still joined. I must conclude that they are the victims of an attempted planting, especially as several Japanese families live close by. No live shells could be found.” Edmondson & Wilson (1940) reported 10 barrels from Japan were planted in Kalihi Basin, Pearl Harbor, and Kāne‘ohe Bay in 1920, and that it was called the “Damon clam” because a Mr. Damon was instrumental in transplantations. They also note that in 1937, 400,000 young specimens were transplanted from Kalihi Basin and Pearl Harbor to localities on Kaua‘i, Hawai‘i, Lāna‘i, Maui, and O‘ahu [this appears to be the record noted in Kay (1979) as 400,000 pounds transported in 1957].

Brock (1952) summarized the history of *Venerupis* in Hawai‘i and gave details of records from 1920 to 1937. Brock (1960) noted it was well established on O‘ahu, Moloka‘i, and Hawai‘i, and possibly on Maui and Kaua‘i, and Withington (1966) reported that it had been planted again in Kāne‘ohe Bay. Kay (1979, pp. 20, 570) and Yap (1978) discuss the fishery in the 1960s. Withington (1966), in

a long story in the *Honolulu Star-Bulletin*, noted that 10,000 clam diggers turned up on September 1, 1966, the opening day of clamming season, to search for clams in Kāne‘ohe Bay. Titcomb (1979) reproduced a photograph of “opening season” for taking *Venerupis philippinarum* in Kāne‘ohe Bay in September, 1968, showing hundreds of people on the tidal flats. She states that “Following the 1968 season, however, soil erosion, associated with heavy rain, contributed to the demise of the Kaneohe Bay population.” The population in Kāne‘ohe Bay has decreased considerably since sewage release ceased in the Bay in 1977–1978 (R. Kinzie, pers. comm., 2001; see also Hunter & Evans, 1995). It was reported at 12 of 15 sites in Pearl Harbor in 1996 and at one site in Kāne‘ohe Bay in 1999 (Coles *et al.,* 1997, 1999a). Yap (1978) studied aspects of the biology of *Venerupis* in Kāne‘ohe Bay. Peak spawning occurs in January and February; new recruits appear from April to June. The native crabs *Thalamita* and *Calappa* and the native gastropod *Natica gualteriana* are predators of *Venerupis* [Higgins, 1969 (*Natica),* Yap, 1978 (crabs)]. Cheng & Rifkin (1968) reported cestode larvae from *Venerupis* in Kāne‘ohe Bay.

Venerupis philippinarum is known in Hawai‘i as *okupi* (see Bryan, 1919 for origin of the name) or the Damon clam. It also goes by the name of *pupu ‘olepe* (Titcomb, 1979).

Lioconcha fastigiata (Sowerby, 1851) **Introduced**

Goodwin (2003) reported (as *Lioconcha fastigata*) this relatively small south and western Pacific venerid from 0.3 to 30 m of water near “the Pearl Harbor entrance.” Based upon the photographs given by Goodwin, Gustav Paulay agrees with this identification and its prior absence from the Hawaiian biota (G. Paulay, pers. comm., June 2003). Goodwin (2003) reported that most specimens were “buried in silty sand only a few inches from the surface.” He suggested that *L. fastigiata* may have been introduced in ballast water. The first specimens were collected about December 1985 (D. Goodwin, pers. comm., July 2003).

Mercenaria mercenaria (Linnaeus, 1758) **Released**; **Not Established**

The Annual Report of the Hawaii Department of Land and Natural Resources for 1967–1968 (Hawaii Department of Land and Natural Resources, 1968) noted that two large specimens of this well-known North American Atlantic clam, the quahog, were collected in 1967 in Kāne‘ohe Bay. These were believed to be linked to an authorized private introduction in the 1930s and would thus have to be clams about 30 years old, within the known age of *M. mercenaria*. Also in 1967–1968, the State imported 985 *Mercenaria* from Connecticut that were planted in Kāne‘ohe Bay and in the Nomilo fishpond on Kaua‘i. The next year’s report (Hawaii Department of Land and Natural Resources, 1969) recorded that had grown slightly and largely survived. Kay (1979, p. 20) stated that *Mercenaria* had “apparently settled and are reproducing.”

No populations of *Mercenaria mercenaria* are known to have survived in Hawai‘i. It is listed at: http://www.hawaiiaquaculture.org/products.html [accessed February 2007] as a species currently under commercial aquaculture production in Hawai‘i.

Hiatellidae

Hiatella arctica (Linnaeus, 1767) **Introduced**

= *Saxicava hawaiensis* Dall, Bartsch, & Rehder, 1938 *fide* Kay, 1979

One or more species of fouling and nestling bivalves bearing this name now occur in temperate and subtropical harbors worldwide. Dall *et al.* (1938) described Hawaiian populations as a new species, *Saxicava hawaiensis*. The type material of *S. hawaiensis* was dredged by Thaanum on a coral reef at Fort Armstrong and off Honolulu Harbor, both in shallow water. These collections were likely made before 1920 (Dall *et al*., 1938, p. 5).

Evans *et al.* (1972; 1971 collections), Kay (1979), Grovhoug (1979), and Grovhoug & Rastetter (1980) all reported if from Pearl Harbor; Grovhoug & Rastetter (1980) add Kāne‘ohe Bay, based on 1976–1977 collections. Coles *et al.* (1999b) record it from Honolulu Harbor, Ke‘ehi Lagoon, and Barbers Point Harbor. Coles *et al.* (2002a) record it at Mokumanu Island off Kāne‘ohe Bay in 2000, at Waikīkī in 2001 and Hawai‘i Kai in 2002 (Coles *et al.* 2000b). Coles *et al.* (2004, 2006) report it

in 2002 at Kauaʻi, and 2003 Molokaʻi, Maui, and the island of Hawaiʻi. We regard it as an early introduction with ship fouling.

Pholadidae

Martesia striata (Linnaeus, 1758) **Introduced**

= *Martesia hawaiensis* Dall, Bartsch & Rehder, 1938 [type locality Pearl Harbor] *vide* Kay, 1979

Martesia was first reported from Pearl Harbor by Gordon (1916) and Bartsch (1916). We take 1915 to be the first year of record, based on Gordon's statements; no earlier material is in the Bishop Museum collections. Clapp & Kenk (1963) stated that Gordon reported that a "pile-driver scow, constructed of Douglas Fir covered with ships' felt and sheathed with 1-inch Redwood planks, was inspected after 18 months of service at the Naval Station at Pearl Harbor, Hawaii. The outer sheathing showed practically no damage from teredinids, but was attacked by a borer which produced a hole ⅛ inch wide and increasing to ¾ inch as it penetrated deeper. Asphalt and felt did not impede the progress of the [*Martesia*]. The author recommends that the scow be sheathed with copper rather than Redwood."

Clapp & Kenk (1963) noted that Bartsch (1916) commented on Gordon's paper and photograph, stating that the "photographs show a *Martesia* and shipworms (*Xylotrya* and *Teredo*) in the timber... *Martesia* may bore into rocks and wood, but is confined to the outer two inches." Anonymous (1917), at about the same time, indicated that *Martesia"...* was reported by the Bureau of Yards and Docks to cause considerable trouble in timber structures around the Hawaiian Islands. Specimens were taken from timber near the Pearl Harbor dry dock. In addition to wood, this mollusk is reported to bore through tar paper and asphalt coverings, and even rock ... ." Miller (1924a), reporting upon formal studies initiated in 1922, also found *M. striata* in Pearl Harbor, and noted "burrows attributed to this species" in a wood test block in Nawiliwili Bay, Kauaʻi. Dall *et al.* (1938) described it as a new species (above) from Pearl Harbor, and noted additional material from a beached drift log at Kaʻaʻawa, Oʻahu. Henderson (1990) reported specimens collected in Pearl Harbor in 1986. It remains common in fouling in Pearl Harbor (Coles *et al.*, 1999a).

Martesia is now recorded from circumtropical and circumsubtropical seas globally (Turner & Santhakumaran, 1989). Its origin remains unknown, but it is likely to be the southern hemisphere, and perhaps the southwestern Pacific Ocean. It may have commenced its global voyages as early as the 1500s in wooden ships.

We regard it as introduced with ship fouling and boring communities. No fossil *Martesia* are known from the Islands. As with another introduced clam, *Venerupis philippinarum*, *Martesia* has a Hawaiian name: *Olepe-naka-loa*, meaning "long face" (Titcomb, 1979).

Teredinidae

Bennett (1840) may have been the first to inadvertently record the earliest marine introduction in the Hawaiian Islands during his visit there in 1835. Relative to shipworm activity, he noted "The *Teredo navalis* called, *par excellance*, 'the worm' by sailors, infests the coast of Oahu in sufficient numbers to do serious injury to a boat left but for a single night exposed to their attacks." As we regard no shallow-water shipworm as native to the Islands, this statement likely represents a ship-inoculated invasion of one of the many introduced shipworms.

Much later, Edmondson (1962b) wrote "... the appearance of exotic species of shipworms in Honolulu and Pearl Harbors during World War II is substantial evidence that surface craft are still a factor in the dispersal of marine wood borers." Unfortunately Edmondson never specified which species he had in mind of shipworms appearing in World War II. Edmondson (1940) noted that "In the earlier surveys no species of *Bankia* were observed in Hawaii ... . The recent appearances of ... one or more species of *Bankia* introduces additional and perhaps more destructive members to the catalogue of shipworms invading Hawaiian waters." It may be that by the 1960s Edmondson had in mind this presumably 1920s–1930s episode, albeit pre-war. Edmondson (1940) further noted that "Boats of many descriptions, including wooden-bottomed fishing sampans of long cruising ability, offer easy transportation among the islands of the Hawaiian archipelago for marine boring organisms."

We regard the shallow water, fixed-wood dwelling shipworms of the Hawaiian Islands as ship-introduced species. These introductions may have commenced with the arrival of the first European wooden vessels in the Islands. Edmondson (1940, 1946b, 1946c, 1946d, 1962b), and other workers, have often referred to the role of ships in dispersing teredinids globally and specifically to the Islands. However, the global shipworm literature in general rarely identifies, or speculates, which of two processes—natural dispersal in drifting wood, or human-mediated dispersal in ships—may play the more important role for which species, or, indeed, when it may play the only role (Carlton, 1999). Rather, both processes are presumed to be amalgamated with, by implication, natural drift playing the more fundamental and important role.

As a result, introduced shipworms are rarely identified as such for many ports of the world, and the post-Edmondson era literature on Hawaiian teredinids makes no reference to their potential non-indigenous status. An examination of the detailed studies of Edmondson reveals, however, that while there is an oceanic (high seas) drift teredinid fauna that comes ashore on the islands, the harbor-dwelling species are not found in such drifting materials. The native (naturally occurring) pelagic drifting shipworms of the Central and North Pacific Ocean include *Lyrodus medilobatus* (Edmondson, 1942), *Teredo princesae* Slvickis, 1928 (= *Teredo gregoryi* Dall, Bartsch, & Rehder, 1938), and *Teredo triangularis* Edmondson, 1942. Edmondson (1962b) further considered *Teredo clava* and *Teredo palauensis* as species that have adopted a “typically oceanic existence.”

Paulay (1996) commented on Roch’s (1976) revisions of the names of Hawaiian teredinids; we follow Paulay’s conclusion here and retain the nomenclature and taxonomy of Turner (1966).

A modern survey of the shipworms of the Hawaiian Islands has not been undertaken. It may well be that the six introduced species treated here have been joined in recent decades by additional nonnative shipworms. A modern-day assessment of the economic damage of shipworms in the Islands is also lacking. Earlier assessments are largely anecdotal:

> “A few years ago a long wooden trestle was built off Sand Island opposite Honolulu Harbor to carry the equipment used in laying a concrete sewer outfall. Since the trestle was needed only temporarily, it was not treated for protection against marine borers. But the shipworms won the race; in less than 70 days large sections collapsed, dropping heavy machinery into the sea.*”* Smith (1956).

We take this damage to have been caused by one or more of the shipworms treated below.

Bankia bipalmulata (Lamarck, 1801) **Introduced**

= *Bankia hawaiiensis* Edmondson 1942 (from Honolulu Harbor, 1939)

= *Bankia konaensis* Edmondson 1942 (from submerged algaroba branch in Kealakekua Bay, Kona, Hawai‘i).

This Southern Hemisphere shipworm [the type locality is questionably India (Turner, 1966)] was first collected in 1939 (Edmondson, 1942, p. 136) and described as two different new species. As *B. hawaiiensis,* Edmondson (1942) reported it from O‘ahu (Pearl Harbor, Honolulu Harbor, Hanauma bay, and in drift timbers at Kalihi Entrance), Kaua‘i (drift materials at Wailua), and Hawai‘i (Kona coast, in Kealakekua Bay and at Kahalu‘u). Edmondson (1944c) recorded *Bankia hawaiiensis* in test blocks to about 23 m in O‘ahu. Long (1974) also reported it off O‘ahu.

Lyrodus affinis (Deshayes, 1863) **Introduced**

= *Teredo milleri* Dall, Bartsch & Rehder 1938, *nomen novum* for *T. affinis*, but an unnecessary nomenclatural change (see Turner, 1966, pp. 86 and 111; name change also in and rejected by Edmondson, 1940, p. 245).

Miller (1924a) recorded *L. affinis* from Nawiliwilli, Kaua‘i, in 1923, and also noted its presence in Honolulu Harbor. Edmondson (1940) noted that on O‘ahu it “dominates in Hanauma Bay, on Waikiki Reef, and in the Ala Wai Canal, and also occurs in Kaneohe Bay.” Edmondson (1940, p. 248) noted that this shipworm was “a constant menace to small craft occupying the anchorage at the mouth of the Ala Wai Canal.” Edmondson (1942) noted that it was “almost wholly absent from test blocks in Pearl Harbor”, and added additional records from Kaua‘i, Maui, Moloka‘i, and Hawai‘i. Edmondson (1944c) found it at 23 m in test blocks off O‘ahu, and Long (1974) also recorded it from off O‘ahu. We regard this shipworm as probably native to the Southern Hemisphere.

Lyrodus pedicellatus (Quatrefages, 1849) **Introduced**

= *Teredo hawaiensis* Dall, Bartsch & Rehder 1938, from 386 to 463 m (*Albatross* station 3810 [March 27, 1902], as 211–253 fathoms, off the south coast of Oʻahu) from a dredged palm log (*fide* Turner, 1966, plate 1F caption), the name applied as a "new species" for the material identified by Miller (1924a) as *Teredo bartschi.*

= *Teredo diegensis* Bartsch, 1916 (from San Diego)

= *Teredo honoluluensis* Edmondson 1946b (from test block, Honolulu Harbor, Oʻahu)

= *Teredo kauaiensis* Dall, Bartsch & Rehder,1938 (from Nawiliwili, Kauaʻi, as a new species, for material originally identified by Miller as *Teredo diegensis* [= *Lyrodus pedicellatus*]; Edmondson (1942) favored retaining *diegensis*, and placed *T. kauaiensis* in synonymy. *Teredo kauaiensis* was proposed in part because Dall, Bartsch & Rehder noted, "From what we know of the distribution of shipworms, we are disinclined to believe that this is *T. diegensis*."

= *Teredo midwayensis* Edmondson 1946 (from Midway Island)

This "blacktip shipworm," with a complicated global taxonomic history, has been spread for centuries by wooden sailing vessels. Based upon the number, frequency, and location of most records (including synonyms), it appears to be a species of southern hemisphere origin, although typical of an exotic, ship-dispersed species, the type locality is Spain. Dall *et al.*'s (1938) comment, relative to proposing the name *T. kauaiensis*, is a classic example of overlooking the probable role of ships in creating the modern distribution of this shipworm.

Curiously, it was first recorded in 1902 from Hawaiʻi as a new species, *Teredo hawaiensis*, from a deep water log off Oʻahu. *Lyrodus pedicellatus* is not a deep water species; the log was doubtless derived from shallow water. It has been recorded from the Hawaiian Islands by Miller [(1924a, as *Teredo bartschi.*; Dall *et al.* (1938); Edmondson (1942, as *Teredo hawaiiensis*); and Edmondson (1946b)]. Edmondson (1942) noted its presence at Midway Island.

Teredo bartschi Clapp, 1923 **Introduced**

=*Teredo hiloensis* Edmondson, 1942 (from Hilo Harbor)

= not *Teredo bartschi* of Miller, 1924a (see *Lyrodus pedicellatus*)

This shipworm, possibly also of southern hemisphere origin, was recorded by Edmondson (1942) from Hilo Harbor (from between 1935 and 1941). Edmondson (1946b, p. 221) confirmed that he concurred with R. Miller's identification of this species from Oʻahu. It was described from Port Tampa, Florida, and Coan *et al.* (2000) refer to it as a Caribbean species. However, we regard it as introduced to the Caribbean (see also Carlton & Ruckelshaus, 1997).

Teredo clappi Bartsch, 1923 **Introduced**

= *Teredo trulliformis* Miller 1924 (from Honolulu Harbor)

This shipworm was first described from a ship's keel at Key West, Florida, but we regard it as introduced to the western Atlantic, including Florida and the Caribbean (see also Carlton & Ruckelshaus, 1997). It was recorded from Honolulu Harbor, Pearl Harbor, and Nawiliwili, Kauaʻi, as a new species by Miller (1924a; 1922–1923 collections). Further records are those of Edmondson (1940, from Waikīkī Bay, Kāneʻohe Bay, and Ala Wai Canal), Edmondson (1942, submerged algaroba timber in Kealakekua Bay and at Pearl Harbor, Honolulu Harbor, Waikīkī, Ala Wai Canal, Kāneʻohe Bay), Edmondson (1944c, in test blocks to 23 m off Oʻahu) and Kay (1979, common in Kāneʻohe Bay). The introduced flatworm *Taenioplana teredini* is found in the burrows of this species.

Teredo fulleri Clapp, 1924 **Introduced**

Edmondson (1942) records this shipworm from the Islands, although it is omitted in Kay (1979). We take the records to date between 1935 and 1941. Edmondson notes that it "was first recovered locally from submerged algaroba branches in Kalihi Entrance, Oʻahu, and later was taken from the same kind of wood in Kealakekua Bay, Hawaiʻi, at Olowalu, Maui, and on the shore of Molokaʻi." He also noted its occurrence in Apia, the seaport capital of Western Samoa, in the keel of a trading vessel seeing service between Samoan islands. Edmondson hypothesized that *T. fulleri* was native to the Central Pacific Ocean and not to the West Indies, from where it was described.

Teredo furcifera von Martens, 1894 **Introduced**

=*Teredo parksi* Bartsch, 1921 (young *T. furcifera*; from Pearl Harbor)

=*Teredo bensoni* Edmondson 1946 (see discussion, below)

=*Teredo furcillatus* Miller of Dall, Bartsch, and Rehder 1938 (from Samoa)

This shipworm was first described from the Molucca Islands in Indonesia (Turner, 1966). It was described again from the Hawaiian Islands in Pearl Harbor as *T. parksi* by Bartsch (1921), although no date of collection is again. Records from Hawai‘i include Miller (1924a, as *Teredo furcillatus* and *T. parksi*), Dall *et al.* (1938, as *Teredo furcillatus* and *Teredo parksi* Bartsch, from Pearl Harbor; also in block of wood at Waikīkī, O‘ahu), Edmondson & Ingram (1939, as *T. parksi*, the common shipworm destroying wood structures in Kāne‘ohe Bay and Pearl Harbor and infesting test panels), Edmondson (1942, as both *T. parksi* and *T. furcillatus,* with details of distribution on Kaua‘i and O‘ahu), and Edmondson (1946b, as *Teredo bensoni*, new species): “live mature specimens were recovered from the wooden guard rail of the dredger *Benson* on its return to Honolulu after completing operations at Canton Island. Four months after [its] return from Canton Island, a single immature shipworm closely resembling the type specimen was recovered from a test block in Honolulu Harbor near the dry dock where the *Benson* had been reconditioned.”

Additional Records: **Imported Nonnative Bivalves**

Over the decades a number of nonnative species of clams and other bivalves have been intentionally brought to Hawai‘i for mariculture or experimental purposes. Imported species are listed below. Details of importation are provided by Coleman (1923), Edmondson & Wilson (1940), Brock (1952, 1960), Hanna (1966), Lachner *et al.* (1970), Kay (1979), Heslinga & Perron (1983), and Eldredge (1994).

From the Indo-Pacific:

Pinctada fucata martensi (Dunker, 1872) **Released**; **Not Established**

Hayami (2000) treats *P. martensii* and *P. fucata* (Gould, 1850) as separate taxa.

Tridacna crocea Lamarck, 1819 **Released**; **Not Established**

Tridacna squamosa Lamarck, 1819 **Released**; **Not Established**

Meretrix meretrix Linnaeus, 1758 **Released**; **Not Established**

Of these, we comment briefly on the last, *Meretrix meretrix*, as apparently adult shells were at one time characteristic of the Kāne‘ohe Bay shores, and it is possible that old shells could still be found. Edmondson (1933) noted that “A species introduced into Hawai‘i from Japan and occasionally seen in Hawaiian waters is *Cytherea (Meretrix) meretrix* Linnaeus. ... The species apparently finds a habitat in muddy bottoms. Many empty shells are to be found in certain localities along the south shore of Kaneohe Bay.” These were apparently the results of plantings made in 1926 (Brock, 1952). Plantings were made again in 1939 in Kāne‘ohe Bay (Brock, 1952), Edmondson & Wilson (1940) noting that 20,000 clams from Japan had been released and that “rapid growth has taken place.” Apparently the population survived robustly, moving Brock (1952) to categorize it as a species that was “either firmly established or appear(s) to be becoming established”, with Brock (1960) listing it under “Established Introduced Species”, and further commenting that it was “well established on Oahu and possibly on other islands as well.” After that, no further mention of its status is found in the original literature; it is not listed by Kay (1979). We presume that the population died out. We do not list it as “failed”, as there is no actual evidence of reproduction.

From North America:

Mya arenaria Linnaeus, 1758 **Apparently Released**; **Not Established**

Clinocardium nuttallii (Conrad, 1837) **Released?**

or ***Protothaca staminea*** (Conrad, 1837)

Tivela stultorum (Mawe, 1823) **Released**; **Not Established**

In addition, several nonnative oysters have been imported and planted in Hawai‘i. Details are provided by Anonymous (1940), Edmondson & Wilson (1940), Brock (1952, 1960), Galtsoff (1964), Hanna (1966), and Kay (1979). The two oyster species that did not survive are as follows:

From the Indo-Pacific:
Pustulostrea tuberculata (Lamarck, 1804) **Released**; **Not Established**
[in Hawaiian literature previously as *Crassostrea amasa* (Iredale, 1939)]
From North America:
Ostrea conchaphila (Carpenter, 1857) **Released**; **Not Established**
[in the Hawaiian literature previously as *Ostrea lurida* (Carpenter, 1857)]

CRUSTACEA
Copepoda (copepods)

Introduced and Cryptogenic Copepoda

Species	Date	Vector	Native to
Introduced Species			
Pseudodiaptomus marinus	1964	BW	Japan
Psammopsyllus stri	1979	SBA	Panama (Caribbean)
Teredicola typica	1939	SF	Southern hemisphere?
Cryptogenic Species			
Haplostomides hawaiiensis	1985	SF	

Pseudodiaptomidae
Pseudodiaptomus marinus Sato, 1913 **Introduced**
Jones (1966) reported this Japanese copepod as abundant in 1964 and 1965 in the Ala Wai Canal, O‘ahu, in water of 18 ‰. Maximum numbers were found near the inland end of the canal, about 2.4 km from the mouth. Walter (1986, p. 147), in reviewing the complex taxonomic history of *P. marinus*, examined Jones’ material and concluded they were the same as Japanese populations. Fleminger & Kramer (1988) subsequently reported *P. marinus* from southern California embayments. We regard it as introduced by ballast water. It should be expected in other Hawaiian localities, such as Pearl Harbor.

Leptopontiidae
Psammopsyllus stri Mielke, 1983 **Introduced**
Kunz (1993) reported this interstitial harpacticoid copepod in coarse and medium sand, from Kaua‘i [Lumahai Beach, Wahina Bay (lagoon near the mouth), Anahola Beach] and from O‘ahu (Pūpūkea Beach), all collected in 1979. It was previously known only from the Atlantic Ocean, on the Caribbean coast of Panama. Noting that similar distributions were known for other interstitial copepods where the same species was believed to be on either coast of North or Central America, Kunz offered a variety of speculations, including geological processes and aquatic waterfowl, as to the origin of such broadly disjunct distributions, but only one that seems applicable to the occurrence of an Atlantic interstitial sand species on islands in the mid-Pacific Ocean. Kunz (1993) remarked that, “Eine Verfrachtung von Bestandteilen der Sandfauna durch Ballastsand von Segelschiffen ist nicht auszuschließen” [Transport as a member of the sand fauna in ballast sands of sailing ships is not impossible]. We consider *Psammopsyllus stri* to be introduced. It may further prove to be one of many examples of sand biota that must have been moved globally by sailing vessels up to the early 20th century.

Claussidae
Teredicola typica Wilson, 1942 **Introduced**
Charles H. Edmondson found this parasitic copepod, the female of which clings tightly to the lining of the infrabranchial cavity of the host, in five species of the shipworm genus *Teredo* and one species

of the shipworm genus *Bankia* in Honolulu Harbor (the first record was 1939), as well as at additional stations on O'ahu, on Hawai'i (Hilo Harbor), and on Maui (Kahului). It was described by Wilson (1942) as a new species with a type locality of Honolulu Harbor. Edmondson (1942, as *Teredo milleri*) noted it was in 75 percent of specimens of *Lyrodus affinis* in Honolulu Harbor; additional records were Kalihi Entrance, Waikīkī, and Hanauma Bay, all on O'ahu. Edmondson (1942 and 1945b) provided further notes on its biology and natural history. Wilson (1957) redescribed this species based upon specimens from Honolulu Harbor. Humes & Turner (1972) and McKoy (1975) reported it from Australia, New Zealand, and Japan. As this species is associated only with what we regard as introduced shipworms, we consider this copepod to be introduced as well.

Ascidicolidae

Haplostomides hawaiiensis Ooishi, 1994 **Cryptogenic**

Ooishi (1994) described this symbiotic copepod, the first copepod associate of an ascidian reported from Hawai'i, from the introduced ascidian *Polyclinum constellatum*. The material was collected in 1985 and again in 1993 on O'ahu from Ke'ehi Lagoon (Honolulu), in ascidians "attached to ropes, floats and small ships' bottoms." While ascidicolid copepods are not necessarily host specific (Ooishi & Illg, 1977; Marchenkov & Boxshall, 2003), we hypothesize that this copepod is also not native. Nevertheless, we treat it as cryptogenic, pending further information about its host specificity and distribution outside of the islands.

Amphipoda (amphipods)

Introduced and Cryptogenic Amphipoda

Species	Date	Vector	Native to
Introduced Species			
Gammaridea: **Caprellidae**			
Caprella scaura	1929	SF, BW	Unknown
Caprella penantis	1921	SF, BW	Unknown
Caprella equilibra	1944	SF, BW	Unknown
Caprella danilevskii	1921	SF, BW	Unknown
Paracaprella pusilla	1937	SF, BW	Unknown
Gammaridea: **other families**			
Incisocalliope derzhavini	1967	SF, BW	Japan
Jassa falcata	1997	SF, BW	North Atlantic
Ericthonius brasiliensis	1935	SF, BW	North Atlantic
Monocorophium acherusicum	1943	SF, BW	Northwest Atlantic
Monocorophium insidiosum	1959	SF, BW	Northwest Atlantic
Laticorophium baconi	1967	SF, BW	Northeast Pacific
Grandidierella bispinosa	1996	SF, BW	Indo-Pacific
Grandidierella japonica	1992	SF, BW	Japan
Paraleucothoe sp.	1996	SF, BW	Unknown
Leucothoe micronesiae	1997	SF, BW	Indo-Pacific
Elasmopus "rapax"	1937	SF, BW	North Atlantic
Podocerus brasiliensis	1935	SF, BW	North Atlantic
Stenothoe gallensis	1935	SF, BW	Unknown
Stenothoe valida	<1924	SF, BW	North Atlantic
Tropichelura insulae	1922	SB	Indo-West Pacific
Cryptogenic Species			
Gammaridea: **other families**			
Elasmopus pectenicrus	1937	SF, BW	
Ruffojassa ventosa	1967	SF, BW	
Ruffojassa angularis	1967	SF, BW	
Photis hawaiensis	1936	SF, BW	
Platorchestia platensis	<1922	SBA	

Gammaridea: **Caprellidae** (skeleton shrimp)

"The wide dispersal of caprellids may be accounted for, without doubt, by their clinging habits and their customary association with fouling organisms, which are frequently transported on the bottoms of ships. Caprellids have been taken from fouled buoys and the bottoms of boats in Hawaii and elsewhere" (Edmondson & Mansfield, 1948). Caprellids are another group of crustaceans that achieved a wide global distribution via ship hull fouling centuries before systematic collections commenced. This, combined with unresolved species complexes in so-called "cosmopolitan" taxa, has prevented a clear resolution of the history and biogeography of potential invaders in many areas of the world. We consider at least four species of common Hawaiian caprellids to be nonnative species.

Guerra-García & García-Gómez (2001) found that *Caprella danilevskii* and *Caprella penantis* inhabit areas of high exposure or strong currents, suggesting an ability to do well on ship bottoms on the high seas.

Caprella scaura Templeton, 1836 **Introduced**

A now-global caprellid of unknown origin, described originally from "among marine plants at Riviere Noir, Mauritius" (Templeton, 1836) in the Indian Ocean, centuries after the first Portuguese vessels touched at those islands in the 1500s. It is now said to occur on most coasts of the world (McCain, 1968; Arimoto, 1976), with many purported synonyms (McCain & Steinberg, 1970; Arimoto, 1976). Bishop Museum material is from 1929 (Pearl Harbor), 1943 (Waikīkī, boat bottom), and later years. Edmondson & Mansfield (1948) illustrated specimens from Pearl Harbor and Waikīkī. Evans *et al.* (1972) also record it from Pearl Harbor (1971). Coles *et al.* (1999b) record it from Keʻehi Lagoon, Ala Wai Harbor, and Kewalo Basin, based upon 1997–1998 collections; it was also found in 2003 at Māʻlaea Harbor, Maui (Coles *et al.*, 2004). We regard this species as a ship introduction.

Caprella penantis Leach, 1814 **Introduced**

= *Caprella acutifrons* Latreille, as used by Edmondson, 1946a: 241; Edmondson & Mansfield, 1948

This is another cosmopolitan species (Arimoto, 1976) with centuries of ship-borne dispersal obscuring any original geographic patterns. Of its occurrence in Hawaiʻi, Edmondson & Mansfield (1948) wrote: "This species ... seems to be the most abundant of the Caprellidae to be found in the shoal waters of Hawaii. It is typically associated with the hydroid *Pennaria* ... Large numbers ... have been taken in Kaneohe Bay, Kahana Bay, and Honolulu Harbor, where colonies of the hydroid grow luxuriantly. This caprellid is a voracious species, a dozen specimens being capable of completely stripping a large colony of *Pennaria* of its polyps in a few hours." MacKay (1945) reported large numbers in Honolulu Harbor also eating the polyps of *Pennaria*, based on observations made in 1941–1942.

Bishop Museum material dates from 1921 and later years. Schellenberg (1938) reported it from Kāneʻohe in 1927 as "Seichtwaßer, sehr zahlreich" (shallow water, very numerous). We regard this species as a ship introduction.

Caprella equilibra Say, 1818 **Introduced**

This now-cosmopolitan caprellid was first recorded from Hawaiʻi by Edmondson & Mansfield (1948) based upon material (in the Bishop Museum collections) collected in 1944 by Edmondson from algae on a submerged buoy 1.6 km off the west coast of Oʻahu in 4.6 m of water. It remains present in Ala Wai Harbor where specimens (identified by I. Takeuchi, pers. comm. to R.C. DeFelice, May 1999) were found to be common in 1998. We regard this species as a ship introduction.

Caprella danilevskii Czerniavskii, 1868 **Introduced**

Caprella danilevskii is a fourth species of caprellid that has apparently been widely dispersed from its original home. Described from the Black Sea (McCain & Steinberg, 1970) it too is now said to occur on most coasts of the world. Edmondson & Mansfield (1948) noted it from many shoal-water stations around Oʻahu "typically associated with the brown seaweeds *Sargassum* species. It has also been recovered from the tufted colonies of the bryozoan *Bugula neritina*." It may have spread from

an initial inoculation in ports and harbors to more open systems, as have other invasions in Hawai‘i. Bishop Museum collections contain specimens from O‘ahu collected in 1921 and later years. We regard this species as a ship introduction.

Paracaprella pusilla Mayer, 1890 **Introduced**

This Atlantic caprellid (McCain, 1968) has been reported from several locations in the Pacific theater, including Amoy, China (McCain, 1968) and the Hawaiian Islands. It has now recently been reported from Chile, a first record for the Pacific coast of South America (Guerra-Garcia & Thiel, 2001). Edmondson & Mansfield (1948) noted it from Honolulu Harbor in 1937 from the screen of a water intake pipe at an electrical company. Additional material came from a hydroid (*Pennaria*) colony in 1941 in Honolulu Harbor. Edmondson & Mansfield (1948) note that it had been previously known from the West Indies “and South America.” McCain (1968) notes a wide distribution in the western North Atlantic and western South Atlantic Oceans (type locality Rio de Janeiro, Brazil), with outlier records in the eastern South Atlantic (tropical West Africa, Congo), South Africa (Durban), the Indian Ocean (Tanzania), and the Suez Canal (as well as the Pacific stations noted above). It appears to be a strongly Caribbean species. We also regard this species as a ship introduction.

Gammaridea (gammarid amphipods)

Pleustidae

Incisocalliope derzhavini (Gurjanova, 1938) **Introduced**

= *Parapleustes derzhavini*

= (?) *Parapleustes derzhavini makiki* Barnard, 1970

This Asian amphipod was first collected in 1967 in Kāne‘ohe Bay in 3 to 4 m of water from washings from corals and coralline and “fleshy” algae (Barnard, 1970, 1971). Ishimaru (1984) synonymized Barnard’s subspecies into the stem species. Chapman (1988) concluded that *P. derzhavini* was “likely to have been introduced to Hawaii from Asian and North American coasts with the fouling on the hulls of ships and with discharged ballast water... or on logs towed to Hawaii from North America.” An alternative interpretation is that of Bousfield & Hendrycks (1995), who elevate Barnard’s subspecies to full species level, as *Incisocalliope makiki*. We tentatively retain Ishimaru’s interpretation here, as a worker who was intimately familiar with within-species variation in Japanese populations of *I. derzhavini.*

Ischyroceridae

Jassa falcata (Montagu, 1808) **Introduced**

While Barnard (1970), based upon surveys in 1967, was unable to find *Jassa falcata* in Hawai‘i (and took pains to point out its absence), Coles *et al.* (1999b) collected this species at Sea Land Pier in Honolulu Harbor in 1997. We regard this North Atlantic species as a ship fouling or ballast water introduction.

Ericthonius brasiliensis (Dana, 1853) **Introduced**

= *Ericthonius disjunctus* Stout as reported by Edmondson & Ingram (1939)

This widely-distributed amphipod was first collected in Kāne‘ohe Bay fouling studies in 1935 and later years (Edmondson & Ingram, 1939, as *E. disjunctus*, as identified by Clarence Shoemaker; see Barnard, 1955 for synonymy). Barnard (1955) reported it from Pearl Harbor (1938), Waikīkī Beach (1943, on the bottom of a small boat), off of Barbers Point (one mile offshore, on iron buoy suspended to depth of 9 m), and from Honolulu Harbor (1951). Barnard (1970) noted that it was a strong candidate as an introduced species. Barnard (1971) reported that it formed “great masses of silty tubes attached to piles and docks in harbors in Oahu”, but that it also occurred “sparingly in the open sea to depths of at least 30m” (an error apparently for “30 feet” [9 m] as reported in Barnard, 1955). Grovhoug (1979) reported it from Pearl Harbor (based on 1978 collection), where it still occurs (Coles *et al.*, 1999a; 1996 collections). The ”great masses of silty tubes” noted by Barnard (1971) were not observed in 1996, but there may be seasonal aspects to this species’ abundance. Coles *et*

al. (1999b) also report it from Honolulu Harbor, Keʻehi Lagoon, Ala Wai Harbor, Barbers Point Harbor, and Kewalo Basin (1997–1998 collections), and Coles (2002b) report it at Waikīkī (2001). Coles *et al.* (2006) report it from Kauaʻi, Molokaʻi, and the island of Hawaiʻi, based upon 2003 collections.

We tentatively treat it here as a North Atlantic species, where most of the historical records are centered. It was introduced in ship fouling or ballast water.

Ruffojassa ventosa (Barnard, 1962) **Cryptogenic**

= Eurystheus ventosa, = Ventojassa ventosa

Barnard (1970, 1971) reports this warm-temperate Californian species from collections made in Oʻahu in 1967. Locations included (Barnard, 1970) the "open sea off the west end of Pearl Harbor, 4–5 m, sand bottom, wash of giant encrustation mass from hard sand reef;" off "Ewa Beach, in 18 and 30 m, wash of *Pocillopora*, other corals, and bryozoans"; "off the west end of Pearl Harbor, 25–30 m, several giant *Pocillopora* heads and large masses of short-tufted red algae, calcareous encrustations", and "seaward of Moku Manu, windward Oahu, 33 m, stem of black coral *Antipathes irregularis* Verrill, including bivalve community attached to coral." Coles *et al.* (2002b) report it at Waikīkī based on 2002 collections. While these habitats are not typically those of ship-mediated invaders, the disjunct distribution, and the frequency of other known invasions in open marine waters in Hawaiʻi, suggests that this species is cryptogenic in the Hawaiian fauna and may have been transported by ships to the islands.

Ruffojassa angularis (Shoemaker, 1942) **Cryptogenic**

= Parajassa angularis

Barnard (1970, pp. 202–204) noted that "This species and *Ventojassa ventosa* were not suspected to be present in the Hawaiian fauna prior to this study. They are enigmatic ... it is of considerable interest that together they have crossed the wide ocean gap between North America and Hawaiʻi." It is, like *R. ventosa*, otherwise known from warm-temperate waters of the Pacific coast (California and Mexico). Specimens were collected in 1967 at two of the same sites as noted above for *R. ventosa*, off the west end of Pearl Harbor.

Isaeidae

Photis hawaiensis Barnard, 1955 **Cryptogenic**

This mysterious amphipod has been known only from Oʻahu since its first collections in 1936 in Kāneʻohe Bay (Barnard, 1955). It was reported from Pearl Harbor based on 1978 collections by Grovhoug (1979). Barnard (1970, 1971) added no further new data, and the species remains unknown from elsewhere. Coles *et al.* (1997) report it again from Pearl Harbor (1996 collections). It remains present in Kāneʻohe Bay (2000 collections; Coles *et al.*, 2002a) and occurs in other Oʻahu harbors (1997 and 1998 collections: Honolulu Harbor, Keʻehi Lagoon, Ala Wai Harbor, Barbers Point Harbor, and Kewalo Basin). Coles *et al.* (2006) report it from Maui (2003 collections); additional records are from harbors at Nawiliwili and Port Allen, Kauaʻi; Kahului and Māʻlaea on Maui; and Hilo Harbor, also based on 2003 samples (Coles *et al.*, 2004).

Photis hawaiensis may represent an introduction first described from the site of invasion. We predict that it will be found to be native elsewhere, perhaps having been described under another, earlier name.

Corophiidae

Monocorophium acherusicum (Costa, 1857) **Introduced**

= Corophium acherusicum

This North Atlantic amphipod was mentioned by Shoemaker (1947) from "Oahu" (based on Smithsonian Institution specimens, but without any further data). Barnard (1955, 1971) recorded it from the bottom of a small boat at Waikīkī Beach (1943 record). It was collected in Pearl Harbor in 1996 (Coles *et al.*, 1997, 1999a), and in Keʻehi Lagoon, Ala Wai Harbor, and Kewalo Basin in 1997–1998 (Coles *et al.*, 1999b). We consider it introduced (as did Barnard) in ship fouling or ballast water.

Monocorophium insidiosum Crawford, 1937 **Introduced**

= *Corophium insidiosum*

This North Atlantic amphipod was first reported from the Hawaiian Islands by Barnard (1970), who noted specimens from Hilo collected in 1959. Barnard (1971) noted that Hilo specimens were "highly aberrant" morphologically, suggesting that the differences in Hawaiian material "may represent the loss of phenotypic stability as the result of a 'founder effect'." It was collected in Pearl Harbor in 1996 (Coles *et al.*, 1997, 1999a). Janet Lambertson (pers. comm., 1999) reports that in 1992 *C. insidiosum* (identified by Faith Cole) was abundant on O‘ahu in Ka‘elepulu Stream, Kailua, and also occurred at Kāne‘ohe Beach Park, Kāne‘ohe. We consider it introduced (as did Barnard) in ship fouling or ballast water.

Laticorophium baconi (Shoemaker, 1934) **Introduced**

= *Corophium baconi*

Barnard (1970, 1971) reported this Pacific American species questionably from Kāne‘ohe Bay based upon collections in 1967. Grovhoug & Rastetter (1980) recorded it from Pearl Harbor and Kāne‘ohe Bay (1976–1977 collections) and Grovhoug (1979) reported it from Pearl Harbor (1978 collections), where it still occurs (1996 collections; Coles *et al.*, 1997, 1999a). Coles *et al.* (1999b) report it from Honolulu Harbor, Ke‘ehi Lagoon, Ala Wai Harbor, and Kewalo Basin based upon 1997–1998 collections. It was found in 2002 collections at Port Allen, Kaua‘i (Coles *et al.*, 2004). Barnard discussed and listed (1970, Table 4, column 1) this species as a probable introduction, with which we concur. It was introduced in ship fouling or ballast water.

Aoridae

Grandidierella bispinosa Schellenberg, 1938 **Introduced**

Muir (1997) reported this Indo-Pacific species from Pearl Harbor, based on 1996 collections (Coles *et al.*, 1997). It was found at a brackish water location on the north shores of the East Loch, Pearl Harbor. It was previously known from the Bismarck Archipelago, Fiji, and the Marianas Islands. Myers (1985) described its habitat in Fiji as being "in mangrove litter and among phanerograms (*Syringodium, Halophila*)." Coles *et al.* (1999a) listed it as cryptogenic. Given its absence in earlier collections from estuaries and harbors on O‘ahu and its location in Pearl Harbor, we regard it as introduced, in ship fouling or ballast water.

Grandidierella japonica Stephensen, 1938 **Introduced**

= (?) *Neomicrodeutopes makena* Barnard, 1979 (see below)

Muir (1997) reported this brackish water Japanese species as a "new state record" from brackish water sites from throughout Pearl Harbor based on 1996 collections. Janet Lambertson (pers. comm., 1999) reports that in 1992 *Grandidierella japonica* (identified by Faith Cole) was collected on O‘ahu in abundance from Kāne‘ohe Beach Park, Kāne‘ohe (near Waikalua fishpond, at the mouth of Kāne‘ohe Stream) and from Ka‘elepulu Stream, Kailua. The population was still "thriving" in 1993 and 1994. It has also been introduced to the west coast of North America (Chapman & Dorman, 1975). Chapman & Dorman (1975) suggested that *Grandidierella makena* (Barnard, 1970) (= *Neomicrodeutopes makena*), described from a high energy, high surf location at Makapu‘u Point, on O‘ahu (based on 1967 collections) might be a junior synonym of *G. japonica*. Muir (1997) felt that the two species were distinct; the matter requires reexamination (J. Chapman, pers. comm., 1999). It was introduced in ship fouling or ballast water.

Leucothoidae

Paraleucothoe sp. **Introduced**

Specimens of this sponge- or ascidian-associated gammarid were collected in 1996 in Pearl Harbor (Muir, 1997) in fouling communities (Coles *et al.*, 1997). Coles *et al.* (2006) report it from Kaua‘i and Moloka‘i, based upon 2003 collections. It is similar but not identical to various *Paraleucothoe* species, and in particular to *P. fllindersi* Stebbing, 1888 (Muir, 1997), known only from a single

specimen collected in Flinder's Passage, Australia. The *Paraleucothoe* in Pearl Harbor thus remains unidentified and perhaps undescribed. It was listed as *P. ?flindersi* in Coles *et al.* (1999a) as a cryptogenic species, and as *P. findersi* in Coles *et al.* (2004), where it was reported in every harbor sampled on Kaua'i, Moloka'i, Maui, and Hawai'i. We concur with Muir (1997) that it is introduced. We tentatively treat it here as an Indo-Pacific species, arriving in ship fouling or ballast water.

Leucothoe micronesiae Barnard, 1965 **Introduced**

Coles *et al.* (1999b) record this species from Honolulu Harbor based upon 1997 collections. The type locality of this species is Ifaluk Atoll in the Caroline Islands (Barnard, 1965). Ledoyer (1986) subsequently recorded it from Madagascar. We regard it as introduced.

Melitidae

Elasmopus "rapax" Costa, 1853 **Introduced**

Barnard (1970) discussed this species as "… undoubtedly a strong candidate... as an import by artificial means." Barnard (1955, 1970) reported material from Kāne'ohe Bay (1937), Pearl Harbor [1948 (C.H. Edmondson) and 1951], and the Wai'anae shore (1952). Barnard's (1955) record of it from the Honolulu Aquarium is *Elasmopus calliactis* Edmondson, 1951; see Barnard, 1970, p. 131). Grovhoug (1979) also reported it from Pearl Harbor. Coles *et al.* (1997, 1999a) further record it from Pearl Harbor (1996 collections); Coles *et al.* (1999b), based upon 1998 material, report it from Ala Wai Harbor and Kewalo Basin. Coles *et al.* (2006) report it from reefs and Coles *et al.* (2004) from harbors on Kaua'i, Moloka'i, Maui, and the island of Hawai'i based upon 2002–2003 collections.

Elasmopus "rapax" was introduced in ship fouling or ballast water. We place the species name in quotation marks as this taxon may represent a worldwide complex of closely related species. We tentatively treat it here as a North Atlantic species, where most of the historical records are centered.

Elasmopus pectenicrus (Bate, 1862) **Cryptogenic**

Barnard (1955) first reported this "tropicopolitan" (Barnard, 1970) species from Hawai'i, in and near Pearl Harbor in fouling communities, based upon material collected between 1937 and 1950, to depths of 18 m. It had been reported from the Caribbean Sea, Red Sea, Indian Ocean, and tropical Pacific Ocean (Barnard, 1955). Coles *et al.* (1999b) report it from Honolulu Harbor, Ala Wai Harbor, and Kewalo Basin. Its apparent restriction to harbor locations on O'ahu (Barnard, 1970, 1971), combined with the probability that a global species complex is involved, lead us to consider it cryptogenic.

Podoceridae

Podocerus brasiliensis (Dana,1853) **Introduced**

Barnard (1955) first reported *P. brasiliensis* from Kāne'ohe Bay (1935), Pearl Harbor (1937) and Hanauma Bay (1937); Barnard (1970) suggested that it was a "strong candidate to be an introduced species"; Barnard (1971) noted that it occurred in Hawai'i "mainly as fouling organism in harbors." Grovhoug (1979, 1978 collections) reported it from Pearl Harbor as well, where it still occurs (Coles *et al.*, 1997, 1999a; 1996 collections). Coles *et al.* (1999b) report it from Ala Wai Harbor and Kewalo Basin based on 1998 material; Coles *et al.* (2002b) report it at Waikīkī (2001specimens), and Coles *et al.* (2004) report it in Kahului Harbor, Maui (2003 collections).

We tentatively treat it here as a North Atlantic species, where most of the historical records are centered. It was introduced in ship fouling or ballast water.

Stenothoidae

Stenothoe gallensis Walker, 1904 **Introduced**

= *Stenothoe valida* of Schellenberg, 1938

Schellenberg (1938) first reported this species from Kāne'ohe Bay, O'ahu ("Seichtwaßer, mehrere females ovig. 4 mm. O'ahu, Riff, Mitte Kāne'ohe Bay...", [Shallow water, several females, oviger-

ous, 4 mm, O‘ahu, Reef, Middle Kāne‘ohe Bay]). Barnard (1955) listed it from Kāne‘ohe Bay (1935–1937 material) and Pearl Harbor (buoy, 1944; dry dock, 1948, 1950). Barnard (1970) discussed the possibility of its introduction, and taxonomic challenges. Barnard (1971) noted that in O‘ahu it was primarily a “fouling organism in harbors probably associated with hydroids.” Coles *et al.* (1997, 1999a) report it from Pearl Harbor based on 1996 collections. Coles *et al.* (2002a) report it from Kāne‘ohe Bay (2000 collections) and from Hale O Lono and Kaunakakai Harbors on Moloka‘i.

Stenothoe gallensis is known from warm waters worldwide [for example, Caribbean, Mediterranean, Sri Lanka, and in French Polynesia in the Gambier Archipelago on the island of Mangareva (Barnard, 1955)]. Its origin is unknown. We regard it as a ship fouling or ballast water introduction.

Stenothoe valida Dana, 1853 **Introduced**

Barnard (1970) reported this species as a questionable identification, noting its possible introduction as a typical harbor species. However, the specimens Barnard had in hand were collected in 1967 by D.M. Devaney from seaward of Moku Manu, O‘ahu, on the stems of black coral (and possibly from the bivalve community attached to the coral), causing Barnard to make the following remarks: “So-called *S. valida* has been found in Hawai‘i only in association with the black-coral *Antipathes irregularis* off the east coast of Oahu in 33 m of water depth. Under normal circumstances that unusual habitat would suggest a misidentification of *S. valida*, for the species normally inhabits harbors... the Oahuan population of *Antipathes* is composed of colonies moved by biologists to that locale from other parts of Hawaii. One might thus expect that a eurytopic harbor fouling organism could find an open niche in such an artificial situation. But *S. valida* has not as yet been collected in Hawaiian harbors.” Barnard (1971) repeated this record. Chilton (1924) earlier noted that he had “recently received specimens from the Hawaiian Islands which appear to belong to this species.”

We tentatively admit Chilton’s record as the first for the islands, but note that the next record (other than the 1967 material, above) appears to be that of collections made in 1996 in Pearl Harbor (Coles *et al.*, 1999a). The 1978 record for Pearl Harbor noted by Coles *et al.* (1999a) is based on a report by Grovhoug (1979) who questionably identified his material as either *S. gallensis* or *S. valida*. Coles *et al.* (1997, 1999a) report it from Pearl Harbor based on 1996 collections; Coles *et al.* (1999b) report it from Honolulu Harbor, Ala Wai Harbor, Barbers Point Harbor, and Kewalo Basin (1997–1998 collections); Coles *et al.* (2002a) further report it in Kāne‘ohe Bay (2000). Coles *et al.* (2006) report it from Kaua‘i, based upon 2002 collections; Coles *et al.* (2004) further record in harbors on Moloka‘i and Maui, from 2003 collections.

Stenothoe valida is now reported from many areas of the world; we tentatively regard it as a North Atlantic species.

Cheluridae

Tropichelura insulae (Calman, 1910) **Introduced**

Miller (1924b) reported this wood-boring amphipod, originally described from Christmas Island in the Indian Ocean, from wooden test blocks in Samoa and in Honolulu Harbor, based upon collections made in 1922. Barnard (1955) recovered specimens in 1949 from Honolulu Harbor as well, and noted further records from the Caroline and Mariana Islands. Cookson (1991) reported the first record from Australia (Green Island, associated with *Limnoria*). While Barnard (1970, p. 17) stated that “The question as to whether this species has been distributed around the world by modern shipping is entirely open to question,” he listed it in his Table 4 as a possible candidate for human importation. Barnard (1971) noted it again from Honolulu Harbor, on pilings and floating docks.

We believe this species is a classic case of an introduction in the days of wooden-hulled ships. We regard it as introduced from the Indo-West Pacific.

Talitridae

Platorchestia platensis (Kroyer, 1845) **Cryptogenic**

= *Orchestia platensis*

This now globally occurring sand hopper or beach hopper has been reported from the Hawaiian Islands for many years over a wide variety of habitats and elevations. Chilton (1922) stated that "... in the Hawaiian islands *Orchestia platensis* is found from the seashore up to very considerable heights, and numerous other examples of the same kind could be given." Subsequent reports are given at http://www2.bishopmuseum.org/HBS/checklist/citation.asp?grp=Arthropod, including records from the islands of Kaua'i, O'ahu, Lāna'i, Maui, and Hawai'i. While Fee (1967) studied beach specimens from Kāne'ohe Bay, the identity of his material was uncertain according to that author. Alicata (1936) reported *P. platensis* (as *O. platensis*) from inland poultry farms, "especially in damp and wet areas around water fountains", based upon material identified at the time by M.A. Miller. Earlier records of *P. platensis* from high elevations in Hawai'i (from the islands of Hawai'i, O'ahu, and Lāna'i) by Stebbing (1900) have been assigned to *Platorchestia pickeringi* by Barnard, 1955 (as *Orchestia pickeringi*). Barnard (1971, p. 131) referred to the "Hawaiian beach-hopper *Orchestia platensis*" as making excellent introductory laboratory specimens for a study of amphipods.

If Hawaiian populations include true *P. platensis,* we admit here as cryptogenic populations the strictly littoral, marine, beach-wrack associated populations that may have been introduced with early ship's ballast.

Tanaidacea (tanaids) and **Isopoda** (isopods)

Introduced and Cryptogenic Tanaidacea and Isopoda

Species	Date	Vector	Native to
Introduced Species			
Tanaidacea			
Parapseudes pedispinis	1996	SF,BW	Northeast Pacific
Apseudes sp.	1996	SF,BW	Japan?
Isopoda			
Gnorimosphaeroma rayi	1972	SF,BW	Japan
Sphaeroma walkeri	1943	SF,BW	Indian Ocean
Paradella dianae	2002	SF, BW	Eastern Pacific
Pistorius bidens	2002	SF, BW	Australia
Paracerceis sculpta	1943	SF,BW	Northeast Pacific
Exosphaeroma sp.	1996	SF,BW	Unknown
Mesanthura sp.	1996	SF,BW	Unknown
Limnoria tripunctata	1922	SB	Southern hemisphere?
Paralimnoria andrewsi	1922	SB	Indo-West Pacific
Caecijaera horvathi	1975	SB	Southern hemisphere?
Littorophiloscia culebrae	1984	SBA	North Atlantic?
Halophiloscia couchii	1997	SBA	Northeast Atlantic
Armadilloniscus ellipticus	1985	SBA	Unknown
Alloniscus oahuensis	1879	SBA	Indo-Pacific
Porcellio lamellatus	1973	SBA	Northeast Atlantic
Buchnerillo sp.	1985	SBA	Atlantic?
Olibrinus truncatus	1985	SBA	Southern hemisphere?
Ligia exotica	1996	SF, SBA	Unknown
Cryptogenic Species			
Tanaidacea			
Leptochelia "*dubia*"	1932	SF,BW	

Additional Taxa Treated and Their Status

Species	Date	Vector	Native to
Isopoda			
Sphaeroma quoianum	ca. 1920	SF/BW	New Zealand
Status: *Deleted*			
Sphaeroma terebrans			
Status: *Erroneous record; see discussion*			

Tanaidacea (tanaids)
Parapseudididae
Parapseudes pedispinis Boone, 1923 **Introduced**
This Eastern Pacific tanaid, previously known from California to Ecuador, was reported by Muir (1997) from Pearl Harbor, based on 1996 collections (Coles *et al.*, 1997). Coles *et al.* (1999b) report it also from Honolulu Harbor (1997 collections). Coles *et al.* (2006) report it from Moloka‘i, based upon 2003 collections. Muir regarded it as an introduced species, and we concur. It was introduced in ship fouling or with ballast water.

Apseudididae
Apseudes sp. **Introduced**
This tanaid is widely distributed in Kāne‘ohe Bay (on the Kāne‘ohe Bay Sand Bar) and in Pearl Harbor (1996 collections) (Muir, 1997; Coles *et al.*, 1997). Muir (1997) found it to be most closely related to the Japanese *Apseudes nipponicus* Shiino, 1937, but felt that differences between Hawaiian material and *A. nipponicus* warrant the description of the Kāne‘ohe Bay—Pearl Harbor specimens as a new species. Given its broad distribution on both the north and south sides of O‘ahu, it is not likely to have been missed in earlier surveys, including the World War II buoy surveys (Miller, 1940, 1968). We regard it as introduced, regardless of whether it is described or not.

Anthruridae
Leptochelia "dubia" (Krøyer, 1842) **Cryptogenic**
Miller (1940) reported this tanaid, which has a purported global distribution, from various stations on O‘ahu and Maui, with the earliest collection being at Waikīkī by C.H. Edmondson in 1932. Additional collections included Kawela Bay, Kāne‘ohe Bay, Hanauma Bay, and Hālona on O‘ahu, and Hawea Point, Hāna, and Hanamanioa on Maui. Grovhoug (1979) reported it (as a questionable identification) from Pearl Harbor in 1978. Bailey-Brock (1984) found it in densities up to 32,800 per square meter in the sand beds of the onuphid worm *Diopatra leuckarti* at Niu Valley on the south shore of O‘ahu. Bishop Museum collections also include specimens collected in 1938 at Black Point, O‘ahu.

Coles *et al.* (1997, 1999a) record it from Pearl Harbor (1996 collections); Coles *et al.* (1999b, based on 1997–1998 collections) report it from Honolulu Harbor, Ke‘ehi Lagoon, Ala Wai Harbor, Barbers Point Harbor, and Kewalo Basin; Coles *et al.* (2002a) report it from Kāne‘ohe Bay (2000), and Coles *et al.* (2002b) report it from Waikīkī (2001). Coles *et al.* (2004, 2006) report it from reefs and harbors on Kaua‘i, Moloka‘i, Maui, and the island of Hawai‘i, based upon 2002–2003 collections.

The systematics of this species remain to be elucidated; compounding the problem is that it is probable that both a species complex is involved and that one or more members of this species group have been transported in ship fouling, with oysters and by other means. We regard it as cryptogenic until Hawaiian material has been reexamined and compared with other subtropical populations.

Isopoda (isopods)
Sphaeromatidae
Gnorimosphaeroma rayi Hoestlandt, 1969 **Introduced**
Hoestlandt (1973, 1975) reported this Japanese isopod from the Wai‘anapanapa Caves on Maui Island; the specimens were collected in 1972 (NMNH collections). Subsequently, Hoestlandt identified additional specimens of *G. rayi* from Waiahuakua Stream (Kaua‘i) and from Lua o Palahemo

pond and Waiahukini (Hawai‘i) (H. Hoestlandt to D.M. Devaney, *in litt.*, August 3, 1976). Collection dates are 1974–1975 for the last three sites (BPBM collections). Holthuis (1973, p. 11) noted this species as unidentified isopods from Lua o Palahemo pond, with a salinity of 22 ‰, an usually low salinity for this more marine isopod.

Although described originally from California, Hoestlandt later found it in the Sea of Japan and believed it be introduced to California from there with oyster culture. We regard it as introduced to Hawai‘i as well, perhaps in ship fouling or in ballast water.

Paradella dianae (Menzies, 1962) **Introduced**

Coles *et al.* (2004) report this well known and widespread, often harbor-dwelling isopod from fouling communities from Kaua‘i in 2002 and from Maui in 2003. Now reported from harbors around the world, it is native to the warm waters of the Eastern Pacific, where it is a member of a small group of *Paradella* with distinctively sculptured pleons and pleotelsons (Wetzer & Bruce, 2007)

Pistorius bidens Harrison & Holdich, 1982 **Introduced**

Coles *et al.* (2004) report this Australian isopod from fouling communities in Kaua‘i in 2002, Moloka‘i in 2003, and Maui in 2003.

Sphaeroma walkeri (Stebbing, 1905) **Introduced**

This well-known ship-dispersed isopod (Carlton & Iverson, 1981) was first collected in the Hawaiian Islands in 1943 in Hilo (Miller, 1968) and again in 1961 at Hanamā‘ulu Bay, Kaua‘i. Bishop Museum material also includes collections from Pearl Harbor in 1976. Carlton & Iverson (1981) review its global dispersal history. We regard it as introduced. That it is uncommon is revealed by the remarks of Edmondson (1955) who, unaware of the 1943 collections [which were not to be published until 1968 (Miller, 1968)], and a long observer of the boring and fouling fauna of the Islands, noted that "[*Sphaeroma*], in so far as I know, has not been observed in Hawaiian waters." It was also noted by Grovhoug & Rastetter (1980) for Kāne‘ohe Bay and Pearl Harbor (1976–1977 collections).

Sphaeroma quoianum Milne-Edwards, 1840 **Deleted**

= *Sphaeroma quoyanum*, incorrect subsequent spelling
= *Sphaeroma pentodon* Richardson, 1904

A specimen of this widespread isopod is in the Smithsonian Institution collections, collected by Paul Bartsch in Pearl Harbor, probably in 1920 (see *Callinectes sapidus*). There are no further records.

Sphaeroma terebrans Bate, 1866 **[See Discussion]**

O'Neill (1983) and Pendleton & O'Neill (1986) state that "The principal borers recorded from Pearl Harbor are the crustaceans, *Limnoria tripunctata* and *Sphaeroma terebransi* [sic], and the mollusks..." While the Indian and Atlantic Ocean isopod *S. terebrans* would not be unexpected in the Hawaiian Islands, there are no other records of this species from Hawai‘i, and no indication of the source of these statements. In their own studies, O'Neill & Pendleton (1968) do not record any species of *Sphaeroma* from Pearl Harbor. We consider this report a *lapsus* and do not consider it further here.

Paracerceis sculpta (Holmes, 1909) **Introduced**

Miller (1968) reported this eastern Pacific species from Pearl Harbor and Hilo Harbor (Hawai‘i) based upon material collected during World War II (1943), noting that "probably it was transported on the hulls of naval ships plying between San Diego and Hilo and Pearl Harbor." Grovhoug (1979) reported it again from Pearl Harbor based upon specimens collected in 1978. It was also noted by Grovhoug & Rastetter (1980) for Kāne‘ohe Bay and Pearl Harbor (1976–1977 collections), by Coles *et al.* (2002a) in Kāne‘ohe Bay, and by Coles *et al.* (2004) in Port Allen Harbor, Kaua‘i.

Exosphaeroma sp. **Introduced**

Coles *et al.* (1997, 1999a) report an *Exosphaeroma* sp. from Pearl Harbor, based on 1996 collections. Although not yet identified to species, we regard this isopod as introduced, as no other sphaeromatids of this or any related genera (such as *Paracerceis* or *Dynamenella*) are known to exist naturally in the Islands. We regard it as introduced with ship hull fouling or in ballast water.

Anthuridae

Mesanthura sp. **Introduced**

This isopod, previously unknown from the islands, was collected in Pearl Harbor surveys of 1996 (Coles *et al.*, 1999a). Coles *et al.* (1999b) record it from Honolulu Harbor, Ke‘ehi Lagoon, Barbers Point Harbor, and Kewalo Basin; further stations include Kāne‘ohe Bay (Coles *et al.*, 2002a) and Waikīkī (Coles *et al.*, 2002b). As with the introduced tanaid *Apseudes* sp., given the broad distribution of this isopod, it is not likely to have been missed in earlier surveys, including the World War II buoy surveys (Miller, 1940, 1968).

Limnoriidae

Limnoria tripunctata Menzies, 1957 **Introduced**

= *Limnoria lignorum* of pre-1957 Hawaiian authors

This wood-boring gribble was collected at least as early as 1922 in test blocks in Pearl and Honolulu Harbors and at Nawiliwili Bay on Kaua‘i (Miller, 1924b, as *Limnoria lignorum*). Numerous specimens are in Bishop Museum collections from Honolulu Harbor collected between 1945 and 1949 and identified by R.J. Menzies. While it is curiously absent from Menzies’ 1957 monograph, *L. tripunctata* is marked on map 3 of Menzies’ 1959 paper (p. 33c) as being on the Hawaiian islands. Cooke (1977b) found it in 1975 at Makai Range, Makapu‘u, O‘ahu heavily infesting Douglas fir test blocks at a depth of 1 m after a submergence period of 6 months. Coles *et al.* (1999a) continue to report its presence in Pearl Harbor (1996 collections).

Paralimnoria andrewsi (Calman, 1910) **Introduced**

Miller (1924b, as *Limnoria andrewsi*) reported this wood-boring gribble, originally described from Christmas Island, Indian Ocean, from Honolulu Harbor and Nawiliwili (Kaua‘i), as well as Samoa, based on test blocks suspended in 1922. *Paralimnoria andrewsi* occurred in Honolulu Harbor with *Limnoria tripunctata*, but greatly outnumbered this latter species; in turn, *Limnoria tripunctata* “predominates to such an extent [in Pearl Harbor] that if [*P.*] *andrewsi* occurs [there] at all its presence has been overlooked.” This interesting observation in two harbors only a few kilometers apart may indicate competition between the two species. Bishop Museum collections include specimens collected in Honolulu Harbor in 1949.

Paralimnoria andrewsi occurs in the Indian Ocean (Christmas Island, its type locality, above, and the Cocos Islands), in the South Pacific Ocean (Samoa, Philippines, Papua New Guinea), in the North Pacific Ocean (Japan and Hawaiian Islands), and in the Atlantic Ocean (Florida, Caribbean [Puerto Rico], Ghana) (Cookson, 1991). We regard it as introduced to the Atlantic Ocean, to Hawai‘i and perhaps to Japan as well.

Janiridae

Caecijaera horvathi Menzies, 1951 **Introduced**

Cooke (1977b) reported this tiny, eyeless asellote isopod from the tunnels of the wood boring gribble *Limnoria tripunctata* in test blocks of Douglas fir below the pier at a depth of 1 m at Makai Range, Makapu‘u, O‘ahu, in March 1975. Carlton (1979a) considered it introduced with *Limnoria* to Los Angeles—Long Beach Harbors (its type locality) as well. Cooke (1977b) suggested that it could be introduced. We consider it introduced, with ship boring communities, possibly in the hulls of yachts, to the Hawaiian Islands. Its origin remains unknown, but in concert with the general nature of the wood-boring warm-water biota, it may be native to the southern hemisphere.

Oniscidea

We include in our treatment here eight species of maritime isopods that are intimately associated with salt water habitats.

Philosciidae

Littorophiloscia culebrae (Moore, 1901) **Introduced**

= *Philoscia culebrae*; = *Vandeloscia culebrae*

Taiti & Howarth (1995) describe this species as, "A strictly halophilic littoral species found under debris, logs, and stones on both rocky and sandy shores." It was first found (Taiti & Ferrara, 1986) in O'ahu in 1984 (Ala Moana Park beach, under coconuts, S. Taiti collector). It was previously known from Florida, Puerto Rico, Cuba, Virgin Islands, Angola, and Madagascar (Taiti & Ferrara, 1986; Taiti & Howarth, 1996), and thus appears to be a species of largely Atlantic origin. Taiti & Howarth, (1996) added new records from Pearl and Hermes Atoll (1983) and Lisianski (under rocks on beach, 1983). Stefano Taiti regards this species as introduced (pers. comm., August 1996), possibly with early ship ballast. Taiti (1999) extended the range to Midway Atoll (1997 collections, under splash zone rocks on jetty).

Halophilosciidae

Halophiloscia couchii (Kinahan, 1858) **Introduced**

Taiti (1999) reported the first record of this maritime isopod from the Hawaiian archipelago, based upon specimens collected in Midway in 1997. He notes that "this halophilic species occurs on coasts of marine and brackish waters." Its native range appears to be the warm eastern Atlantic Ocean; Taiti (1999) notes that "it has also been introduced to Virginia, Bermuda, Argentina, and Western Australia."

Scyphacidae

Armadilloniscus ellipticus (Harger, 1878) **Introduced**

= *Armadilloniscus litoralis* Budde-Lund, 1885 (*fide* Garthwaite *et al.*, 1992)

Taiti & Ferrara (1989, as *A. litoralis*) record this species from Coconut Island, O'ahu, based upon specimens collected by S. Taiti in 1985; they note that "... this species has a very wide distribution, which is certainly due to the ease with which this halophilic form is passively transported." Its origin is not clear, as it is known from the Atlantic coast of North America (Massachusetts to Florida; the type locality of *A. ellipticus* is in Connecticut), Bermuda, the Azores, Madeira, and Mediterranean (the type locality of *A. litoralis* is the Venice Lagoon, Italy), in the Indian Ocean from Madagascar, and in the Pacific Ocean from Tahiti, Malaysia (Pulau Pinang), North Korea, Hong Kong, Japan, and Hawai'i. Genetic analyses should aid in determining its geographic origin. Schultz (1972) provided a detailed habitat description for Bermuda; he notes that this species "at times of high tide (is) many times completely under water." Stefano Taiti regards this species as introduced (pers. comm., August 1996), possibly with early ship ballast. Taiti (1999) extends the range of this isopod in the Archipelago to Midway Atoll (1997 collections, under splash zone rocks on jetty).

Scyphacidae

Alloniscus oahuensis Budde-Lund, 1885 **Introduced**

This species was recorded from O'ahu by Budde-Lund in 1879 and then formally described in 1885. Taiti & Howarth (1996) note that *A. oahuensis* "is a strictly littoral species that occurs under logs or litter in the upper part of sandy shores." It is now recognized as widely distributed in the Indian and Pacific Oceans; S. Taiti regards this as an introduced species in the Hawaiian Islands (pers. comm. August 1996). Schultz (1984) provided a detailed redescription of the species based upon material from Hālawa Valley, Moloka'i Island, noting that it is a species found "on and near marine beaches

and along the margin of rivers which empty into the sea." Schultz also records specimens from Kaua‘i. Taiti & Ferrara (1991) record it from a number of stations in 1984–1985 around O‘ahu. Taiti & Howarth (1996) add further Hawaiian records from O‘ahu (Kāne‘ohe Bay, near Kahalu‘u mud flats above high water (1973); Kawainui Marsh, litter adjacent to marsh (1980); Popoi‘a Islet, debris (1973); Moloka‘i: 1.6 km west of Kamehameha, Coconut Grove, near *mauka* edge of mangrove (1974). Taiti *et al.* (1992) also record it from the Togian Islands, Indonesia (1987). Taiti & Ferrara (1991) discuss the status of an older record from an anomalous habitat from Lāna‘i noted by Schultz (1984) and conclude that this material would require reexamination. It was likely carried to the Islands with ship ballast.

Porcellionidae

Porcellio lamellatus lamellatus Budde-Lund, 1885 **Introduced**

Schultz (1972) noted that this species in Bermuda "lives in sandy soil and is also present on the upper parts of the beach in the transition region to the large vegetation zone .... It was especially abundant in grass patches on the side of a steep cliff-like slope ...where it was living with *Armadillidium vulgare*." Taiti & Ferrara (1991) recorded it from Turtle Bay, O‘ahu, based upon specimens collected in 1984. Taiti & Howarth (1996) further recorded it from French Frigate Shoals (1984, under debris), Kaua‘i (1973, leaf litter on beach), and Moloka‘i (1974, near mauka edge of mangrove). This species is native to eastern and southern Europe and northern Africa, and is also now known from Bermuda, Cuba, Argentina, western Australia (Rottnest Island) (Schultz, 1972; Taiti & Ferrara, 1991, 1996). Stefano Taiti regards this species as introduced (pers. comm., August 1996).

Family Uncertain [*fide* Taiti & Howarth, 1996 and S. Taiti (pers. comm., May 2001)].

Buchnerillo sp. **Introduced**

Taiti & Ferrara (1991) reported this littoral species from Coconut Island, O‘ahu, based upon specimens collected in 1985. They noted that it appeared similar to *B. oceanicus* Ferrara from Somalia. Only one other species is known, *B. litoralis* Verhoeff, from the Mediterranean, Madeira, and Florida. Stefano Taiti regards this species as introduced (S. Taiti, pers. comm., August 1996).

Olibrinidae

Olibrinus truncatus Taiti & Ferrara, 1991 **Introduced**

Taiti & Ferrara (1991) described this maritime isopod as a new species from Coconut Island, O‘ahu (collected in 1985). Stefano Taiti regards it as introduced to the Hawaiian Islands (S. Taiti, pers. comm., August 1996). Taiti *et al.* (1992) recorded it from Pulau in the Togian Islands, Sulawesi, Indonesia, noting that it "is strictly halophilic and most probably amphibious, since it is common in and around mangrove forests under stones and logs which are submerged during the high tide." They further comment that "Its apparently disjunct range is certainly due to the lack of investigations in most parts of the Pacific area."

Ligiidae

Ligia exotica Roux, 1828 **Introduced**

A recent (1996) collection of this species at Hilo by R.C. DeFelice represents the first valid record of *L. exotica* from the Hawaiian Islands. The specimens were identified by S. Taiti. Previous records of *L. exotica* from Hawai‘i by Robertson, Edmondson, Van Name, and others, are all based on *Ligia hawaiiensis*, an endemic species (S. Taiti, pers. comm., 1996).

Cumacea (cumaceans) and **Mysidacea** (mysids)

Introduced Cumacea and Mysidacea

Species	Date	Vector	Native to
Cumacea			
Nannastacus sp.	1996	BW	Unknown
Scherocumella sp.	<1996	BW	Unknown
Mysidacea			
Holmesimysis costata	1967	BW	Northeast Pacific

Cumacea (cumaceans)
Nannastacidae
Nannastacus sp. **Introduced**
This cumacean was collected in 1996 (Coles *et al.*, 1997) from Kāneʻohe Bay (the Kāneʻohe Bay Sand Bar), Pearl Harbor, and from Hanalei Bay on Kauaʻi (Muir, 1997). They are "relatively uncommon (but) widely distributed, particularly in medium to fine grain, carbonaceous sediments" (Muir, 1997). Cumaceans were previously unknown from the Hawaiian Islands. It is regarded as an unquestionable introduction to the Islands (L. Watling, pers. comm., 1999), probably by night-entrained ballast water (J.T. Carlton, unpublished data).

Scherocumella sp. **Introduced**
Another introduced species of cumacean from Oʻahu, from floats in Pearl Harbor based on specimens collected by B. Burch, is reported by L. Watling (pers. comm., February 1996).

Mysidacea (opossum shrimps, mysids)
Mysidae
Holmesimysis costata (Holmes, 1900) **Introduced**
This opossum shrimp, previously known from the Pacific coast of North America from southern California to the Queen Charlotte Islands, was reported from the Hawaiian Islands by Holmquist (1979), as "Off beaches of Hawaii; Jan[uary] 1967; M. Berrill, leg. (USNM 122235); 1 juv. male, 1 juv. female." Michael Berrill reports (pers. comm., February 1998) that these mysids were collected on a beach in Waikīkī, in shallow water just beyond the breaking waves and that they were abundant, occurring in large schools. We regard it as a ballast water introduction, a conclusion with which C. Holmquist concurs (C. Holmquist, *in litt.*, 10 September 1986). The species occurs in a wide variety of shallow-water habitats (Holmquist, 1979), often over sediments and seagrasses, and including enclosed bays and harbors (for example, San Pedro, in southern California; Friday Harbor, Washington, netted at pier), thus making it susceptible to ballast water entrainment.

Cirripedia (barnacles)

Introduced Cirripedia

Species	Date	Vector	Native to
Amphibalanus amphitrite	1902	SF	Southern Hemisphere
Amphibalanus eburneus	1929	SF	Northwest Atlantic
Amphibalanus reticulatus	1929	SF	Southern Hemisphere
Chthamalus proteus	1993	SF	Western Atlantic

Edmondson (1948) reported briefly upon his observations of fouling on the hull of the Swedish scientific research vessel *Albatross*, while it was drydocked in Honolulu Harbor on 1 December 1947. Edmondson noted that the hull was “neatly and evenly covered by a species of rock barnacle described many years ago from the peninsula of Lower [Baja] California. The nearest the *Albatross* came to the type locality of the barnacle was the Pacific end of the Panama Canal. As large quantities of the barnacle were deposited in Honolulu Harbor from the dry dock, it is anticipated that this unique form may make its appearance in local waters before very long.” In the Bishop Museum collections there are three lots of barnacles collected from the *Albatross* in December 1947 at Honolulu, identified as *Balanus tintinnabulum peninsularis*?, *Lepas anatifera*, and *Conchoderma auritum*. The first barnacle has not been found in Hawai‘i. The last two species occur widely on floating materials, whales, and boat bottoms around the world. In a letter in Bishop Museum files dated 8 April 1960, Edmondson indicates that I.E. Cornwall identified the material and that the *Albatross* had come through the Panama Canal on the way to Hawai‘i. Edmondson further notes in this letter that “*B. tintinnabulum peninsularis* Pilsbry... was the principal fouling on the hull of the boat, although large numbers of *Conchoderma auritum* were also present and also what appeared to be *Lepas anatifera.” Balanus tintinnabulum peninsularis* is now considered a full species, *Megabalanus peninsularis* Pilsbry, 1916 (Newman & Ross, 1976; Henry & McLaughlin, 1986).

Gordon (1970) reviewed the Hawaiian barnacles, reporting *Amphibalanus amphitrite* and *Amphibalanus eburneus* from wooden floats and styrofoam docks on Coconut Island in Kāne‘ohe Bay. Newman (1986) reviewed the history and biogeography of Hawaiian barnacles, including the *Amphibalanus* species discussed here.

Balanidae

Amphibalanus amphitrite (Darwin, 1854) **Introduced**

= *Balanus amphitrite; = Balanus amphitrite hawaiiensis* Broch, 1922

This now widespread barnacle of southern hemisphere origin was first collected in 1902 in Honolulu Harbor (Henry & McLaughlin, 1975). This material was collected by the R/V *Albatross* on July 3, 1902 (USNM catalogue number 32517, http://goode.si.edu/mcs/iz/Query.php [accessed July 2003]). The first published record of these specimens is that of Pilsbry (1907, p. 190), who noted that “Some small specimens [of *Balanus amphitrite*] taken from the bottom of a tug at Honolulu are similar externally to figure 2e of plate 5 of Darwin’s Monograph, except that the compartments diverge less above, the aperture being somewhat smaller and hardly dentate.”

Bryan (1915, material identified by H.A. Pilsbry) and Broch (1922, as the new subspecies *hawaiiensis*, specimens collected “on broken china” in 1915 in Pearl Harbor) are additional early published records. Pilsbry (1928) repeated the W.A. Bryan record (1915, off Honolulu Harbor) and further reported material from Pearl City, from the West Lock of Pearl Harbor between Waipahu and Ho‘ae‘ae (‘Ewa), very abundant between tides on an *Anomia* reef in 1913, and from Kualoa, Kāne‘ohe Bay, on volcanic rocks in 1920.

Edmondson (1933, as *B. a. hawaiiensis*) noted that it was very common in Pearl Harbor on piling and shore rocks. Edmondson & Ingram (1939) provide growth data on fouling panels in Kāne‘ohe Bay in 1935 and subsequent years. Evans *et al.* (1972) and Long (1974) recorded it from Pearl Harbor (and from nearshore panels off Pearl Harbor). Henry & McLaughlin (1975) note additional specimens collected from Pearl Harbor (1931 and later), Honolulu Harbor, and Kāne‘ohe Bay (the latter, 1959). It was also noted by Grovhoug & Rastetter (1980) for Kāne‘ohe Bay and Pearl Harbor (1976–1977 collections). It is widespread throughout the main Hawaiian Islands, with records from Kaua‘i, O‘ahu, Moloka‘i, Maui, Lāna‘i, and Hawai‘i (Coles *et al.*, 1999a, 1999b, 2002a, 2002b, 2004, 2006).

Utinomi (1960) reviewed some of the early global records of this species. Hoover (1998, 2006) presents a color photograph from Coconut Island, O‘ahu. We regard it as introduced by ship fouling.

Amphibalanus eburneus (Gould, 1841) **Introduced**

= *Balanus eburneus*

This western Atlantic Ocean "ivory barnacle" was first collected in 1929 in Pearl Harbor (Henry & McLaughlin,1975). Edmondson (1931) wrote that "the barnacle (*Balanus eburneus*), among which the crab [*Panopeus pacificus*] is found, is a typical species of the east coast of the United States, which is suggestive of the view that both the crabs and barnacles may have been transported to Hawai'i through shipments of oysters or on the bottoms of ships." Edmondson (1933) noted that it was in Pearl Harbor, on buoys, floats, and oyster shells. Hutchins (1949, page 67) reported it in fouling on five buoys set in Hawaiian waters in 1943, noting that "the presence of *B. eburneus* is evidently the result of its introduction to the islands on ships, since the form is native to the Atlantic coast of North America." Matsui *et al.* (1964) reported specimens from McCully Bridge, Ala Wai Canal, and Mā'alaea Bay Harbor, Maui, all collected in 1962. Evans *et al.* (1972) and Long (1974) found it on fouling panels in Pearl Harbor and in nearshore waters off Pearl Harbor. It was also noted by Grovhoug & Rastetter (1980) for Kāne'ohe Bay and Pearl Harbor (1976–1977 collections).

Ball (1950) found the endoparasitic gregarine protozoan *Cephaloidophora communis* in this barnacle, presumably from O'ahu, in 1949. It was found only in *Amphibalanus eburneus* and not in two other barnacle species (*Amphibalanus amphitrite* and *Balanus* sp.) nor in 30 species of decapods.

Amphibalanus reticulatus (Utinomi, 1967) **Introduced**

= *Balanus reticulatus*

This ship-dispersed barnacle, likely originating from the Indo-Pacific, was collected as early as 1929 in O'ahu on rocks (Henry & McLaughlin (1975). Henry & McLaughlin listed additional material from "off Oahu" on buoys (1944), Pearl Harbor (1931, 1948), Honolulu Harbor (1954), and Kāne'ohe Bay (1959). Southward *et al.* (1998) report it in 1956 in the Ala Wai Canal. It was also noted by Grovhoug and Rastetter (1980) for Kāne'ohe Bay and Pearl Harbor (1976–1977 collections). It is now widespread around O'ahu (Coles *et al.*, 1999a, 1999b), and is also reported from Nawiliwili and Port Allen Harbors, Kaua'i, and Hilo Harbor (Coles *et al.*, 2004). DeFelice *et al.* (2002) report it from French Frigate Shoals. We regard it as introduced via ship fouling.

Balanus crenatus Bruguière, 1789 **[See Discussion]**

Long (1974) recorded this North American and European barnacle from fouling panels off Pearl Harbor. There are no records before or after Long's report. The record is considered dubious (DeFelice & Godwin, 1999). We do not further consider it.

Chthamalidae

Chthamalus proteus Dando & Southward, 1980 **Introduced**

John Hoover of Honolulu was the first to formally document the existence of this barnacle in the Hawaiian Islands when he photographed it in Kāne'ohe Bay in March 1995 (the date imprinted on the first photographic slide of this barnacle; J. Hoover, pers. comm., June, 1999). When the first surveys were undertaken in 1996 to establish the extent of this species, it was already found to be widespread around O'ahu, including Pearl Harbor (Southward *et al.*, 1998; Coles *et al.*, 1999a), and by 1996–1998 it had been found on Kaua'i, Maui, Midway Island, and Guam (Southward *et al.*, 1998). It now occurs in the South Pacific as well (Zabin *et al.*, 2007).

The first known specimens are from Pearl Harbor, collected in 1993 by Julie Bailey-Brock and first thought to be a native species (Zabin *et al.*, 2007).

John Hoover submitted his photographs to W.A. Newman for identification, who, familiar with the barnacle fauna of the Hawaiian Islands, recognized it as new to the region. Morphological and genetic evidence revealed that it was the tropical Western Atlantic barnacle *Chthamalus proteus*, known from the Caribbean and the Gulf of Mexico at least as far west as Louisiana (Southward *et al.*, 1998). Southward *et al.* noted that the "date of introduction was after 1973 [the last thorough bar-

nacle surveys of O‘ahu] and it could have been as recently as 1994 or 1995... However, considering the present distribution of *C. proteus* in the islands and the usual lag time between an introduction and notable abundance, it was possibly earlier... .” The dates of first records of *C. proteus* in Hawai‘i are not given in Southward *et al.* (1998); these are 1993 and 1995, as noted above. Its abundance and widespread distribution by 1995–1996 suggest an earlier inoculation.

Introduction could have been either on ships’ hulls [in waterline fouling for this high intertidal barnacle (Southward *et al.*, 1998)] or as larvae in ballast water. Southward *et al.* suggest that ballast water “is less likely than transport of adults, since a dense settlement is needed to establish a breeding population of such obligate cross-fertilizing sessile animals.” We note, however, that the discharge of nauplii or cyprids within an embayment or lagoonal environment (such as Pearl Harbor) would provide such opportunities, as discussed below for the crab *Scylla serrata.* This said, the probable mechanism was hull fouling, as the survival of viable larvae in ballast water from the Atlantic to Hawai‘i would appear to be less likely than survival on a hull.

In what may be a unique documentation of the same adult hull fouling organisms making round-trips between ports, Godwin (2003b) noted that *Chthamalus proteus* was on barges that had left Hawai‘i, gone to California and the Pacific Northwest, and were still alive on the barges when they returned to Honolulu Harbor. As *C. proteus* is not yet established in the ports-of-call where these barges visited on the American Pacific coast, there is no question that the same individuals are involved. Godwin noted that these barges are on regularly scheduled routes between the Islands and the mainland. Zabin *et al.* (2007) comment on the potential for *C. proteus* to invade the west coast, from approximately San Diego and south.

Chthamalus proteus settles on many substrates in the intertidal zone (Zabin *et al.*, 2007) and can form very dense populations on mangroves on O‘ahu (J.T. Carlton, personal observations, 1999). Primavera (1999) has observed that *Rhizophora* mangrove seedlings in the Philippines may be vulnerable to barnacle infestation and thus lower survival.

Zardus & Hadfield (2005) found that *C. proteus* in the Pacific represent multiple invasions from the Atlantic, including both the Caribbean and Brazil. Zabin *et al.* (2007) compare aspects of the distributional ecology and life history of *C. proteus* in the Caribbean, Atlantic, and Pacific Oceans. Zabin & Altieri (2007) demonstrated that *C. proteus* preferentially settles where the native pulmonate limpet *Siphonaria normalis* occurs but that limpets depart areas of high barnacle densities.

Orders Decapoda (crabs, shrimps, and lobsters) and **Stomatopoda** (mantis shrimps)

Introduced Decapoda and Stomatopoda

Species	Date	Vector	Native to
Decapoda			
Macrobrachium lar	1956	R	Guam & Tahiti
Scylla serrata	1926	R	Samoa
Panopeus lacustris	1947	SF,BW	Western Atlantic
Acantholobulus pacificus	1929	SF,BW	Eastern Tropical Pacific
Pilumnus oahuensis	1929	SF,BW	Unknown
Glabropilumnus seminudus	2003	SF, BW	Indo-Pacific
Nanosesarma minutum	1996	SF,BW	Japan, Indo-Pacific
Pachygrapsus fakaravensis	1996	SF,BW	Japan, French Polynesia
Metopograpsus oceanicus	2006	SF,BW	Indo-Pacific
Hyastenus spinosus	<1965	SF,BW	Indo-West Pacific
Stomatopoda			
Gonodactylaceus falcatus	1954	SF, BW	Indo-West Pacific

Additional Taxa Treated and Their Status

Species	Date	Vector	Native to
Decapoda			
Upogebia pugettensis	1916	R, BW	Northeast Pacific
Status: *Deleted*			
Hemigrapsus penicillatus			
Status: *Erroneous record?; see discussion*			
Macrobrachium rosenbergii	1965	R	Indo-Pacific
Status: *Released; not established*			
Carcinus maenas	1873	SF	Northwest Atlantic
Status: *Deleted*			
Callinectes sapidus	1985–1992	R	Northwest Atlantic
Status: *Released; not established*			
Charybdis helleri			
Status: *Intercept*			
Atergatopsis immigrans			
Status: *Intercept*			
Schizophrys aspera			
Status: *Intercept*			
Eriocheir sinensis			
Status: *Erroneous record; see discussion*			
Litopenaeus stylirostris			
Litopenaeus vannamei			
Marsupenaeus japonicus			
Penaeus monodon			
Status (above four species:) *Escaped; Not Established*			
Fenneropenaeus chinensis			
Fenneropenaeus indicus			
Status: *Transported to island; see text*			
Stomatopoda			
Gonodactylellus hendersoni			
Status: *Native*			

Order Decapoda
Thalassinidea (mud shrimps)
Upogebiidae
Upogebia pugettensis (Dana, 1852) **Deleted**

A single specimen of a *Upogebia* was collected in Hawai‘i, probably on O‘ahu, in 1916 by W.A. Bryan (Edmondson, 1933, 1944b, 1946a; K. Sakai, 1982). The specimen was identified in 1977 by K. Sakai as *Upogebia pugettensis*, a well known mud shrimp from the North American Pacific coast. Sakai (1982) referred to this Hawaiian specimen as *Upogebia littoralis*; this is a *lapsus*, however, as *U. littoralis* is an older name for two different Atlantic and Mediterranean species. Sakai (*in litt*., February 2000) indicated to us that it was likely *U. pugettensis*, and this is the name that appears on the specimen label as identified by Sakai. The specimen was missing for many years from the Bishop Museum collections but was found in August 2004 in the laboratory of Professor de Saint Laurent in the Muséum National d’Histoire Naturelle in Paris by Alain Crosnier.

Edmondson and Sakai both suggested that it may have been an accidental introduction from North America. The planting of oysters from the California coast in the islands does not correlate in time with the discovery of this bay-dwelling thalassinid in Hawai‘i. It may be that it arrived with unreported shellfish shipments from the mainland, or as a young stage in ballast water. This odd and isolated record is thus reminiscent of a single specimen of the western Atlantic *Upogebia affinis* that was found in 1912 in San Francisco Bay (Williams, 1986).

Caridea (shrimp)
Penaeidae

Litopenaeus stylirostris (Stimpson, 1874) **Escaped**; **Not Established**
= *Penaeus stylirostris*
(native to Baja California to Peru)

Litopenaeus vannamei (Boone, 1931) **Escaped**; **Not Established**
= *Penaeus vannamei*
(native to Gulf of California to Peru)

Marsupenaeus japonicus (Bate, 1888) **Escaped**; **Not Established**
= *Penaeus japonicus*
(native to Eurasia, Africa, South Pacific)

Penaeus monodon Fabricius, 1798 **Escaped**; **Not Established**
(native to Eurasia, Africa, South Pacific)

Penaeid shrimp culture commenced in the Hawaiian Islands in the 1970s. The above four species (whose range data are from Perez Farfante & Kensley, 1997), as well as *Fenneropenaeus chinensis* (Osbeck, 1765) (= *Penaeus chinensis*) and *Fenneropenaeus indicus* (H. Milne Edwards, 1837) (= *Penaeus indicus*) were transported to the islands for aquaculture and research (Eldredge, 1994). Primarily during pond flooding, the above four species are known to have escaped, but none became established (Brock, 1992a, 1992b; Davidson *et al.*, 1992; Eldredge, 1994).

Palaemonidae

Macrobrachium lar (Fabricius, 1798) **Introduced**

Brock (1960) and Eldredge (1994) reviewed the history of the prawn *Macrobrachium lar* in Hawai‘i; individuals were brought from Guam in 1956 and from Tahiti in 1961. They are now established in streams on all main islands. We include *Macrobrachium* here because its life history includes a marine phase, with larval stages spent in brackish and marine waters. Adult prawns may also occur in 2–3 ‰ water (Englund *et al.*, 2000a). Maciolek & Timbol (1981) reported it from the freshwater portions of the Kahana Estuary, O‘ahu, based on collections made from 1969 to 1971. It was first intentionally imported in 1956 from Guam (released in Moloka‘i) and in 1957 (released in Nu‘uanu Stream, O‘ahu). The native range is the Indo-Pacific, from East Africa to the Ryukyu Islands and the Marquesas.

In Hawai‘i, *M. lar* is said to be “in direct competition with the only native prawn, *M. grandimanus*” (Eldredge, 1994). *Macrobrachium lar* and *M. grandimanus* overlap in relatively small regions of brackish water, with *M. lar* being found upriver in freshwater and *M. grandimanus* being found downriver in brackish water; *M. lar* may be more likely to interact with the native freshwater shrimp (R. Englund, pers. comm., February 2000). *Macrobrachium lar* preys on native freshwater snails and gobies in Hawai‘i (Englund *et al.*, 2000a).

Macrobrachium rosenbergii (deMan, 1879) **Released**; **Not Established**

Eldredge (1994) reviews the history of the Indo-Pacific giant freshwater prawn *Macrobrachium rosenbergii* in the Hawaiian Islands and noted that there is no evidence that is became established. It was first imported intentionally in 1965, but no reproduction was observed in the wild, and no subsequent populations are known.

Brachyura (crabs)

A persistent mystery in the Hawaiian exotic crab fauna is the xanthid crab *Atergatopsis immigrans*. Edmondson (1962a) described this as a new species, *Neoliomera immigrans*, based on “two specimens... taken from fouling on the bottom of a barge [from Guam] in a Pearl Harbor dry dock in 1950.” One female and one male crab were collected. This crab has not been recorded from Hawai‘i since—nor, curiously, apparently from anywhere else in the world. It is not a failed invasion, in the sense that established reproducing populations were never recorded in Hawai‘i. One specimen is at the Smithsonian Institution; the other is at the Bishop Museum. Guinot (1969) transferred the species into the genus *Atergatopsis*, commenting that “Au prealable, il conviendrait de verifier si *immigrans* n’est pas synonyme d’une *Atergatopsis* deja connue” (“To begin with, it is advisable to verify if

immigrans is not a synonym of an *Atergatopsis* already known"). She noted that *A. immigrans* was similar to both *A. granulata* Milne Edwards, 1865 and *A. lucasi* Montrouzier, 1865, species not mentioned by Edmondson in his comparison to other species of *Neoliomera*. Guinot (1971) indicated that the assignment to the genus *Atergatopsis* should be verified by direct examination of the original specimens, although later authors (such as Serene, 1984) have followed her generic placement.

Portunidae

Scylla serrata (Forsskål, 1775) **Introduced**

The Samoan crab (also known as the mangrove or red crab) was first introduced into the Hawaiian Islands in order to start a fishery in Kāneʻohe Bay in 1926. Between 1926 and 1935, 98 crabs were released on Oʻahu, Hawaiʻi, and Molokaʻi, all from Samoa (Brock, 1952, 1960). Given this small inoculation size, and the probability that the current populations arose from only a fraction of these crabs, genetic studies on the Hawaiian populations would be of interest. By 1940 it had "already become thoroughly established about our shores, entering estuaries of streams and ascending far up some of the larger rivers" (Edmondson & Wilson, 1940). Edmondson (1954) noted that large specimens may exceed 20 cm in breadth and weigh "several pounds" and that it is valued as food "and brings a fancy retail price at the Honolulu fish markets"; Brock (1960) made similar comments. The *Honolulu Advertiser* of 13 March 1955 carried a photograph of a specimen from Hawaiʻi measuring 21.6 cm across and weighing 6.4 kg. Maciolek & Timbol (1981) reported it from the Kahana Estuary, Oʻahu, based on collections made from 1969 to 1971. Eldredge (1994) noted that as of 1992 it was one of the "major species collected in certain areas of the island of Hawaiʻi." *Scylla serrata* was found in Pearl Harbor in 1996 (Coles *et al.*, 1999a).

Brock (1960) attributed part of the success of the crab, in light of the relatively few individuals released, as being due to the fact that "some of the estuarine areas where this species was released have a low rate of tidal flushing, a situation which may be conductive [conducive] to the rapid growth of a population within the estuarine area." Cohen *et al.* (1995) came to a similar and independent conclusion relative to the establishment of the European crab *Carcinus maenas* in San Francisco Bay, California: "[lagoons] may nurture new inoculations of nonindigenous species. The shallow lagoons are typically a few degrees warmer than the Bay in the spring to fall months, when they are characterized by high primary productivity.... The lagoons are also retentive environments, which may be crucial to maintaining the critical densities of adult organisms needed for sexual reproduction." Brock (1960) notes a broad distribution from Africa and India through tropical Asia and into Polynesia.

Carcinus maenas (Linnaeus, 1758) **Deleted**

The U.S.S. *Portsmouth*, under the command of J.S. Skerrett, visited the Hawaiian and Fanning Islands in 1873–1874, while engaged in a survey of the North Pacific Ocean islands. Aboard was Assistant Surgeon T.H. Streets of the U.S. Navy (Jordan & Evermann, 1905). On his visit he collected one large male specimen of this North Atlantic crab (Streets, 1877, as *Carcinides maenas*) probably in Honolulu Harbor. Edmondson (1954) and subsequent authors doubted the record, Edmondson noting that "So far as I can determine, there is no other record of the species from Hawaii, and its presence here now is very doubtful. I have not seen living examples of this species." The specimen in question is at the Smithsonian Institution. We have examined it, and it is *Carcinus maenas*, as also reported in Carlton & Cohen (2003).

Callinectes sapidus Rathbun, 1896 **Released**; **Not Established**

Six female specimens of this well-known Atlantic blue crab were trapped between 1985 and 1992 in Kāneʻohe Bay near the Heʻeia State Park and Kāneʻohe Marine Corps base (Eldredge, 1995). Eldredge notes that it has been commonly imported into Hawaiʻi since 1967, mostly from Louisiana. Font & Tate (1994) note that *C. sapidus* have been observed being packed in Louisiana for air delivery to Hawaiʻi, and that in Hawaiʻi, Hilo fishmarkets often receive shipments of crabs from the Gulf of Mexico. Thus it is likely that the crabs found in Kāneʻohe Bay are intentional private releases.

However, it is of interest that Stephenson (1976) noted a juvenile male *Callinectes* collected by P. Bartsch in September 1920 in Pearl Harbor that was not further identifiable since it lacked the abdomen and pleopods, although the specimen resembled *C. sapidus*. The identity of this specimen (in the Smithsonian Institution) may be determinable using molecular techniques.

Charybdis helleri (Milne Edwards, 1867) **Intercept**

This crab is consistently cited in the literature as occurring in the Hawaiian Islands. The record is that of Edmondson (1954), who, however, only records a single male specimen "taken from among the fouling on the hull of a ship in dry dock in Pearl Harbor Navy Yard. The ship had seen service in Guam sometime previous to its defouling and may have transported the portunid to Pearl Harbor as a juvenile." This specimen is in the Bishop Museum collections, collected 5 April 1950. Despite Edmondson stating that "There is no evidence that this species is established in Hawaii," subsequent authors have recorded the Hawaiian Islands as within the crab's range. We regard this record as an interception and do not further consider it here; it is not a member of the Hawaiian decapod biota. *Charybdis helleri* has since been introduced to eastern North and South America (Tavares & de Mendonca, 1996).

Panopeidae

Panopeus lacustris Desbonne, 1867 **Introduced**

= *Panopeus herbstii* of authors, not of H. Milne Edwards, 1834

This Atlantic mudcrab was first collected in December, 1947 "from the fouling of a boat in Pearl Harbor" (Edmondson, 1962a). In 1953, numerous specimens were collected in Maunalua Bay, O‘ahu, "where the species appears to be well established. Its introduction into Hawaiian waters doubtless came about through transportation on the bottom of a ship in very recent times" (Edmondson, 1962a). It remains present in Pearl Harbor (Coles *et al.*, 1999a).

This species was originally reported from Hawai‘i as *Panopeus herbstii*, but Williams (1983) split this taxon into six species. Williams' reexamination of O‘ahu material at the Smithsonian Institution revealed which of the six species the Hawaiian population represented. While *Panopeus herbstii sensu lato* was a crab ranging from cool temperate New England waters to tropical Caribbean waters (and thus the appearance of this crab in Pearl Harbor could also have been linked to importations of Atlantic oysters from more northern waters), the resolution of the Hawaiian populations as *P. lacustris* provides finer scale geographic and transport mechanism resolution. *Panopeus lacustris* is a subtropical to tropical crab, ranging from Bermuda and southern Florida through the Caribbean and south to Brazil. It occurs over a wide range of shallow-water habitats in the western Atlantic Ocean, including algal mats, sabellariid reefs, mudflats in seagrass beds, under coral debris, and on mangroves. It is thus a member of the "Caribbean element" now found in the Hawaiian Islands. It likely arrived in ship's fouling or in ballast water, as commercial oysters are not known to have been transported to Hawai‘i from regions where *P. lacustris* is found.

Acantholobulus pacificus (Edmondson, 1931) **Introduced**

= *Panopeus pacificus* Edmondson, 1931

= *Neopanope* sp. Edmondson, 1931 (1929, Pearl Harbor), *fide* Forest & Guinot (1961) and Felder & Martin (2003)

= (?) *Acantholobulus mirafloresensis* (Abele & Kim, 1989, new combination in Felder & Martin, 2003, for *Panopeus mirafloresensis*).

Charles H. Edmondson (1931) described this crab as a new species from Pearl Harbor. While Edmondson did not provide a collection date, the type material in the Bishop Museum bears the date December 1929. Edmondson (1931) noted that it was "associated with sponges, barnacles and tunicates attached to buoys and floats ... . The barnacle (*Balanus eburneus* Gould), among which the crab is found, is a typical species of the east coast of the United States, which is suggestive of the view that both crabs and barnacles may have been transported to Hawaii through shipments of oysters or on the bottoms of ships." Edmondson (1933) notes that it also occurred in Pearl Harbor associated with the crab *Pilumnus oahuensis*. Many years later, Edmondson (1962a) repeated his thought that

"As *P. pacificus* has been taken only in Pearl Harbor among fouling complexes on buoys, it may have been transported to Hawaii on the bottoms of boats." It remains common today in Pearl Harbor (Coles *et al.*, 1997, 1999a) and also occurs in Kāneʻohe Bay (Coles *et al.*, 2002a; 2000 collections), and in Keʻehi Lagoon, Ala Wai Harbor, and Kewalo Basin (Coles *et al.*, 1999b, 1997–1998 collections), all on Oʻahu. Coles *et al.* (2006) report it from Kauaʻi, based upon 2002 collections; it was found in 2003 at Kaunakakai Harbor, Molokaʻi, and Hilo Harbor (Coles *et al.*, 2004).

In an earlier draft of this monograph in 2001 we wrote: "We regard it as introduced in ship fouling or ballast water. As colder water northern hemisphere estuarine panopeids are relatively well known and have not been matched with *P. pacificus*, we predict that it will be found to be a junior synonym of an earlier-named warmer-water if not outhern hemisphere panopeid."

Based upon the revisionary work of Felder & Martin (2003), it may be native to either the tropical eastern Pacific Ocean or to the tropical western Atlantic Ocean. In the tropical eastern Pacific it may have gone under the names of *P. mirafloresensis* or *P. bermudensis* of authors (Felder & Martin, 2003, place eastern Pacific records of *P. bermudensis* Benedict & Rathbun, 1891 into *P. mirafloresensis*). Felder & Martin (2003) note that "except for the apparent larger size evident in most specimens of *A. pacificus*, there are ... no obvious morphological characters to distinguish it from *A. mirafloresensis*." We note that introduced populations of nonnative species often tend to a larger body size than their conspecifics in their native regions.

Acantholobulus mirafloresensis occurs "throughout coastal waters of the tropical eastern Pacific region" (Felder & Martin, 2003). If the Hawaiian populations of *A. pacificus* should morphologically and genetically match eastern tropical Pacific populations of *A. mirafloresensis*, we conclude that this crab, having attached to ship bottoms possibly in the Panama area, was introduced in hull fouling to Pearl Harbor from the tropical eastern Pacific in the early decades of the twentieth century.

However, Felder & Martin (2003) also note that *Acantholobulus bermudensis* (Benedict & Rathbun, 1891) cannot be morphologically distinguished from *Acantholobulus mirafloresensis*. As is common in transisthmanian systematics and biogeography, these auhors retain the two species as western Atlantic and eastern Pacific cognates, respectively. Should these two taxa prove identical genetically, *A. mirafloresensis* will become a junior synonym of *A. bermudensis*. If *A. pacificus* and *A. mirafloresensis* prove to be genetically identical, then both will fall to the synonymy of the older *A. bermudensis*.

Forest & Guinot (1961) reported *Panopeus pacificus* from Tahiti based upon two specimens collected in 1901. No further material has apparently been collected in Tahiti over a century. We suggest that *A. pacificus* no longer occurs in Tahiti, and that the specimens represent a failed introduction from ship hull fouling, hailing either from the eastern Pacific or from the western Atlantic.

We conclude that *Acantholobus pacificus* is unquestionably introduced to Hawaiʻi. Its exact biogeographic origin and systematic affinities await further work on related taxa in the Americas.

Pilumnidae

Glabropilumnus seminudus (Miers, 1884) **Introduced**

Coles *et al.* (2004, 2006) found this crab in 2003 on two islands, at Molokaʻi (Hale o Lono Reef) and at Maui (Kahului Harbor, Pier 1). It occurs broadly through the Indo-West Pacific (Davie, 2002). Davie (2002) lists Hawaiʻi in its distribution, a record based upon the report of Edmondson (1952b). Edmondson's record, however, was based upon a single specimen found on the same Guam barge in 1950 as noted for *Schizophrys aspera*; it was not known to be established in Hawaiʻi at the time of Davie's listing.

Pilumnus oahuensis Edmondson, 1931 **Introduced**

Edmondson described this species based upon specimens collected in 1929 (Bishop Museum type specimen) from Pearl Harbor. Edmondson found it "associated with masses of sponges, tunicates and barnacles which are attached to buoys, floats, and piling." Edmondson (1962a) added Honolulu Harbor (BPBM material from Honolulu Harbor commences in 1947). It was also noted by Grovhoug & Rastetter (1980) for Kāneʻohe Bay and Pearl Harbor (1976–1977 collections).

It is still found in Pearl Harbor in fouling (Coles *et al.*, 1999a) as well as in other harbors and

bays around O‘ahu (Honolulu Harbor, Ke‘ehi Lagoon, Ala Wai Harbor, Barbers Point Harbor, Kewalo Basin [Coles *et al.*, 1999b]; Kāne‘ohe Bay [Coles *et al.*, 2002a] and Waikīkī [Coles *et al.*, 2002b]). Coles *et al.* (2004, 2006) report it from Kaua‘i, Moloka‘i, Maui, and the island of Hawai‘i, based upon 2003 collections; these are the first reports outside of O‘ahu. It has not been recognized elsewhere in the Pacific. Because of its harbor and habitat restriction we regard this species as unquestionably introduced through ship fouling or ballast water. It may eventually be recognized as a previously described xanthid from elsewhere in the Pacific.

Xanthidae

Atergatopsis immigrans (Edmondson, 1962) **Intercept**

This crab is discussed in the introduction to Brachyura, above.

Grapsidae

Nanosesarma minutum (De Man, 1887) **Introduced**

This tiny widespread Pacific and Indian Ocean crab was first collected in 1996 in fouling communities in Middle Loch, Pearl Harbor (Davie, 1998, Coles *et al.*, 1999a) where it was found to be common. We regard it as introduced in ship fouling or in ballast water. Vannini & Valmori (1981) report it from Somalia to Tanzania, Madagascar, Singapore, Thailand, and Java as “common on rotten wood half buried in the mud, in mangroves.” Dai & Yang (1984) report it from China, Japan, Indonesia, Singapore, Thailand, India, and Madagascar, from intertidal “muddy flats and under stones.” Davie (1998), who adds the Hong Kong-Japanese species *Nanosesarma gordoni* (Shen, 1935) to the synonymy of this species, notes it is found “in fouling and amongst oysters ... in the intertidal and shallow subtidal zones of sheltered shores” and that “it is common around major shipping ports such as Hong Kong and Singapore.” Under the name *N. gordoni*, Sakai (1976) noted it is found intertidally “among the oysters or sponges growing on rocky shore(s).”

Pachygrapsus fakaravensis Rathbun, 1907 **Introduced**

This rocky intertidal crab, previously known from French Polynesia (the type locality is the Tuamotus) and Japan, was collected in 1996 by Darryl Takaoka from Barbers Point Harbor, O‘ahu (Davie, 1998), based upon two specimens. Peter Ng (pers. comm., February 2000) found it to be common at K‘ewalo, O‘ahu, in February 2000. Sakai (1976) notes the habitat as “coral reef, at high tidal mark.” Barbers Point is the major container ship terminal on O‘ahu. We regard it as introduced by ballast water, as modern container ships are unlikely to support extensive external fouling communities, nor would a ship’s seachest appear to be a conducive environment for this rocky shore crab.

Metopograpsus oceanicus (Jacquinot, 1852) **Introduced**

This crab was previously known from East Africa to the Philippines and Palau, and was first collected in Guam in 1997 (Paulay, 2007). In February 2006, Gustav Paulay found this crab in the supratidal of Coconut Island, Kāne‘ohe Bay, where it co-occurs with the native *Metopograpsus thukuhar* (Paulay, 2007). As Paulay (2007) notes, there has been little documentation of the intertidal crab fauna of the Hawaiian Islands since the 1960s, so it is difficult to judge how long this crab has been in the region. That said, it would not have been overlooked by C.H. Edmondson in the 1950s had it been present. *Metopograpsus* collections from O‘ahu made by Darryl Takaoka in the 1990s, and now in the Bishop Museum collections, await re-examination.

Varunidae

Hemigrapsus penicillatus (de Haan, 1835) **[See Discussion]**

Asakura & Watanabe (2005) note that *Hemigrapsus penicillatus* has been reported from Hawai‘i. The record is based upon six specimens collected by W.A. Bryan in 1903 “at Laysan Island;” these were deposited in Bishop Museum Collections as catalog number 236 (Edmondson, 1951, pp. 236–237; 1959, pp. 180–181). However, the specimens are lost. An error in initial reporting may

have been involved; the Bishop Museum ledger catalog number 236 refers to six specimens of this crab, but from Japan (where the species is native and common).

Eriocheir sinensis Milne Edwards, 1854 **[See Discussion]**

Reports in the literature imply that this well-known Chinese mitten crab was or is present in the Hawaiian Islands. For example, Rudnick *et al.* (2000) note that it "was also found in Hawaii in the 1950s, with no subsequent reports of occurrences," citing Edmondson (1959). There are however no records, past or present, of which we are aware of *Eriocheir sinensis* in the Hawaiian Islands. Edmondson (1959, p. 155) makes a passing reference to this crab being used as food in Asia.

Majidae

Hyastenus spinosus A. Milne-Edwards, 1872 **Introduced**

Tinker (1965) noted that this "spiny spider crab", ranging from "Hawaii southward and westward across the tropical Pacific and Indian Oceans" was "found in shallow water where the marine growth was abundant. It is known to dwell on piers and pilings which are covered with a variety of algae and invertebrate animals." It is not mentioned by Sakai (1965, 1976) nor Dai & Yang (1984) for Japan and China, nor by Poupin (1994) relative to the common crabs of French Polynesia. However, Griffin (1974, 1976) recorded it from the Indian Ocean, detailing its distribution as Indo-West Pacific, from the Red Sea and Gulf of Aden, eastern Africa from Durban to Cape Guardafui, Sri Lanka, the coasts of India, Singapore, Gulf of Siam, northern Australia, Philippine Islands, and up to Fiji. However, its habitat outside of Hawai'i is generally reported as in somewhat deeper waters from 12–67 fathoms, on coarse sand and broken shells, although reported in Torres Strait, Australia, from 5–7 fathoms (Griffin, 1966, 1976).

Curiously, the first Hawaiian record appears to be the mention by Tinker (1965) in his popular book. Not a tiny crab, it was not mentioned in any of C.H. Edmondson's earlier books and papers on the Hawaiian fauna in general or the decapod fauna in particular, and it thus may be a fairly recent (post-World War II) arrival. No early Hawaiian specimens exist in Bishop Museum collections, although two specimens were found in 1996 in Pearl Harbor (BPBM collections; Coles *et al.*, 1997). No similar crab has been encountered elsewhere in the Islands.

Based upon its localization in Pearl Harbor, association with fouling communities, and its relatively recent reporting from the Islands, we consider it introduced.

Schizophrys aspera (H. Milne Edwards, 1834) **Intercept**

Edmondson (1951) thought this majid might have been established on O'ahu, but the specimens he had in hand were from a barge newly arrived in 1950 from Guam into Pearl Harbor. Davie (2002) includes Hawai'i in the range of this species, but *S. aspera* does not occur here.

Stomatopoda (mantis shrimps)

Gonodactylidae

Gonodactylaceus falcatus (Forsskål, 1775) **Introduced**

= *Gonodactylaceus mutatus* (Lanchester, 1903), as used by Barber & Erdmann (2000) for Hawaiian populations of *G. falcatus*

= *Gonodactylus aloha* Manning & Reaka, 1981

In a well-known paper on invasion processes, Kinzie (1968) argued that an Indo-Pacific species of mantis shrimp (which he identified as *Gonodactylus falcatus*) was introduced to the Hawaiian Islands. Manning & Reaka (1981) subsequently described the same Hawaiian population as a new species, *Gonodactylus aloha*, and considered it endemic. Kinzie (1984), in a paper titled, "Aloha also means goodbye," examined their arguments in detail and concluded that at the least the species was cryptogenic. Carlton (1987) also referred to it as cryptogenic, noting that "*G. aloha* may be native to, but undiscovered in, the southwestern Pacific and/or [there may be] morphological distinctions in Hawaiian populations due to founder effect." Carlton (1996) later treated it as clearly introduced, closing a nearly 30-year circle in this species' Hawaiian history.

Manning & Lewinsohn (1986) restricted *Gonodactylaceus falcatus* to the Red Sea, and provided comparisons of *G. aloha* and *G. falcatus*. Manning (1995) expanded the view of *G. falcatus* to include populations both in the Red Sea and Indian Ocean to at least Mombasa, Kenya and Mauritius, and possibly to New Caledonia and Japan, although bringing the last two locations into question. According to the data of Manning and Reaka, the two species are identical or overlap in all characters with the exception that *G. aloha* lacks and *G. falcatus* has a median caruncle on the sixth abdominal segment. However, in the original description of *G. aloha*, this character is said to be variable (“median caruncle occasionally present on sixth somite, rarely well-developed”). The color characteristics chosen by Manning & Lewinsohn (1986) show overlap in color between the two species, although Manning & Reaka (1981) argue for other color differences (but see Kinzie, 1984). Manning & Reaka’s color and morphological distinctions between *G. aloha* and *G. falcatus* were based on Red Sea specimens of *G. falcatus*.

Gonodactylaceus aloha has thus been on uncertain grounds for some time. Barber & Erdmann (2000) and Ahyong (2001, 2002) concluded that *G. aloha* was a synonym of *G. mutatus*, a species previously known from New Caledonia, southern China, and Vietnam to the western Indian Ocean. Ahyong (2001) then concluded that *G. mutatus* was a junior synonym of *G. falcatus* (and concurred that *G. aloha* is indeed a synonym of *G. mutatus*), and thus the name returns to the same one used by Kinzie originally, closing another loop of more than 30 years duration.

The first specimens of *G. falcatus* were observed in Hawai‘i 1954 in dead coral heads in Kāne‘ohe Bay [Kinzie, 1968, who also noted that another species of *Gonodactylus* was observed at the same time on the Waikīkī reef, but this may have been *Gonodactylellus hendersoni* (see Kinzie, 1968, p. 469, and discussion, below)]. Kinzie suggested that it was introduced onto O‘ahu with concrete barges towed to the islands at the end of World War II, particularly from the area of the Philippines and the South China Sea. It was also noted by Grovhoug & Rastetter (1980) for Kāne‘ohe Bay and Pearl Harbor (1976–1977 collections). Brock (1995) found it in Pearl Harbor (1993–1994), where it remains (Coles *et al.*, 1999a). It is now widely distributed throughout the main islands, including O‘ahu, Moloka‘i, Maui, Kaua‘i, and Lāna‘i. Kinzie (1968) demonstrated experimentally that the more aggressive *G. falcatus* had displaced the native stomatopod *Pseudosquilla ciliata* from coral head habitats in Kāne‘ohe Bay. Caldwell & Dingle (1975) reviewed Kinzie’s study. Reaka (1975, 1976, 1979a, 1979b) reported upon molting and life history of *G. falcatus* from Kāne‘ohe Bay.

Given the vast movement around the Pacific Basin during and after World War II of landing craft, barges, and other vessels with inhabitable holes and crevices, it is remarkable that this is the only recognized stomatopod introduction. It seems probable that given the assumption that most species of Pacific stomatopods are widespread across the Pacific Ocean, new discoveries were attributed to natural larval dispersal, when in fact many populations of stomatopods discovered in the last half of the twentieth century may represent cryptogenic if not introduced records.

Gonodactylellus hendersoni (Manning, 1967) **Native**

Kinzie (1968) speculated that this stomatopod was introduced to O‘ahu. It is a widely distributed species across the central and Indo-Pacific Oceans. Roy Caldwell (pers. comm., February 2000) reports that he has examined specimens of this species collected in Hawai‘i many years before the first record of 1958 reported by Kinzie (1968) and repeated by Manning & Reaka (1981). Caldwell believes that it is a naturally widespread species throughout the Pacific and may have been overlooked earlier in Hawai‘i because it is relatively small, generally found in subtidal rubble, and not as easy to collect as larger stomatopods. More broadly, the taxonomic status of the Hawaiian populations remain uncertain, pending additional examination of more specimens (S. Ahyong, pers. comm., 2001).

INSECTA

Introduced and Cryptogenic Insecta

Species	Date	Vector	Native to
Introduced Species			
Odonata			
Enallagma civile	1936	R, O	Western North America
Ischnura ramburii	1973	R, O	North/South America
Crocothemis servilia	1994	R, O	Middle East, Asia, Australia
Tramea lacerata	1873	R, O	Eastern North America
Hemiptera			
Trichocorixa reticulata	1877	R, O	North America
Mesovelia amoena	1971	R, O	North/South America
Mesovelia mulsanti	1933	R, O	North/South America
Micracanthia humilis	1988	R, O	North America
Hymenoptera			
Kleidotoma bryani	1923	R, O	Guam, Palmyra Island
Coleoptera			
Enochrus sayi	1931	O	Western North Atlantic
Tropisternus salsamentus	1968	BW	California
Cercyon fimbriatus	2001	R, O	Eastern Pacific
Parathroscinus murphyi	1996	BW	Southeast Asia
Diptera			
Canaceoides angulatus	1922	R, O	Tropical E Pacific
Procanace williamsi	1944	R, O	Asia (Japan?)
Tethina willistoni	1919	R, O	Western Atlantic
Atrichopogon jacobsoni	1958	R, O	Western Pacific
Atrichopogon sp.	1998	R, O	Unknown
Cricotopus bincinctus	1955	R, O	Unknown
Goeldichironomus holoprasinus	1969	R, O	North/South America
Telmatogeton japonicus	1946	R, O	Japan
Dolichopus exsul	1930	R, O	West Indian (Caribbean)
Medetera grisescens	1914	R, O	Indo-Pacific
Syntormon flexible	1917	R, O	Indo-West Pacific
Psychoda salicornia	1945	R, O	California
Brachydeutera ibari	1980	R, O	Asia
Ceropsilopa coquilletti	1946	R, O	North America
Clasiopella uncinata	1946	R, O	Taiwan, Australasia
Discocerina mera	1948	R, O	Western/South Pacific
Donaceus nigronotatus	1958	R, O	Asia
Ephydra gracilis	1946	R, O	Eastern Pacific
Ephydra milbrae	1950	R, O	Eastern Pacific
Hecamede granifera	1923	R, O	Western/South Pacific
Mosillus tibialis	1944	R, O	North America
Paratissa pollinosa	1945	R, O	Caribbean, S. America
Placopsidella marquesana	1951	R, O	Indo-Pacific
Psilopa girschneri	1952	R, O	Unknown
Scatella stagnalis	1967	R, O	Unknown
Hostis guamensis	1946	R, O	Australia
Cryptogenic Species			
Collembola			
Oudemansia esakii	1939	R, O	
Coleoptera			
Thinophilus hardyi	1996	R, O	
Dermaptera			
Anisolabis maritima	1912	SBA	
Orthoptera			
Thetella tarnis	<1994	SBA	
Additional Taxon Treated and Its Status			
Coleoptera			
Cyclodinus mundulus	1877–1884	SBA	California
Status: *Establishment unknown*			

Englund (2002) referred to all of the species treated below as introduced to Hawai‘i, but also indicates in a column labeled “mode of introduction” that many of these species are cryptogenic as well. However, Englund used “cryptogenic” to mean an unknown mechanism of introduction, rather than (by definition) an unknown biogeographic origin of the species. Englund’s cryptogenic corresponds to the term polyvectic (two or more possible mechanisms of introduction) as used by Carlton & Ruiz (2005).

We treat 43 species of brackish-water and maritime insects here, largely as examples of this introduced facies. We are not aware of any review of the invasive marine and maritime insects of the Hawaiian Islands: a thorough study of the shoreline maritime arthropods of the Islands may well reveal dozens, if not scores, of additional nonnative species.

Odonata (damselflies and dragonflies)
Coenagrionidae
Enallagma civile (Hagen, 1862) **Introduced**
The “familiar bluet” damselfly, introduced from western North America and first found in 1936 on O‘ahu, a species also living in brackish waters in Pearl Harbor in Honouliuli Stream (16 ‰ salinity), and on the O‘ahu south shore at Ordy’s Pond, Barbers Point (24 ‰) (Englund *et al.*, 2000a, 2000b). Polhemus & Asquith (1996) provide a brief summary.

Ischnura ramburii (Sélys-Longchamps, 1850) **Introduced**
The “Rambur’s forktail” damselfly, native to North and South America, and found at Hilea, Hawai‘i in 1973 (Englund *et al.*, 2000a, 2000b). “*Ischnura ramburii* has the distinction for being the most saline tolerant introduced damselfly, with adults observed around water up to 32 ‰ salinity” (Englund, 2000a). Although *I. ramburii* reproduces only in freshwater, the larvae and juveniles occur in 10 ‰, and adults are common around salt water environments (R. Englund, pers. comm., 2000); it is thus present in an ecological sense in the estuarine-marine facies. Polhemus & Asquith (1996) provide a brief summary. Based upon a preponderance of records, we treat this species biogeographically as eastern American.

Libellulidae
Crocothemis servilia (Drury, 1770) **Introduced**
The “scarlet skimmer” dragonfly, native to the Middle East, Asia, and Australia, first collected in *taro* fields in Waiahole Stream, O‘ahu, in 1994; it is found as well in estuarine areas on O‘ahu, including Pearl Harbor (Englund *et al.*, 2000a, 2000b). Polhemus & Asquith (1996, p. 49) give a color photograph.

Tramea lacerata Hagen, 1862 **Introduced**
The “black-mantled glider” dragonfly, native to eastern North America, was first recorded in O‘ahu in 1873 (Englund *et al.*, 2000b). It is present at Ordy’s Point, Barbers Point, and is saline tolerant, with females observed ovipositing in 24 ‰ water (Englund *et al.*, 2000b).

Dermaptera (earwigs)
Anisolabis maritima (Bonelli, 1832) **Cryptogenic**
While there are many early literature records of this widespread littoral earwig on the islands, many of these are now assigned to a number of endemic species (Brindle, 1979). There appear to be few valid records of the “true” *A. maritima*; we regard these as potentially ship-introduced populations, perhaps with early ballast dumpings. Brindle (1979) admitted only two valid records: specimens recorded on Laysan Island by Fullaway (1914), and material collected at Ka‘alaea Beach, O‘ahu (1953) and in beach litter in the west Loch of Pearl Harbor (1974). It also occurs on Midway Island, where it has been since at least 1960 (Nishida & Beardsley, 2002). The Laysan Island material would have been collected between 1905 and 1912 (F. Howarth, pers. comm., 2003). Nishida (2002) listed it from many locations from Midway Island down through the Archipelago.

Orthoptera (crickets, grasshoppers)

Thetella tarnis Otte & Alexander, 1983 **Cryptogenic**

We thank F.G. Howarth for pointing out to us this maritime cricket. It was described from Australia (at Portland Roads, Cape York) as "abundant in piles of stone around pier." It was subsequently reported from Hawai'i (without collection date) by Otte (1994) with a habitat noted as "Rocky coastal areas. Lives among wet boulders and in cracks and crevices in the splash zone of all islands. In places it is found among roots and in trash along the beach." It is a widespread species across the Pacific and Indian Oceans (D. Otte, pers. comm., September 2005). Modes of transport include rafting (these crickets lay their eggs on shore vegetation and sticks that could thus be transported by ocean currents; D. Otte, pers. comm.) or historically with shore ballast. The survival of eggs on vegetation, for the length of time required to drift to the Hawaiian Islands, has not been demonstrated. We thus consider it cryptogenic, pending genetic analysis of these widespread populations.

Hemiptera (water bugs)

Corixidae

Trichocorixa reticulata (Guérin-Méneville, 1857) **Introduced**

= *Corixa blackburni* White, 1877 (O'ahu?); = *Arctocorixa blackburni*

This well-known North American water boatman was described as *Corixa blackburni* from the Hawaiian Islands by White (1877), based upon specimens collected by the Reverend T. Blackburn. Zimmerman (1948b) noted that "it is common in brackish pools in the lowlands" and recorded specimens from O'ahu, Moloka'i, and Maui. Blackburn's field notes were published by White (1878) and include the following observations of this aquatic insect in Hawai'i of the 1870s: "Very common in salt-water pools on the sea-shore. These pools are formed artificially for the manufacture of salt. As the liquid becomes more dense by evaporation, the *Corixae* migrate to pools more recently filled. Some would appear, however, to remain too long, as in the last stage of evaporation, the pools generally contain a few dead Corixae."

Material in the Bishop Museum collections includes some of the specimens found by the Reverend T. Blackburn as well as additional collections from 1904 and later years.

Williams (1944) provided detailed habitat data for this species (under the name *Arctocorixa blackburni*) in Hawai'i, including the interesting note that he observed "a single individual at Waikiki swimming and diving in shallow water about 130 feet out from the shore." Englund *et al.* (2000a) report this boatman in 1998 in Pearl Harbor at Pouhala Marsh wetlands near Kapakahi stream on a pond near the salt flats with 8–9 ‰ salinity.

Mesoveliidae

Mesovelia amoena Uhler, 1894 **Introduced**

This water treader, of North and South American origin (Englund, 2002), was first collected in 1971 on the island of Kaua'i at Waikanaloa Cave, Hā'ena, and on O'ahu in 1971 along the Waimea River (Englund *et al.*, 2000a). Englund *et al.* (2000a) report the species from brackish streams (to 9 ‰) in Pearl Harbor. Based on Moreira *et al.* (2008), we treat this species and the next as biogeographically part of the eastern North American.

Mesovelia mulsanti White, 1879 **Introduced**

A water treader of North and South American origin first collected in 1933 in a reservoir at Waipi'o, O'ahu (Williams, 1944; Englund *et al.*, 2000a). Zimmerman (1948b) reported it from Kaua'i, O'ahu, and Moloka'i. Englund *et al.* (2000a) report it from fresh and brackish (to 4.5 ‰) streams in Pearl Harbor.

Saldidae

Micracanthia humilis (Say, 1832) **Introduced**

This North American shore bug was first collected in Kawainui Marsh, O'ahu, in 1988 (Englund *et al.*, 2000b). Along the south shore of O'ahu, Englund *et al.* (2000b) found it along the lower Ala Wai Canal in 28 % and Mākua Stream (15 ‰), as well as at fresh water sites.

Hymenoptera (wasps)
Eucoilidae
Kleidotoma bryani Yoshimoto, 1962 **Introduced**
This maritime wasp was first collected in 1923 at Pearl City Peninsula, O‘ahu (Beardsley, 1990). Yoshimoto (1962) described this species from O‘ahu, based upon collections in 1937 (Maunalua) and 1927 (Koko Head). Beardsley (1990) noted a further specimen from 1965 collected at the Waipi‘o Peninsula on O‘ahu. It is otherwise known from Guam and Palmyra Island. Beardsley (1990) notes that while the host is unknown, “the collection records suggest that this is a parasite of some fly which breeds in a littoral environment.”

Coleoptera (beetles)
Hydrophilidae
Enochrus sayi Gundersen, 1977 **Introduced**
This Eastern North American water scavenger beetle, which occurs in salinities of up to 16 ‰, was reported by Englund *et al.* (2000a) from Pearl Harbor fresh and brackish streams based upon 1998 collections. The earliest O‘ahu records are from 1931 from Hale‘iwa (Hansen, 1995). Other records, from 1937 to 1982, are from Barbers Point, ‘Ewa, Hickham Air Force base, Honolulu, Kāne‘ohe, Kawainui Marsh, Maunalua, and Mt. Tantalus. Englund *et al.* (2000a) note that the proclivity of this species to be attracted to light may have caused colonists to enter ships or planes as they were being loaded, and thus carried to the islands. Englund *et al.* (2000a) provide additional habitat data in Pearl Harbor. Howarth & Preston (2002) report Maui as a new island record.

Tropisternus salsamentus Fall, 1901 **Introduced**
This Californian water scavenger beetle was first collected on Maui in 1968, on O‘ahu in 1970, and on Hawai‘i in 1975; it occurs from sea level to 4000 feet (Hansen, 1995). As with *Enochrus sayi*, it is attracted to light. It occurs in fresh and brackish water (up to 16 ‰) in puddles in the Waiawa Springs complex in Pearl Harbor (Englund *et al.*, 2000a). Englund *et al.* (2000b) report it as abundant at Ordy’s Pond, Barbers Point, in 24 ‰. Englund (2002) suggests ballast water as the transport vector.

Cercyon fimbriatus Mannerheim, 1852 **Introduced**
Howarth & Preston (2002) report this Pacific American beach beetle from Maui (at the Kahului Airport, on the beach and in the strand line) based upon specimens collected in 2001.

Limnichidae
Parathroscinus murphyi Woolridge, 1990 **Introduced**
= *Parathroscinus* sp. Samuelson, 1998
= *Parathroscinus* cf. *murphyi* “Wooldridge”[*sic*] 1990 of Englund *et al.*, 2000a
Samuelson (1998) reported this introduced brackish water limnichid beetle as established in Pearl Harbor, noting that it “is rather common on mudflats and near streams associated with the harbor.” He considered the origin as “probably from Southeast Asia.” Records from Pearl Harbor include Pouhala Marsh between Waikele Stream and Kapakahi Stream (1996); mudflats at Waimalu at Blaisdell Park (1997) and Honouliuli Stream-estuary area, based on sweepings over mud and saltbush (1997). Englund *et al.* (2000a) note that in Pearl Harbor *Parathroscinus* “sometimes formed dense clouds as these small beetles flew just above the exposed tidal mudflats” and that it “has become one of the most common insects on mudflats where mangrove grows.” Englund *et al.* (2000b) note that it is present in “virtually every stream and estuary containing tidal mudflats” on the south and west shores of O‘ahu, including the Ala Wai Canal. Englund (2002) remarked that “populations have now exploded, and they were found in extremely high densities throughout Pearl Harbor.”

Englund *et al.* (2000a) note that the Hawaiian material keys to *P. murphyi* from Singapore. Englund (2002) suggests ballast water as the mechanism of introduction.

Anthicidae

Cyclodinus mundulus (Sharp, 1885) **Establishment Unknown**

Sharp (1895) described this maritime beetle from Hawai‘i as *Anthicus mundulus*; it was collected sometime between 1877 and 1884 (*vide* the introduction to Blackburn & Sharp, 1895), and was found on both O‘ahu and Kaua‘i (*vide* the table on page 286 in Sharp, 1895: neither the dates nor location appear with the species description). The O‘ahu material was collected in Honolulu, according to the label with the specimen (Chandler, 2005, page 13). This species is found under seaweeds and other drift on beaches, in salt marshes, and occasionally inland but rarely far from the coast. Introduction with solid ballast seems probable.

Werner (1966) mistakenly synonymized *Anthicus mundulus* with the California beetle then known as *Thicanus annectens*. Chandler (2005) resurrected *Cyclodinus mundulus*, a Californian-Mexican species, noting that “it has been introduced to Hawai‘i [its type locality] and the Dominican Republic.”

Although not verified from the Islands since its first collection (Werner, 1966), two matters move us to register this species as *Establishment Unknown* versus *Deleted* (the normal assignment, based upon no individuals collected for 50 or more years). Young (1979) noted that a data card on file at the Bishop Museum listed this species from Kaua‘i, “although [the] record could not be confirmed by specimens” (and as of 2007, no specimens of this species were in the Bishop Museum collections). The data card noted that the specimens were from “salt marshes near sea level.” The date of this material is also not known, but would presumably have been subsequent to the original collections (which do not make mention of a habitat on Kaua‘i). In addition, there have been no specific searches, as far as is known, for this beetle (D.S. Chandler, pers. comm., February 2007).

If this beetle has become extinct on the Islands, it would be a rare example of a name being based upon an introduced population that no longer exists.

Diptera (flies)

Canacidae

Canaceoides angulatus Wirth, 1969 **Introduced**

This subtropical and tropical Eastern Pacific beach fly was first described from Hawai‘i; the earliest material is from Wāwāmulu Beach near Koko Crater in 1922 (Englund *et al.*, 2000a). It is recognized, however, as being native to North and South America. It occurs in Pearl Harbor streams in salinities of up to 35 ‰ and in a variety of shoreline habitats, such as the splash zone on rocky shorelines, on wet sand or mud, and among mangroves (Englund *et al.*, 2000a). Hardy & Delfinado (1980) record it from O‘ahu, Kaua‘i, Moloka‘i, Maui, Hawai‘i, Laysan Island, Lisianski Island, Wake Island, and Midway Island. Englund *et al.* (2000b) report numerous recent collections on O‘ahu, including the Ala Wai Canal.

Procanace williamsi Wirth, 1951 **Introduced**

The first record of this beach fly is from 1944 on O‘ahu, from where it was described as a new species, although it is now recognized as native to Asia, and perhaps specifically to Japan (Englund *et al.*, 2000a). It is one of the most common beach flies on O‘ahu (Englund *et al.*, 2000b). It is common in Pearl Harbor streams in salinities of up to 30 ‰ (Englund *et al.*, 2000a) and in many shoreline locations on the south shore of O‘ahu, including the muddy banks of the Ala Wai Canal (Englund *et al.*, 2000b).

Tethina willistoni (Melander, 1913) **Introduced**

=*Tethina variseta* (Melander, 1952)

A fly collected in 1919 at Barbers Point (O‘ahu) and later at Wai‘anae, O‘ahu in 1946 (Hardy & Delfinado, 1980). It is associated with maritime habitats, including rocky shores and mangroves of Pearl Harbor, and in O‘ahu streams along the south shore in salinities up to 42 ‰ (Englund *et al.*, 2000a, 2000b, as *T. variseta*). Mathis & Foster (2007) note that it is a Western Atlantic species.

Ceratopogonidae

Atrichopogon jacobsoni (de Meijere, 1907) **Introduced**

This biting midge was taken in estuarine waters in Pearl Harbor streams (Englund *et al.*, 2000a), and R. Englund advises (pers. comm., 2000) that it be included in our treatment of estuarine and marine introduced insects. It was first collected on O‘ahu in 1958, and has “Oriental and Pacific regions” origins (Englund *et al.*, 2000a).

Atrichopogon sp. **Introduced**

A second introduced species of *Atrichopogon* occurs both in Pearl Harbor and in saline stream environments on O‘ahu’s south shore (for example, in Mākua Stream at 15–43 ‰ and in Niu Stream at 34 ‰) (Englund *et al.*, 2000a, 2000b). Its origin is unknown; the first date of collection is 1998.

Chironomidae

Cricotopus bicinctus (Meigen, 1818) **Introduced**

This is a widespread (Afrotropical and Holarctic) midge first collected in 1955 in Pearl Harbor; it is “now one of the most ubiquitous introduced aquatic insects in the Hawaiian archipelago,” being found from low to “nearly pristine” high elevations (>1,220 m) (Englund, 2000a). It occurs in brackish waters in Pearl Harbor streams up to 9 ‰ (Englund *et al.*, 2000b).

Goeldichironomus holoprasinus (Goeldi, 1905) **Introduced**

Beardsley (1970) reported this fly from a wide variety of aquatic situations, including “moats, ponds, (and) temporary water receptacles.” Beardsley (1970) noted that it was “common in Honolulu and has been reared from fish ponds on windward O‘ahu.” The first specimens are from 1969. Beardsley *et al.* (1999) add a new record from Pālā‘au State Park, at 1500 feet, on Moloka‘i, collected in 1994. It was described from Brazil and known from the United States. It is also found in brackish ponds (F.G. Howarth, pers. comm., 2005). For biogeographic analysis purposes, based upon its overall distribution, we treat this species as eastern American.

Telmatogeton japonicus Tokunaga, 1933 **Introduced**

This Japanese marine fly was listed by Hardy (1960) as an immigrant. Wirth (1947b) reported it from Hilo in 1946 “scampering over wave-drenched boulders on bay-front at park” and that it occurred on “boulders on the bay-front in a limited area near the outlet of a large storm-sewer, with a heavy growth of the algae *Ulva* sp. and *Enteromorpha* sp. indicating that the water was of considerably lower salinity than pure sea water.” Wirth noted that Tokunaga also found it associated with these same algae in Japan. Whereas the other marine midge in Hawai‘i, *Telmatogeton pacificus* Tokunaga, 1935, is widespread through the Islands (Nishida, 2002), *T. japonicus* appears to be restricted to the island of Hawai‘i, suggesting a human-mediated introduction.

Dolichopodidae

Dolichopus exsul Aldrich, 1922 **Introduced**

A West Indian (Caribbean) fly first found in 1930 in O‘ahu, and found by Englund *et al.* (2000b) in Pearl Harbor in hypersaline environments of Mākaha Stream (38 ‰) and along the concrete channel at the mouth of Wai‘alaenui Stream (32 ‰).

Medetera grisescens Meijere, 1916 **Introduced**

This fly, thought to be native to Asia, the South Pacific (including Australasia), and the Indian Ocean, was first collected in Honolulu in 1914 (Englund *et al.*, 2000a). It was collected in 1998 in Hālawa Stream flowing into Pearl Harbor in 32–37 ‰.

Syntormon flexible Becker, 1922 **Introduced**

A long-legged fly native to the western and southern Pacific, it was first collected in 1917 in Mānā, Kaua‘i (Englund *et al.*, 2000a). It occurs in brackish waters in streams flowing into Pearl Harbor

(Englund *et al.*, 2000a), and in other streams on the south shore of O‘ahu in salinities up to 37 ‰ (Englund *et al.*, 2000b).

Thinophilus hardyi Grootaert & Evenhuis, 1997 **Cryptogenic**
This fly was described from O‘ahu based upon 1996 collections. Grootaert & Evenhuis (1997) suggested that it was “not a recent introduction, but that due to its small size it was overlooked until now.” Subsequently, Englund *et al.* (2000a) proposed that it was introduced, and native to Australasia. Further research since Englund shows that *T. hardyi* may be cryptogenic. Since 1996, the genus has been collected extensively in the Indo-Pacific, but *T. hardyi* has not been found, suggesting it may be a Hawaiian endemic (N.L. Evenhuis, pers. comm., February 2007). Specimens of a *Thinophilus* from the Galapagos were identified by Bickel & Sinclair (1997) as *T. hardyi*, but comparison of the male genitalia shows they are a distinct species, and the Galapagos population may be undescribed (N.L. Evenhuis, pers. comm., 2007).

The habitat is “marshy sandplate on top of a porous lava bench protected by a rocky shore from the sea. The sand was covered with brown patches of diatomacea. Sea water welled up through the lava bench from time to time. The *Thinophilus* were mainly active on the wet sand around the upwelling sea water” (Grootaert & Evenhuis, 1997). Englund *et al.* (2000b) found this fly to be moderately common at a number of south shore O‘ahu stations in salinities ranging from 15 to 43 ‰.

Psychodidae
Psychoda salicornia Quate, 1954 **Introduced**
Quate (1954), in describing this fly from San Francisco and Tomales Bays, California, also noted specimens collected in light traps in Honolulu, O‘ahu, in 1945 and 1946. In California this species is found on the stems and branches of the pickleweed, *Salicornia*. Hardy (1960) added no new records. While there are no further reports of this species in Hawai‘i, we retain it on the list, since psychodids are rarely if ever identified to species on the islands, and it may thus still be present. Englund *et al.* (2000a), for example, record a *Psychoda* sp. from brackish water sties at ‘Aiea Stream, E‘o Stream, and Hālawa Stream.

Ephydridae
Brachydeutera ibari Ninomya, 1930 **Introduced**
A probable Asian species first collected at Beck’s Cove, Kāho‘olawe Island in 1980 (Evenhuis, 1987). Specimens were found in estuarine water in E‘o Stream on barnacles at a golf course bridge in 1998 (Englund *et al.*, 2000b).

Ceropsilopa coquilletti Cresson, 1922 **Introduced**
A shore fly first collected on O‘ahu in 1946 and now found in streams in Pearl Harbor (Englund 2000a) and in streams on the O‘ahu south shore in salinities from 15 to 43 ‰ (Englund *et al.* 2000a, 2000b). Described from California, it is considered Nearctic (Englund *et al.*, 2000a).

Clasiopella uncinata Hendel, 1914 **Introduced**
A shore fly native to Taiwan and Australasia and first found on O‘ahu in 1946. It occurs in shoreline habitats in Pearl Harbor, including among mangroves, and in saline streams on the O‘ahu south shore on a variety of soft and hard substrates in salinities of up to 39 ‰ (Englund *et al.*, 2000a, 2000b).

Discocerina mera Cresson, 1939 **Introduced**
This shore fly was first collected in 1948 on O‘ahu. It is strongly associated with saline and estuarine habitats on O‘ahu, being found in saline streams on the south shore (up to 39 ‰) and in a variety of habitats along the Pearl Harbor shoreline (Englund *et al.*, 2000a, 2000b). It is native to the western and/or southern Pacific Ocean.

Donaceus nigronotatus Cresson, 1943 **Introduced**
Described from Taiwan, this fly was found on O‘ahu in 1958, and now occurs on soft and hard bottoms along the Pearl Harbor shore and in saline streams on the O‘ahu south shore, in salinities up to 39 ‰ (Englund *et al.*, 2000a, 2000b).

Ephydra gracilis Packard, 1871 **Introduced**

= *Ephydra cinerea* Jones, 1906

In what would appear to be a classic case of a population explosion by a new invader followed by a nearly complete collapse, this Western North America brine fly was found to be breeding by the millions in July 1946 in saltwater ponds opposite the Moanalua Gardens, the water in the ponds having become increasingly saline as dredging operations had closed the inlet from Ke‘ehi Lagoon (Wirth, 1947a). Earlier in the year specimens had been found at Hickam Field (April in a light trap) and on Sand Island, opposite Honolulu (May). In August 1946 they were found at Iroquois Point, near Pearl Harbor, abundant in salt marsh pools. Wirth noted that “the close proximity of favorable breeding habitats at California seaplane bases, the large numbers of adults produced at times, their habit of swarming into moving vehicles (where they are a pest, as in trains crossing Great Salt Lake), and finally the proximity of receptive habitats near the O‘ahu seaplane bases, together develop conditions favorable for insect ‘transplantation’.” Wirth thus concluded that these flies were introduced by seaplanes from California to O‘ahu seaplane bases.

Curiously, this fly was not noted again in the islands for the next 50 years. It was rediscovered in low numbers in 1998 in Mākaha Stream and Kuapā Pond in a sampling program focused on detecting aquatic invasions (Englund *et al.*, 2000b). Habitat destruction may have played a role in the demise of the original populations around Hickam Field.

Ephydra milbrae Jones, 1906 **Introduced**

The second species of brine fly to be introduced to the islands, *E. milbrae* was first collected in the Ala Wai Canal in 1950 (Englund *et al.*, 2000a). It is native to western North America. It occurs on the Pearl Harbor shoreline in salinities of up to 44 ‰, and in O‘ahu streams up to 43 ‰ (Englund *et al.*, 2000a, 2000b).

Hecamede granifera Thomson, 1869 **Introduced**

A shore fly collected in 1923 from Mokapu, O‘ahu, and native to the western and/or southern Pacific. It is widespread on Pearl Harbor “seashore habitats” and in saline streams (to 43 ‰) on Oahu’s south shore ((Englund *et al.*, 2000a, 2000b).

Mosillus tibialis Cresson, 1916 **Introduced**

A North American shore fly collected at Mapulehu, Moloka‘i, in 1944, and at Waipahu, O‘ahu, in 1958. In 1998 a specimen was collected over mud and rocks in brackish water of the E‘o canal; it has also been collected in the saline streams of Oahu’s south shore (Englund *et al.*, 2000a, 2000b).

Paratissa pollinosa (Williston, 1896) **Introduced**

= *Paratissa semilutea* of authors

The first records of this Caribbean-South American shore fly are from intertidal beach rocks at Lanikai, O‘ahu, in 1945 (Adachi, 1952a; Hardy & Delfinado, 1980, as *P. semilutea*); Mathis, 1993). Additional collections are those from Pearl Harbor in 1998 (Englund *et al.*, 2000a). Hardy & Delfinado (1980) note that “Adults have been found mostly on dried seaweed washed up onto the each. Adults can often be seen crawling out from under seaweed piles when the seaweed has been disturbed.”

Placopsidella marquesana (Malloch, 1933) **Introduced**

= *Placopsidella cynocephala* Kertesz

A shore fly (described from New Guinea) with a broad Indo-Pacific distribution considered to be introduced to the islands and first found on rocks in 1951 in Hanauma Bay, O‘ahu (Adachi, 1952b). It remains common and widespread in Pearl Harbor estuarine environments and in highly saline O‘ahu south shore streams (up to 42 ‰) (Englund *et al.*, 2000a, 2000b). It is common in seaweed and debris on beaches (Englund, 2000b). It is also known from Kaua‘i, Maui, and Hawai‘i.

Psilopa girschneri Roder, 1889 **Introduced**
A broadly distributed Northern Hemisphere (North America-Europe-Asian) shore fly first reported in 1952 from O‘ahu. A saline environment species, it is common in marine shorelines of Pearl Harbor and on Oahu’s south shore in salinities up to 43 ‰ (Englund *et al.*, 2000a, 2000b).

Scatella stagnalis (Fallen, 1913) **Introduced**
Another broadly distributed northern hemisphere (North America-Europe-Asian) shore fly first reported relatively late (1967) from O‘ahu, with a habitat similar to *Psilopa girschneri* (Englund *et al.*, 2000a, 2000b). Englund (2000b) notes that it “remains one of the most common aquatic fly species of O‘ahu.” Englund (2002) notes that a first-reported date of 1946 is in error.

Hostis guamensis Cresson, 1945 **Introduced**
The type locality of this Australasian fly is a China Clipper: the type specimen was taken from the airplane when it landed on Guam, with previous ports in California (Alameda, in San Francisco Bay), Hawai‘i (Honolulu), and Midway (Hardy & Delfinado, 1980), who suggested that “it is possible that it got into the plane at Honolulu. The Honolulu airport is close to the seashore where this species is known to occur.” It is widespread throughout the “Afrotropical” region (Mathis, 1993) and appears to have been introduced to (at least) the Hawaiian Islands and to Madagascar in the Indian Ocean.

Adachi (1952a) was the first to report it, from specimens collected in 1946 at ‘Ewa, O‘ahu, found resting on seaweed on the beach. It also occurs on Maui (Nishida, 2002).

Collembola (springtails)
Hypogastruridae
Oudemansia esakii (Kinoshita, 1932) **Cryptogenic**
Christiansen & Bellinger (1992) report this Japanese species from Hawai‘i, “found on intertidal zones and beaches.” We note it as an example of cryptogenic collembolans. It was collected on O‘ahu in 1939 (Ala Moana Canal, on intertidal mud), Laysan (1983, unexposed reef), and Pearl and Hermes Reef (1983, lagoon intertidal zone; 1983, raised coral beach).

ACARINA (mites)

Eldredge & Miller (1995) listed two nonindigenous species of mites as marine, based upon Nishida (1994). However, these are freshwater species.

PYCNOGONIDA (sea spiders)

Introduced Pycnogonida

Species	Date	Vector	Native to
Ammothella pacifica	1930	SF,BW	Indo-Pacific
Tanystylum rehderi	2000	SF,BW	Indo-Pacific
Pigrogromitus timsanus	1930	SF,BW	Unknown
Endeis biseriata	1960	SF,BW	Indo-Pacific
Endeis nodosa	1924	SF,BW	Indo-West Pacific
Endeis procera	1996	SF,BW	Indo-West Pacific
Anoplodactylus arescus	1998	SF,BW	Indo-Pacific
Anoplodactylus “californicus“	1937	SF,BW	Unknown
Anoplodactylus digitatus	2000	SF,BW	Unknown
Anoplodactylus erectus	<1942	SF,BW	Eastern Pacific
Anoplodactylus marshallensis	2000	SF,BW	Marshall Islands
Anoplodactylus pycnosoma	2000	SF,BW	Indo-West Pacific
Additional Taxon Treated and Its Status			
Anoplodactylus eroticus	1945	SF, BW	Indian Ocean
Status: *Deleted*			

We treat all of the Hawaiian harbor-dwelling sea spiders here as introduced with shipping. For most of these species, Hawai‘i is far distant from their apparently natural patterns of occurrence, and no shallow-water pycnogonids have been recorded from any high seas drifting material that would suggest that they may have naturally drifted into Hawaiian ports and harbors. A number of species appear to have arrived in the last half of the twentieth century since Edmondson’s and Hilton’s studies.

Ammotheidae

Ammothella pacifica Hilton, 1942 **Introduced**

Hilton (1942a) described this species from the Honolulu Aquarium (now Waikīkī Aquarium) on O‘ahu based upon specimens collected in 1930. It has subsequently been reported from the Indo-Pacific, including the Caroline Islands, Grand Comoro Island, and Madagascar (Stock, 1968). Bishop Museum holdings include specimens collected in 1948 from Honolulu Harbor. Coles *et al.* (2002a) report it from Kāne‘ohe Bay based upon 2000 collections. It is a probable ship-mediated introduction.

Tanystylum rehderi Child, 1970 **Introduced**

This Indo-Pacific sea spider was first recorded in 2000 outside of Kāne‘ohe Bay at Moku Manu islet (Coles *et al.*, 2002a), as identified by C.A. Child. There are scattered records throughout the South Pacific and Indian Oceans (Arango, 2003, who reports the first record from Australia). It occurs in Guam (Child, 1991), where it may also be introduced. We consider it introduced in vessel fouling or in ballast water.

Callipallenidae

Pigrogromitus timsanus Calman, 1927 **Introduced**

= *Clotenopsa prima* Hilton, 1942a, described from Hawai‘i, *fide* Stock, 1968.

This tramp, ship-dispersed pycnogonid of unknown origin was first described from the Suez Canal, and later recorded from the Indian River, Florida (a canal-like environment), the saltwater locks of the Panama Canal, and scattered locations in the Indo-Pacific (C.A. Child, *in litt*. to L.G. Eldredge, 1996 and to S.L. Coles, 1999). Child (1992) reported it from various stations in the western Gulf of Mexico, around Vera Cruz and Yucatan in Mexico. Moazzam (1987) extended it into the Arabian Sea. Arango (2003) describes it as “a pantropical-temperate species frequently collected in shallow habitats (in the) Indo-Pacific, Caribbean and Mediterranean.” Allan Child refers to it as the “canal pycnogonid” [Child (1979) and C.A. Child *in litt*. to L.G. Eldredge, 1996].

It was first collected at Black Point, O‘ahu in 1930 and redescribed as a new species, *Clotenopsa prima* by Hilton (1942a). Coles *et al.* (1997, 1999a) report it from fouling communities in Pearl Harbor based upon 1996 collections, and it also occurs in Ala Wai Harbor and Kewalo Basin, based upon 1998 material (Coles *et al.*, 1999b). It was found in 1999 in Kāne‘ohe Bay (Coles *et al.*, 2002a). We consider it introduced to Hawai‘i in vessel fouling or in ships’ ballast water.

Endeidae

Endeis biseriata Stock,1968 **Introduced**

Stock described this species from New Guinea, Indonesia, and India; along with a single outlying record from Coconut Island, Kāne‘ohe Bay of one female collected in 1960 (Stock, 1968). Stock (1970) then extended the distribution well to the east, to the Gulf of Aqaba from the “piers at Eilat”, based upon specimens collected in 1970. Child (1996) summarized the known distribution, which by then included records from the Red Sea and Madagascar to Indonesia, the Philippines, and Australia, with continuing outlying records in Hawai‘i and Brazil.

Endeis nodosa Hilton, 1942 **Introduced**

William A.Hilton described this species based upon specimens collected in 1924 and again in 1927 in Kāne‘ohe Bay. Evans *et al.* (1974) report it from Pearl Harbor, although it was not recollected in

1996 surveys (Coles *et al.*, 1997). Child (1982) reported an additional specimen collected in 1947 in Honolulu Harbor "on boat hawser" (a towing or mooring rope). It remained unknown from elsewhere until it was collected in 1969 at Enewetak Atoll in the Marshall Islands, on pier pilings and on rocks in a lagoon (Child, 1982). Child commented that it "is probably not rare but only rarely reported because its habitats are seldom sampled." Nakamura & Child (1988a) then reported it from Naha Harbor, Okinawa, Japan, based upon a specimen collected in 1987. We consider it unlikely to be native to the Hawaiian Islands.

Endeis procera (Loman, 1908) **Introduced**

This Indo-West Pacific species was reported from Pearl Harbor by Coles *et al.* (1997) based upon collections made in 1996. Stock (1954) noted it from the Kei Islands in sand and shells at about 50 m depth.

Phoxichilidiidae

Anoplodactylus arescus Marcus, 1959 **Introduced**

This species has been recorded from the Atlantic Ocean (Brazil) but is more widespread throughout the Indo-Pacific [East Africa (Tanzania), Madagascar, Red Sea (the type locality), Philippines, and American Samoa] (Nakamura & Child, 1988b; C.A. Child *in litt.* to S. Coles, 1999). It was first found in Hawai'i in 1998 at Barbers Point Harbor on pier pilings (Coles *et al.*, 1999b) and again in 2000 in Kāne'ohe Bay (Coles *et al.*, 2002a). Identifications were made by C.A. Child. It is often found in sandy sediments. It may have been long overlooked in the islands and been transported here in sand ballast; alternatively, more modern-day transport with ballast water is possible. It also would appear to be an introduction to Brazil.

Anoplodactylus "californicus" Hall, 1912 **Introduced**

= *Anoplodactylus portus* Calman, 1927, *fide* Child, 1987

= *Anoplodactylus projectus* Hilton, 1942a, *fide* Child, 1987 (see Child, 1975, p. 201, for additional basis of synonymy)

This sea spider was described as a new species, *Anoplodactylus projectus* Hilton, 1942a, based upon a specimen collected in 1938 in Pearl Harbor "from bottom of ship." Earliest Bishop Museum material from Pearl Harbor dates from 1937 (identified by J.H. Stock in 1967) with regular collections being made thereafter. Grovhoug & Rastetter (1980) reported it (as *A. portus*) in Kāne'ohe Bay and Pearl Harbor (1976–1977 collections). Coles *et al.* (1997) reports it from Pearl Harbor. It also is found (1997–1998) in Honolulu Harbor, Ala Wai Harbor, Barbers Point Harbor, and Kewalo Basin (Coles *et al.*, 1999b) and in Kāne'ohe Bay (2000 collections; Coles *et al.*, 2002a).

Child (1987) synonymized the global species *A. portus* with *A. californicus*. As such, it is reported as a pantemperate-pantropical species from many parts of the world. Hall's original concept of *A. californicus* was a species that in southern California lived among the bases of the surfgrass *Phyllospadix* on exposed rocky intertidal shores at extreme low tide (Hall, 1913). This is not a habitat characterized by cosmopolitan taxa, nor a habitat that either receives or donates invasions. It seems probable that the concept of *A. californicus* involves more than one species, and we thus place the species name in quotation marks here and recognize it as a nonnative taxon of unknown origin.

Anoplodactylus digitatus (Böhm, 1879) **Introduced**

Coles *et al.* (2002a) newly report this sea spider from the islands based upon material collected in 2000 in Kāne'ohe Bay and identified by C.A. Child. Arango (2003), in recording it for the first time for Australia, noted that it was widely known from the Indo-West Pacific, the West Indies (Caribbean), and the Mediterranean Sea. We suggest that is not likely native to the Hawaiian Islands.

Anoplodactylus erectus Cole, 1904 **Introduced**

A species apparently native to the eastern Pacific Ocean (from British Columbia, Canada, to Colombia), but also known in the South Pacific from French Polynesia (Tuamotu Islands) and American Samoa (Pago Pago Harbor), as well as in the North Pacific in Korea (Child, 1979; Nakamura & Child, 1988b). Stock (1975) reported it on fouling panels in shallow water in Valparaiso and Punta Arenas, Chile.

Hilton (1942b) noted it from “Honolulu” without date or further data. We suggest that it has been introduced to at least Korea and the Hawaiian Islands with vessel traffic.

Anoplodactylus eroticus Stock, 1968 **Deleted**

Stock (1968) described this sea spider from the Gulf of Manaar in India, and from Honolulu Harbor, the latter based upon a specimen collected in 1945. It has not reappeared in recent collections of sea spiders on O‘ahu.

Anoplodactylus marshallensis Child, 1982 **Introduced**

Coles *et al.* (2002a) newly report this sea spider from the islands based upon material collected in 2000 in Kāne‘ohe Bay and identified by C.A. Child. It was previously known from collections made in 1969 from pier fouling on Enewetak Island, Enewetak Atoll, Marshall Islands (Child, 1982). We consider it a likely candidate for fouling or ballast water transport.

Anoplodactylus pycnosoma (Helfer, 1938) **Introduced**

Coles *et al.* (1997) report this species from Pearl Harbor (1996), and from Moku Manu islet outside of Kāne‘ohe Bay (2000) (Coles *et al.* 2002a), as identified by C.A. Child. *Anoplodactylus pycnosoma* is a widely distributed Indo-Pacific species, including records in the North Pacific Ocean in Korea, Japan, and Guam (Child, 1991, Stock, 1994). Staples (1997) lists records from Western Australia and from southern Australia (in Port Philip Bay, a site of many invasions).

PHORONIDA (phoronids)

Introduced Phoronida

Species	Date	Vector	Native to
Phoronis hippocrepia	1976	SF	North/South Atlantic

Phoronis hippocrepia Wright, 1856 **Introduced**

What appears to be a fouling species of Atlantic phoronid has become established in two locations in the Pacific Ocean. The first records of *Phoronis hippocrepia* are from 1976 in Kāne‘ohe Bay (Emig, 1977; Emig & Bailey-Brock, 1987; the latter paper provides the date of 1976). Emig (1982) implies a date of 1975 (figure 1A, species 2, location 42), but the date of the paper cited is 1977, not 1975. *Phoronis hippocrepia* likely occurred in Hawai‘i well before this date, and it should be expected in Pearl Harbor, as well as in other Pacific harbors.

Phoronis hippocrepia is widely known from the North and South Atlantic Oceans but has been recorded only from two stations in the Pacific Ocean, first in Sydney Harbour (Port Jackson), Australia in 1893, then in 1976 in Kāne‘ohe Bay. It has also been introduced into the Miraflores Locks of the Panama Canal (Emig, 1982; Bailey-Brock & Emig, 2000), where it was collected probably in 1972 (see Jones & Dawson, 1973, biotic surveys of that date in the Miraflores Locks).

This moderate-sized (4 cm) phoronid is a “burrowing and encrusting species” (Bailey-Brock & Emig, 2000), occurring in benthic coral rock and burrowing into “oyster shells and barnacles attached to harbor pilings to depths of 30 cm below mean tide level” (Emig & Bailey-Brock, 1987, who present a figure of a phoronid *in situ* within an empty barnacle shell). Bailey-Brock & Emig

(2000) specifically note its occurrence "with fouling communities" on Lilipuna Pier, and "in coral rock from fringing reefs in south and north regions of" Kāneʻohe Bay.

It seems probable that over the course of the past 100 years this Atlantic species has been introduced by ship fouling to the Pacific Ocean, and its appearance in the Panama Canal is particularly compelling evidence for ship-mediated transport. Colonization is doubtless facilitated by asexual reproduction (transverse fission).

KAMPTOZOA (Entoprocta)

Introduced Kamptozoa

Species	Date	Vector	Native to
Barentsia sp.	1966	SF, BW	Unknown

Barentsiidae

Barentsia sp. **Introduced**

We regard this *Barentsia*, reported as *Barentsia gracilis* from Kāneʻohe Bay fouling communities (presumably 1966 collections) by Soule & Soule (1968) and from Pearl Harbor and Kāneʻohe Bay fouling in 1976–1977 by Grovhoug & Rastetter (1980) as an introduced species. It is doubtless still present but largely overlooked as part of the microfouling fauna. Hawaiian populations should be compared to *Barentsia benedeni* (Foettinger, 1887).

BRYOZOA (Ectoprocta) (bryozoans)

Introduced Bryozoa

Species	Date	Vector	Native to
Amathia distans	1935	SF	Unknown
Bowerbankia sp., cf. *gracilis*	1966	SF	Unknown
Bowerbankia sp., cf. *B. imbricata*	1966	SF	Unknown
Zoobotryon verticillatum	<1921	SF	Unknown
Aetea truncata	1935	SF	Unknown
Aetea anguina	1997	SF	Unknown
Bugula dentata	1997	SF	Unknown
Bugula neritina	1921	SF	Unknown
Bugula minima	1996	SF	Unknown
Bugula stolonifera	1935	SF	Unknown
Caulibugula dendrograpta	1997	SF	Indo-Pacific
Caulibugula caliculata	1997	SF	Indo-West Pacific
Synnotum aegyptiacum	1966	SF	Unknown
Caberea boryi	1966	SF	Unknown
Cryptosula pallasiana	1966	SF	North Atlantic
Savignyella lafontii	1935	SF	Unknown
Hippopodina tahitiensis	1948	SF	Indo-West Pacific
Schizoporella sp.	1935	SF	Unknown
Trypostega venusta	1966	SF	Unknown
Watersipora edmondsoni	1966	SF	Indo-Pacific
Watersipora arcuata	1998	SF	E. Pacific
Watersipora subtorquata	1966	SF	Caribbean

Ctenostomata
Vesiculariidae

Amathia distans Busk, 1886 **Introduced**

This well-known fouling bryozoan is now so widespread that its origin remains unknown (Cranfield *et al.*, 1998, suggest that it is native to the Atlantic coast of the Americas). It occurs in the North and South Pacific and North and South Atlantic Oceans. Gordon & Mawatari (1992) and Keough & Ross (1999) consider it introduced to New Zealand and Australia, respectively.

First records for Hawai‘i are 1935 in Kāne‘ohe Bay by Edmondson & Ingram (1939, as *Amathia* sp.). Bishop Museum material for Pearl Harbor commences in 1948 and for Honolulu Harbor in 1946. Soule & Soule (1968; 1966 collections) noted it from Coconut Island in Kāne‘ohe Bay. Long (1974; 1968–1972 collections) found it on fouling panels just offshore of O‘ahu. DeFelice *et al.* (1998) report it from Midway Atoll. Coles *et al.* (2006) report it from many sites on Kaua‘i, O‘ahu, Moloka‘i, Maui, and Hawai‘i based upon collections from 1996 to 2003. Hoover (1998, 2006) presents a color photograph of specimens in Pearl Harbor. From October 2002 to February 2003 this bryozoan was observed growing in massive quantities, described as “enormous tumbleweed-like colonies” in the brackish water Ala Wai Canal in Waikīkī (C. Zabin, pers. comm., January 2004). We consider this a ship-fouling introduction that was certainly in Hawai‘i many years before its first report.

Bowerbankia sp., cf. ***gracilis*** Leidy, 1855 **Introduced**

This is another now-cosmopolitan ctenostome. While often suggested as being native to eastern North America (northwestern Atlantic Ocean)—it was first described from Rhode Island—this species is now too widespread to yet suggest its origin, prior to molecular genetic analysis. Gordon & Mawatari (1992) provide a general global summary; they consider it introduced to New Zealand. While no doubt long present in the islands, first records are only from 1966, based upon collections in Kāne‘ohe Bay and the Ala Wai Canal (Soule & Soule, 1968).

Bowerbankia collected on panels placed just offshore of O‘ahu (1968–1972 collections; Long, 1974) and reported in Pearl Harbor and in Kāne‘ohe Bay based upon 1976–1977 collections (Grovhoug & Rastetter, 1980) are referable to either this species or the next.

Bowerbankia sp., cf. ***imbricata*** (Adams, 1798) **Introduced**

Soule & Soule (1968) report this species from Kāne‘ohe Bay and Ala Wai Canal, based upon 1966 collections. It too has a widespread, global distribution (Gordon & Mawatari, 1992). Its origin is unknown.

Zoobotryon verticillatum (Delle Chiaje, 1828) **Introduced**

= *Zoobotryon pellucidum* Ehrenberg, 1831
= *Zoobotryon pellucidus* of authors (misspelling)

A bryozoan capable of forming massive colonies in fouling communities, it is either native to the Mediterranean (as suggested by Cranfield *et al.*,1998) or arrived there as an invader on ship bottoms from elsewhere by the 18th or early 19th century. We regard its origin as unknown. Robertson (1921) noted that she had received specimens from “Honolulu, Hawaiian Islands”; this appears to be the first mention of the species from Hawai‘i in the literature. The report by Cohen & Carlton (1995) of a Hawaiian record in Robertson (1905) is in error.

Bishop Museum material dates from 1921 for Pearl Harbor and 1946 for Honolulu Harbor. Coles *et al.* (1999b) also report it form Ala Wai Harbor, Barbers Point Harbor, and Kewalo Basin, based upon 1998 collections; Coles *et al.* 2004 report it from Mā‘alea and Kahului Harbors on Maui, based on 2003 collections. DeFelice *et al.* (1998) report it from Midway Atoll. Edmondson (1933) reported it (as *Z. pellucidus*) associated with *Bugula* in fouling communities on O‘ahu. Edmondson & Ingram (1939) note that in Kāne‘ohe Bay a colony grew to 50 mm in height in 56 days, and that it was also occasionally found on boat bottoms in Pearl Harbor. Soule & Soule (1968) report on collections from Kāne‘ohe Bay in 1966, noting that it occurred there “hanging in great tangled streamers.”

Godwin (2003b) noted that *Z. verticillatum* was present on a barge towed from San Diego to O‘ahu in 1999.

Cheilostomata
Anasca
Aeteidae

Aetea truncata (Landsborough, 1852) **Introduced**

= *Aetea recta* of Soule *et al.,* 1987, p. 97

A tiny creeping stolonate bryozoan which now occurs in all oceans (Osburn, 1950; Winston, 1982), and whose origin remains unknown. The earliest record is that of Edmondson & Ingram (1939) based on specimens collected in 1935 in Kāneʻohe Bay. Soule & Soule (1968) continue to record it from Kāneʻohe Bay, based upon 1966 collections, and also report specimens from "off Oahu" at 9.1 and 27.4 m. Coles *et al.* (1997, 1999a) report it from Pearl Harbor (1996), and Coles *et al.* (1999b) report it from Honolulu Harbor (1997) and Kewalo Basin (1998). Bailey-Brock (1989) recorded it on PVC settlement plates on an artificial reef in open waters at 20 m, 2.4 km off the southeast coast of Oʻahu.

Aetea anguina (Linnaeus, 1758) **Introduced**

Another now-cosmopolitan species of *Aetea*, which may involve a species complex (Keough & Ross, 1999, who also consider it introduced to Australia). Reported in 1997 from Honolulu Harbor by Coles *et al.* (1999b).

Bugulidae

Bugula dentata (Lamouroux, 1816) **Introduced**

Zabin (1999) reports this blue-green or turquoise species from 1997–1998 collections from Honolulu Harbor, Ala Wai Yacht Harbor, and Barbers Point, based upon surveys of Oʻahu harbors (Coles *et al.*, 1999b). It also occurs at Koko Marina (Coles *et al.* 2002b) and in harbors at Kauaʻi, Molokaʻi, Maui, and Hawaiʻi (Coles *et al.*, 2004).

It is a species of the Indo-Pacific Ocean (Zabin, 1999) and is also known from Japan (R. Woollacott, pers. comm., October 1996). Hoover (1998, 2006) presents a color photograph from 3 m at Magic Island, Oʻahu (identified as *B. stolonifera*, but in fact *B. dentata*; C. Zabin, pers. comm., 2000). Hoover's photograph was taken in January 1997 (J. Hoover, pers. comm., January 2004, who notes that at that time "they were all over the place at Magic Island boat channel.")

Bugula "neritina" (Linnaeus, 1758) **Introduced**

One of the world's most commonly recognized fouling organisms, now too widespread to know its origin without extensive global genetic analyses. *Bugula "neritina"* is a species complex (for example, Davidson & Haygood, 1999; McGovern & Hellberg, 2003), likely represented by regional endemics along with a now-global port-dwelling, ship-dispersed fouling taxon. Earliest Bishop Museum specimens are from 1921 in Pearl Harbor. Edmondson (1933) reported it to be common in Oʻahu harbors and bays. Edmondson & Ingram (1939) provide growth data in 1935 and later years for Kāneʻohe Bay. Soule & Soule (1968) report it from Kāneʻohe Bay (1966) and Ala Wai Yacht Basin (1966) and note material from Honolulu Harbor as well in Bishop Museum collections (the earliest Honolulu specimens are from 1940). Edmondson (1944a) further reported it from Pearl Harbor, and Long (1974) found it both on Pearl Harbor fouling panels and in panels just offshore of Oʻahu between 1968 and 1972. It remains abundant in Pearl Harbor (Coles *et al.*, 1997, 1999a) and is also still common in Honolulu Harbor, Ala Wai Harbor, and Kewalo Basin (Coles *et al.*, 1999b). It was also found in 2002–2003 collections in harbors on Kauaʻi and Maui (Coles *et al.*, 2004). Mackie *et al.* (2006) found that Hawaiian specimens from Ford Island (Pearl Harbor) were genetically similar to a clade now widespread through the Pacific and Atlantic Oceans.

Ingram (1939) noted that the snail *Atys semistriata* deposits its egg masses on (and may feed upon) *B. neritina* in Kāneʻohe Bay. Entire populations of *B. neritina* can be grazed down on marina floats in a matter of days by *Tilapia* (R. Woollacott, pers. comm., October 1996).

Bugula minima Norman, 1909 **Introduced**

Zabin (1999) reported (as *B. robusta* MacGillivrary, 1869) this widespread *Bugula* from Pearl Harbor (1996), Honolulu Harbor (1997), and Barbers Point (1998) based upon the surveys described by Coles *et al.* (1999a, 1999b). It was present in 1995 in Kewalo Basin and Kāne‘ohe Bay (Zabin, 1999). It also occurs in Nawiliwili Harbor, Kaua‘i, and Kuhului Harbor, Maui (Coles *et al.*, 2004).

Bugula minima was described from the Eastern North Atlantic, and subsequently widely reported from a number of Atlantic and Pacific locations. Hawaiian populations, formerly thought to be *B. robusta*, are now considered to be *B. minima* (Winston & Woolaccott, 2008)

Bugula stolonifera Ryland, 1960 **Introduced**

= *Bugula californica* of authors, including Hawaiian literature

Another *Bugula* found in most seas and whose origin remains uncertain pending global analysis of distribution and genetic patterns. Cranfield *et al.* (1998) and Keough & Ross (1999) consider it introduced to New Zealand and Australia, respectively.

Earliest Bishop Museum material is from 1935 (Kāne‘ohe Bay), 1940 (Pearl Harbor), and 1946 (Honolulu Harbor). Soule & Soule (1968, as *B. californica*) reported it from Kāne‘ohe Bay and Ala Wai Yacht Basin (1966 collections). Long (1974, as *B. californica*) found it on panels offshore of O‘ahu (1968–1972). Coles *et al.* (1997, 1999a, 1999b) report it from Pearl Harbor, Barbers Point Harbor, Ala Wai Yacht Harbor, and Kewalo Basin. Godwin (2003b) noted that *B. stolonifera* was present on a barge towed from San Diego to O‘ahu in 1999.

Caulibugula dendrograpta (Waters, 1913) **Introduced**

Zabin (1999) reports this Indo-Pacific species from Honolulu Harbor and Barbers Point (1997–1998). Coles *et al.* (2000a) report it also from Kāne‘ohe Bay. This and the following species represent the first *Caulibugula* reported from the Islands.

Caulibugula caliculata (Levinsen, 1909) **Introduced**

This western and Indo-Pacific bryozoan was first collected in 1997 in Honolulu Harbor (Zabin, 1999). Previous records are for Hong Kong and the Philippines.

Chorizoporidae

Synnotum aegyptiacum (Audouin, 1826) **Introduced**

Soule *et al.* (1987, p. 119) report this widespread warm-water species from O‘ahu, based upon collections presumably in 1966 (see Soule & Soule,1968), noting that it occurs “mixed with hydroids, bryozoans, and algae in fouling communities.” Coles *et al.* (1999b) report it from Honolulu Harbor, Ala Wai Harbor, and Barbers Point Harbor, based upon 1997–1998 collections. It likely occurs in Pearl Harbor as well.

Synnotum aegyptiacum, originally described from the Red Sea, is known in the Eastern Pacific from southern California to Peru, in the Western Atlantic from Cape Hatteras to Brazil, including the Caribbean and the Gulf of Mexico (Osburn, 1950; Winston, 1982), as well as in the Indo-Pacific and Australia. Its original home remains unknown.

Scrupocellariidae

Caberea boryi (Audouin, 1826) **Introduced**

Soule *et al.* (1987, p. 98, as *Caberia*) report this species as being epizoic on the bryozoans *Amathia* and *Zoobotryon* based upon collections in 1966 in Kāne‘ohe Bay [although this species is not mentioned in Soule & Soule (1968)]. It remains present in Kāne‘ohe Bay (Coles *et al.*, 2002a). Coles *et al.* (2006) report it from Moloka‘i, based upon 2003 collections. It is now reported from most global shores, and its origin is at this time not known.

Ascophora
Cryptosulidae
Cryptosula pallasiana (Moll, 1803) **Introduced**
Soule *et al.* (1987, p. 98) record this common North Atlantic species from Kāneʻohe Bay fouling communities in 1966, although it is not reported in their earlier fouling study (Soule & Soule, 1968). It occurs widely in other Pacific harbors and bays, including the North American Pacific coast, Japan, New Zealand and Australia (Cohen & Carlton, 1995). It is a probable global species complex.

Saviignyellidae
Savignyella lafontii (Audouin, 1826) **Introduced**
= *Catenaria lafontii* in Edmondson & Ingram, 1939
A global species of uncertain origin recorded from fouling communities in many parts of the world. First recorded in 1935 in Kāneʻohe Bay (Edmondson & Ingram, 1939, as *Catenaria lafontii*; identified by R.C. Osburn). Soule & Soule (1968) record it again from Kāneʻohe Bay (1966) and note Bishop Museum specimens from Pearl Harbor and Honolulu Harbor. Long (1974, collections from 1968–1972) recorded it on panels set just offshore of Oʻahu. Coles *et al.* (1999b, 2002a, 2002b, and 2004) report it from a number of locations on Oʻahu, Molokaʻi, and Maui.

The photographs of this species in Hoover (1998, pp.87 and 89; 2006) in deeper waters off Maui are instead *Vittaticella uberrima* Harmer, 1957 (C. Zabin, pers. comm., January 2004).

Escharellidae
Hippopodina tahitiensis Leca & d'Hondt, 1993 **Introduced**
= *Hippopodina feegeensis* of Hawaiian authors, not of Busk, 1884
Tilbrook (2006) determined that the *Hippopodina* long reported from the Islands as *H. feegeensis* is *H. tahitiensis*, described relatively recently from French Polynesia. It was first collected in the Islands in 1948 in Honolulu Harbor (Bishop Museum collections; this material was noted by Soule & Soule, 1968, without date). It appears to have been next collected in 1966 in raft fouling in shallow water in Kāneʻohe Bay (Soule & Soule, 1968). It was also collected in 1996 in Pearl Harbor (as *Schizoporella* sp. in Coles *et al.*, 1997; specimens reexamined and identified by C. Zabin). It was observed in 1994 at the Waikīkī Yacht Club, and for the first time in 1994 at Kewalo Basin (R. Woollacott, pers. comm., October 1996). Coles *et al.* (1999b) report it from Honolulu Harbor, Ala Wai Harbor, and Kewalo Basin, based upon 1997 and 1998 collections.

Schizoporellidae
Schizoporella sp. **Introduced**
One or more species of *Schizoporella*, none native, are present in Hawaiian fouling communities. Uncertainty has attended the identification of species in this genus since the earliest attempts: in 1936, R.C. Osburn examined specimens for C.H. Edmondson collected in 1935–1936 from Kāneʻohe Bay and reported them as "*Schizoporella unicornis* or a closely related species" (A. Wetmore *in litt.* to C.H. Edmondson, 12 September 1936; letter on file at Bishop Museum).

Schizoporella unicornis (Johnston, 1847) has been reported by many workers since Edmondson & Ingram's (1939) studies in Kāneʻohe Bay (specimens collected since 1935). Soule & Soule (1968, based upon 1966 collections) record *S. unicornis* from Kāneʻohe Bay and Ala Wai Yacht Basin and note additional Bishop Museum specimens from Pearl Harbor and Honolulu Harbor. Hurlbut (1991c) reported on settlement and juvenile survival in Pearl Harbor. *Schizoporella errata* (Waters, 1878) is also reported from many stations in Hawaiian harbors and reefs (Coles *et al.*, 1997, 1999a, 1999b, 2002a, b, 2004, 2006). DeFelice *et al.* (1998) reported *S. errata* from Midway Atoll. Godwin (2003b) noted that *S. unicornis* was present on a barge towed from San Diego to Oʻahu in 1999.

The identification of these and other *Schizoporella* species has often presented many challenges (Keough & Ross, 1999), and a thorough reexamination of Hawaiian material is required. Dick *et al.* (2005), for example, note that many records of *S. unicornis* from the north Pacific Ocean are attributable to *S. japonica* Ortmann, 1890.

Hippothoidae

Trypostega venusta (Norman, 1864) **Introduced**

Soule *et al.* (1987, p. 98) record this cosmopolitan species (Osburn, 1952; Winston, 1982) from Kāne‘ohe Bay fouling communities in 1966, although it is not reported in their earlier fouling study (Soule & Soule, 1968).

Watersiporidae

Watersipora edmondsoni Soule & Soule, 1968 **Introduced**

This *Watersipora* was described as a new species from collections made in 1966 from the hull fouling of houseboats in the Ala Wai Yacht Harbor in Honolulu. *Watersipora edmondsoni* is known from Pearl Harbor, as well as from panels placed in waters just offshore (Long, 1974, Grovhoug, 1979, and Coles *et al.*, 1997, 1999a), from Kāne‘ohe Bay [Dade & Honkalehto, 1986 (1983 collections)]; Coles *et al.*, (2002a; Bishop Museum material since 1975); from Kaua‘i (Soule *et al.*, 1987, page 129, plate caption), from Ke‘ehi Lagoon (Coles *et al.*, 1999b, 2002a (1997), and from Waikīkī, Koko Marina, and Hawai‘i Kai (Coles *et al.*, 2000b), and from Molokai’s Kaunanakai Main Dock (Coles *et al.*, 2004). Mackie *et al.* (2006) record *W. edmondsoni* from Waiahole Reef in Kāne‘ohe Bay, based upon collections made in 1999 (J. Mackie, pers. comm., January 2007).

It remained known only from the Hawaiian Islands until reported from several Indo-Pacific locations by Winston & Heimberg (1986). Winston & Heimberg (1986) reported it from Sanur in Bali, based upon collections made in 1984 (J. Winston, pers. comm., January 2004; the date does not appear in the paper). They also interpreted specimens illustrated by Soule & Soule (1975) as falling within the concept of *W. edmondsoni*. These included material collected in 1898 in Torres Strait (between New Guinea and Northeast Australia) and in 1905 in Sri Lanka. It would thus appear that *W. edmondsoni* is Indo-Pacific in origin. Soule & Soule (1968) suggested that it was introduced between 1956 and 1966, based upon collections made by personnel from the Bishop Museum up until 1956 and the failure to collect this species prior to that.

Dick (2006) reported this species as “*Watersipora subovoidea* sensu Harmer, 1957,” from rocky intertidal sites at Kapa‘a Beach Park, on the Big Island, and tentatively placed the Soules’s name in synonymy. It may well be that *W. subovoidea*, in part, captures *W. edmondsoni*, and may eventually be found to be a senior synonym.

Watersipora arcuata (Banta, 1969) **Introduced**

Coles *et al.* (1999b, 2004) report the fouling bryozoan *Watersipora arcuata* from Kewalo Basin (1998 collections) and from Kahului Harbor, Maui (2003 collections). Mackie *et al.* (2006) genetically confirmed *W. arcuata* from both Ala Wai Harbor and Hale‘iwa Harbor on O‘ahu; this material was collected in 2000 (J. Mackie, pers. comm., January 2007). *Watersipora arcuata* is native to the warm waters of the Eastern Pacific and has been introduced to Australia as well (Mackie *et al.*, 2006).

Watersipora subtorquata (d’Orbigny, 1852) **Introduced**

Soule *et al.* (1987, p. 129, figure caption) illustrated *Watersipora “subovoidea”* based upon 1966 collections in Pearl Harbor and Ala Wai Marina. The caption description and the photograph of the aperture match *W. subtorquata*, a species believed to be native to the Caribbean and also introduced to Australia and New Zealand (Mackie *et al.*, 2006).

Echinodermata

Introduced and Cryptogenic Echinodermata

Species	Date	Vector	Native to
Ophiuroidea			
Introduced Species			
Ophiactis savignyi	1847–1849	SF	Indo-Pacific
Cryptogenic Species			
Ophiactis modesta	1902	SF	

Ophiuroidea
Ophiactidae

Ophiactis savignyi (Muller & Troschel, 1842) **Introduced**

= *Ophiactis sexradia* Grube, 1857, described from Hawai‘i, synonymy *fide* Clark, 1949

This widespread ophiuroid is native to the Indo Pacific; its modern-day distribution has been strongly influenced by dispersal in ship fouling, and we suggest here that it was an early ship-borne introduction to the Islands. It was described as a new species, *Ophiactis sexradia,* from Honolulu by Grube (1857), a record repeated by a number of early authors thereafter (Clark, 1949). Grube attributed the specimens to “Dr. Ed. Lenz.” Lenz sailed in the Pacific aboard the Russian skiff *Achta* in 1847–1849 (Lenz, 1863; von Goguslawski, 1884), but we have not yet determined which year he was in the Islands. Clark (1915) reported it specifically from Pearl Harbor but without further data.

Earliest records for Hawai‘i in Bishop Museum collections are from 1924 (Kāne‘ohe Bay) and 1929 (Pearl Harbor); the species still occurs in both locations (Coles *et al.*, 1997, 2002a), and in all of Oahu’s commercial harbors and public marinas (Coles *et al.*, 1999b). Ely (1942) noted that it was “common in Kaneohe Bay and Pearl Harbor, habitually concealed in the canals of sponges, or even in tangled masses of sea weed or crevices in dead coral blocks. it is a gregarious species, and many individuals may be found within a piece of sponge the size of a man’s hand.” MacKay (1945) noted the number as “50 to 75 in a piece of sponge the size of a man’s fist.”

Edmondson (1933) noted that it was “very common” and that “Large numbers of specimens have been taken among the sponges common on piling and buoys in Kaneohe Bay and Pearl Harbor.” Clark (1949) noted that the *Albatross* collected it in 1902 in Pearl Harbor (O‘ahu), Puakō Bay (Hawai‘i), as well as at two deeper water stations between Maui and Lāna‘i, in ‘Au‘au Channel, in 51–79 m (this latter material bears re-examination, relative to the possibility of being a similar-looking but cryptic species). Coles *et al.* (2006) report it from reefs at Kaua‘i and Moloka‘i, and from har areas at Nawiliwili, Kaua‘i, Kaunakakai Main Dock, Moloka‘i, and Hilo Harbor, based upon 2002–2003 collections.

Rowe & Gates (1995) noted it was a tropical circumglobal species occurring from 0 to 550 m. Based upon genetic analyses Roy & Sponer (2002) concluded that this ophiuroid had been introduced to the Atlantic Ocean by shipping. Unpublished nested clade analyses further suggest that human-mediated dispersal is much more likely to have carried this species to distant outlier sites, such as South Africa, Panama, and the Hawaiian Islands (M. Roy, pers. comm., August 2008). Given the genetic evidence combined with its fouling habitat we treat *Ophiactis savignyi* as introduced.

Ophiactis modesta Brock, 1888 **Cryptogenic**

In reporting this brittle star for the first time from Hawai‘i, Ely (1942) made the following interesting statement: “*O. modesta* has previously been taken at Misaki, Japan, Amboina, Thursday Island, and along the Australian coast from Darwin to Lagrange Bay. It is now recorded for the first time from Hawai‘i. H.L. Clark (personal letter) believes that, as both members of this genus are carried about on boat bottoms, their arrival here may have been fairly recent. It is quite difficult to say how recently this species may have arrived in Hawaii.” Ely noted that this species and *O. savignyi* were

collected in almost identical situations (see above, at *O. savignyi*) in shallow water in Pearl Harbor and Kāne'ohe Bay. The only Bishop Museum material is from 1938 collected in Pearl Harbor. Coles *et al.* (2002a) list it for Kāne'ohe Bay, but Coles *et al.* (1997) do not report it further for Pearl Harbor.

Austin H. Clark (1949) then reported on the presence of *O. modesta* in the islands as a deeper water species, noting a modest number of specimens collected by the *Albatross* in 1902 from off Moloka'i in 146–406 m, from between Maui and Lāna'i in 51–79 m, from between Hawai'i and Maui in 90–322 m, and from off Maui in 82–95 m and in 104–124 m. Rowe & Gates (1995) report *O. modesta* from Australia with a depth range of 0–22 m and note a broad distribution in the tropical west Pacific Ocean, including West India and Pakistan. Price & Rowe (1996) add Sri Lanka to the known locations. Clark's (1949) deeper water Hawaiian material could possibly bear re-examination relative to their assignment to *O. modesta*, given the shallow-water records that otherwise characterize this species in Pearl Harbor and Kāne'ohe Bay, and in Australia as well.

CHORDATA

Introduced and Cryptogenic Tunicata (Ascidiacea)

Species	Date	Vector	Native to
Introduced Species			
Didemnum candidum	1930	SF	Northeast Atlantic
Didemnum perlucidum	1999	SF	Unknown
Didemnum psammathodes	1998	SF	Indo-West Pacific
Diplosoma listerianum	1900	SF	Unknown
Lissoclinum fragile	1962	SF	Unknown
Ciona intestinalis	1933	SF	North Atlantic
Ecteinascidia imperfecta	1979	SF	Western Pacific
Corella minuta	<1997	SF	Unknown
Phallusia nigra	1930s	SF	Red Sea-Indian Ocean
Ascidia archaia	1940	SF	Indo-West Pacific
Ascidia sydneiensis	1930s	SF	southern hemisphere
Ascidia species A	<1997	SF	Unknown
Ascidia species B	<1997	SF	Unknown
Styela canopus	1940	SF	Western Pacific
Eusynstyela hartmeyeri	1998	SF	Red Sea-Indian Ocean
Cnemidocarpa irene	1940	SF	Indo-West Pacific
Botrylloides simodensis	1998	SF	Western/South Pacific
Botryllus sp. or spp.	1973	SF	Unknown
Botrylloides sp. or spp.	1973	SF	Unknown
Polyandrocarpa sagamiensis	<1997	SF	Western/South Pacific
Polyandrocarpa zooritensis	<1997	SF	Unknown
Symplegma reptans	1996	SF	Japan
Symplegma brakenhielmi	1967	SF	Indo-Pacific
Symplegma sp.	1998	SF	Unknown
Polyclinum constellatum	1873	SF	Unknown
Microcosmus exasperatus	1940	SF	Unknown
Herdmania mauritiana	1985	SF	Indo-Pacific
Herdmania momus	1930s	SF	Indo-Pacific
Herdmania pallida	1990	SF	Indo-Pacific
Cryptogenic Species			
Polycarpa aurita	<1997	SF	

Tunicata (Urochordata): **Ascidiacea** (sea squirts)
Didemnidae

Didemnum candidum Savigny,1816 **Introduced**

This seasquirt, possibly of Eastern North Atlantic origin, was first found in the Hawaiian islands on Pearl and Hermes Reef, based upon collections by Paul S. Galtsoff in 1930 (Tokioka, 1967). Eldredge (1967) recorded it from Kāneʻohe Bay, Ala Wai Yacht Harbor, and Pearl Harbor, based upon 1961–1963 collections. It was also collected off Barbers Point in 1962 at 40 m (Eldredge, 1967). Additional records include further reports from Pearl Harbor (Long, 1974; 1968–1972 collections; Hurlbut, 1990, 1991a, 1991b), Kāneʻohe Bay (Straughan, 1969b; 1967–1968 collections; Fitzhardinge & Bailey-Brock, 1989; 1985 collections, colonizing artificial substrates in abundance), and Honolulu Harbor, Keʻehi Lagoon, Ala Wai Harbor, and Keʻehi Basin (Coles *et al.*, 1999b, 1997–1998 collections), 1999–2000 collections in Kāneʻohe Bay (Coles *et al.* 2002a), and 2001 collections off Waikīkī (Coles *et al.*, 2002b). Bailey-Brock (1989) recorded it on PVC settlement plates on an artificial reef in open waters at 20 m, 2.4 km off the southeast coast of Oʻahu. Coles *et al.* (2006) report it from Kauaʻi and Molokaʻi and Maui,based upon 2003 collections, and from 2005 collections on Lānaʻi (Coles *et al.*, 2005). Hurlbut (1990, 1991a, 1991b) studied the larval abundance, settlement, and juvenile mortality of this species in Pearl Harbor.

Didemnum perlucidum Monniot, 1983 **Introduced**

Godwin & Lambert (2000) report this species from Keʻehi Lagoon on Oʻahu based upon collections from floating docks in 1999. This is a now widespread species. Although described from the Caribbean, "the origin is ... unknown. It is a fouling species that (has) colonized many harbors in the Atlantic (Brazil, West Indies, Senegal) as well as the Indian Ocean (Maldive Islands, Zanzibar) and the Pacific (New Caledonia, Polynesia) and now Indonesia" (Monniot & Monniot, 1996). It also occurs in the Gulf of Mexico on the Texas coast (Godwin & Lambert, 2000).

It was found in 1999–2000 in Kāneʻohe Bay (Coles *et al.*, 2002a) and in 2001 at Kuapā Pond-Maunalua Bay (Coles *et al.*, 2002b). It likely occurs in other Oʻahu harbors, including Pearl Harbor but was probably mixed with *D. candidum* in earlier studies (S. Godwin, pers. comm., 2000).

Didemnum psammathodes (Sluiter, 1895) **Introduced**

Didemnum psammathodes was found in Keʻehi Lagoon in 1998 (G. and C. Lambert) and at Waikīkī in 2001 and in 2002 at Kuapā Pond-Maunalua Bay (Coles *et al.*, 2002b). It occurs throughout the Indo-West Pacific, from the Caribbean to Brazil (Kott, 1998; Monniot *et al.* 2001), and in Sierra Leone (Monniot & Monniot, 1994), to which Atlantic locations it is likely introduced. Lambert (2003) recorded it from Guam, as cryptogenic.

Diplosoma listerianum (Milne-Edwards, 1841) **Introduced**

= *Diplosoma macdonaldi* Herdman, 1886

Another common compound ascidian of Oʻahu fouling communities and now too widespread to yet determine its original home (although Monniot *et al.* 2001, refer to this as a "European species"). Eldredge (1967) provided the following records, here arranged chronologically:

1900	Honolulu	L. Miller
1902	Honolulu, from tug boat	*Albatross* expedition
1940	Pearl Harbor, hull of *USS Dobin*	D. P.Abbott
1941	Honolulu Harbor	D. P. Abbott and C. B. Mills
1942	Oʻahu: Queens Beach	D. P. Abbott
1946	Oʻahu: Halona Blowhole	D. P. Abbott
1961	Pearl Harbor	L. Eldredge
1961–1962	Kāneʻohe Bay	L. Eldredge

Eldredge (1967) also reported specimens from Midway Point, Midway, collected in 1963.

Various workers have continued to report it from Kāne‘ohe Bay (Rastetter & Cooke, 1979; Grovhoug & Rastetter, 1980; Coles *et al.*, 2002a) and Pearl Harbor (Grovhoug, 1979; Grovhoug & Rastetter, 1980), in Oahu's commercial harbors and public marinas (Coles *et al.*, 1999b), off Waikīkī (Coles *et al.* 2002b), and in Kahului Harbor, Maui (Coles *et al.*, 2004). Bailey-Brock (1989) recorded it (as *D. macdonaldi*) on PVC settlement plates on an artificial reef in open waters at 20 m, 2.4 km off the southeast coast of O‘ahu.

Hurlbut (1990, 1991a, 1991b) studied the larval abundance, settlement, and juvenile mortality of this species in Pearl Harbor.

Lissoclinum fragile (Van Name, 1902) **Introduced**

= *Diplosoma (Lissoclinum) fragile*

Eldredge (1967) reported this now-widespread species from Kāne‘ohe Bay on O‘ahu based upon material collected in 1962 and 1963. It occurs throughout the Western Pacific, South Pacific, and Indian Ocean; described from Bermuda, it is also known from throughout the Caribbean, Brazil, and Sierra Leone on the West African coast (Eldredge, 1997; Monniot & Monniot, 1994).

Cionidae

Ciona intestinalis (Linnaeus, 1767) **Introduced**

Edmondson (1933, Honolulu Harbor) and Abbott (1941, Pearl Harbor) are among the early reports of this species from Hawai‘i. It is widely considered to be native to the North Atlantic Ocean (Monniot *et al.*, 2001), having been ship-dispersed to many harbors around the world. Abbott *et al.* (1997) note that it is found on boat hulls and docks in Pearl Harbor, Honolulu Harbor, and Kāne‘ohe Bay. D.P. Abbott collected it in 1940 along with *Diplosoma listerianum*, *Styela canopus*, and *Ascidia sydneiensis* on the hull of the *USS Dobin* in Pearl Harbor (Bishop Museum collections, and identification reconfirmed by Abbott in November 1980).

Perophoridae

Ecteinascidia imperfecta Tokioka, 1950 **Introduced**

This ascidian was described from Palau Island in the Western Pacific Ocean and later recorded from the Great Barrier Reef (Kott, 1998). Abbott *et al.* (1997) report it growing on worm tubes, dead coral, bryozoans, algae, and solitary ascidians in Kāne‘ohe Bay, Pearl Harbor, and the Ala Moana Yacht Basin. Bishop Museum collections include specimens from Kāne‘ohe Bay collected in 1979.

Corellidae

Corella minuta Traustedt, 1882 **Introduced**

= *Corella japonica* of authors

Abbott *et al.* (1997) report this species from floating docks in Kāne‘ohe Bay. Coles *et al.* (2002a, 2000 collections) continue to report it from there; Coles *et al.* (1999b, 1997 collections) also report it from Honolulu Harbor and from Kahukui Harbor, Maui (Coles *et al.*, 2004). It occurs in the central and western Pacific, as well as in the Caribbean-Florida region (Abbott *et al.*, 1997), to which latter region it is likely also introduced.

Ascidiidae

Phallusia nigra Savigny, 1816 **Introduced**

This Red Sea-Indian Ocean species has been introduced to Micronesia (Guam; Lambert, 2002) and to Hawai‘i. Charles H. Edmondson photographed this species in the 1930s in Pearl Harbor (Bishop Museum Department of Invertebrate Zoology files, photographs identified by G. Lambert in August 2002). Long's (1974) report of *Ascidia melanostoma* may belong here (Abbott *et al.*, 1997, p. 36).

Abbott *et al.* (1997) report it from rocks and dead coral "on barely subtidal mudflats" in Kāne‘ohe Bay and on floats and pilings in Kāne‘ohe Bay, Pearl Harbor, and Ke‘ehi boat harbor. Coles *et al.* (1999b) also report it from 64 sites throughout the main Hawaiian Islands, including Pearl and Honolulu Harbors, Ke‘ehi Lagoon, Ala Wai Harbor, Barbers Point Harbor, and Kewalo

Basin, based upon 1997–1998 collections. Additional records include Kāneʻohe Bay (Coles *et al.*, 2002a), Waikīkī and Koko Marina (Coles *et al.*, 2002b), an Nawiliwili, Kahului and Hilo Harbors (Coles *et al.*, 2004). Hurlbut (1991c) reported on settlement and juvenile survival in Pearl Harbor.

Ascidia archaia Sluiter, 1890 **Introduced**

= *Ascidia corelloides* (Van Name, 1924)

Abbott (1941) reported this western Pacific and Indo-Pacific species (as *A. corelloides*) from the Honolulu Aquarium; 50 years later, he referred to this incident when he noted that "Some years ago, small, clear specimens of *Ascidia archaia* grew on the walls of aquaria in the old Honolulu Aquarium" (Abbott *et al.*, 1997). We take the earliest date to be 1940. Abbott *et al.* (1997) note that "recently" it was collected on solitary ascidians and oysters in the seawater run-off trenches of the Kewalo Marine Laboratory in Honolulu. They also suggest that it lives subtidally off Honolulu. Coles *et al.* (2002a) record it from Kāneʻohe Bay.

Ascidia sydneiensis Stimpson, 1855 **Introduced**

This southern hemisphere (Abbott *et al.*, 1997) species has been introduced to Micronesia (Guam; Lambert, 2002) and to Hawaiʻi. Charles H. Edmondson photographed this species in the 1930s in Pearl Harbor (Bishop Museum Department of Invertebrate Zoology files, photographs identified by G. Lambert in August 2002). It was recorded by Abbott (1941), probably based upon specimens he collected in Pearl Harbor in 1940 on the hull of the USS *Dobin* (Bishop Museum collections; specimens reconfirmed by D. P. Abbott in November 1980). Abbott *et al.* (1997) report it the "commonest large ascidian" of calm Oʻahu harbor waters, noting that it "exploits docks, floats, boat hulls, solid debris on mudflats, and other firm substrates" in Kāneʻohe Bay, Pearl Harbor, and Keʻehi Boat Harbor. Coles *et al.* (1999a) report it from Pearl Harbor, 1996 collections, and Coles *et al.* (1999b) report it from Honolulu Harbor, Keʻehi Lagoon, Ala Wai Harbor, Barbers Point Harbor, and Kewalo Basin, based upon 1997–1998 collections. It also occurs in Kāneʻohe Bay (2000 collections; Coles *et al.*, 2002a), Koko Marina (Coles *et al.*, 2002b), and Nawiliwili, Kaunakakai, and Hilo Harbors (Coles *et al.*, 2004).

Monniot *et al.* (1991) also emphasize the lower-energy habitat of this species, noting that it "flourishes not only on buoys in ports but also on broken shells in sheltered lagoon waters." In this regard, we note the report by Hoover (1998, page 342, 2006) of an ascidian identified as *Ascidia sydneiensis* from exposed, higher-energy rocky shores at about 10-m depth at Pūpūkea, Oʻahu, at a site "favored by scuba divers", where it is usually found "in crevices along vertical walls with only the siphons exposed." Hoover noted that the color of these animals in open water was yellow-green, as opposed to the silt-covered, darker animals of pilings and floats. Hoover also remarked that "specimens were dredged from 150–250 feet by the steamer *Albatross* in the early 1900s" [1902]. Although introduced ascidians do occur in Hawaiʻi in more exposed locations, both of these habitats are very unusual for *A. sydneiensis* and would require further investigation. We have not been able to locate the source of the statement that the *Albatross* collected this species in deep water, which could be in error (J. Hoover, pers. comm., February 2007).

Ascidia species A **Introduced**

Ascidia species B **Introduced**

Abbott *et al.* (1997) report two additional *Ascidia* species as "fairly common on floats and subtidal reefs in protected habitats" in Kāneʻohe Bay and Pearl Harbor. They suggest that *Ascidia* sp. B may be *Ascidia gemmata* Sluiter, 1895, a widespread tropical western Pacific species. Coles *et al.* (1999b) further report *Ascidia* sp. A from Honolulu Harbor, Keʻehi Lagoon, Ala Wai Harbor, and Kewalo Basin, and a reef site and Port Allen Harbor on Kauaʻi based on 2002 collections (Coles *et al.*, 2004, 2006). *Ascidia* sp. B is known from Pearl Harbor (Coles *et al.*, 1997, 1999a), Honolulu Harbor, Keʻehi Lagoon, Ala Wai Harbor (Coles *et al.*, 1999b), Kāneʻohe Bay (Coles *et al.*, 1999a), and Kahului Harbor (Coles *et al.*, 2004).

Ascidia sp. **Introduced**

Godwin & Lambert (2000) report a third unidentified, very long and yellow-green *Ascidia* sp., collected in 1998 in Kewalo Basin, not previously recorded from Hawai‘i. It was found attached to pieces of rug hanging in the water.

Styelidae

Styela canopus Savigny, 1816 **Introduced**

= *Styela partita* (Stimpson, 1852)

Donald P. Abbott collected this Western Pacific species on the hull of the USS *Dobin* in 1940 in Pearl Harbor (Bishop Museum collections; Abbott, 1941). Abbott (1941) noted it occurred on boat bottoms and wharf pilings in Pearl Harbor and Kāne‘ohe Bay. Coles *et al.* (1999b) report it from Honolulu Harbor, Ke‘ehi Lagoon, Ala Wai Harbor, Barbers Point Harbor and Kewalo Basin, based upon 1997–1998 collections. It remains in Kāne‘ohe Bay as well (Coles *et al.*, 2002a), and was found in 2003 in Kahului Harbor, Maui (Coles *et al.*, 2004). Earliest Bishop Museum material from the islands is from Pearl Harbor based upon collections made in 1929 by C.H. Edmondson.

Eusynstyela hartmeyeri Michaelsen, 1904 **Introduced**

= *Eusynstyela aliena* Monniot, 1991

Godwin & Lambert (2000) report this species (as *E. aliena*) from Pearl Harbor (1998), Honolulu Harbor (1998), and Ke‘ehi Lagoon (1998). Coles *et al.* (1999b) also report it from Honolulu Harbor, Ke‘ehi Lagoon, and Barbers Point Harbor, based upon 1997–1998 collections. Coles *et al.* (2002b) further report it in Kāne‘ohe Bay and Hawai‘i Kai. Coles *et al.* (2006) report it from Kaua‘i, based upon 2003 collections. It may have been overlooked in an earlier (Coles *et al.*, 1997) 1996 survey of Pearl Harbor (S. Godwin, pers. comm., 2000). Monniot & Monniot (2001) synonymized *E. aliena*, described from New Caledonia in the southwest Pacific Ocean, with the earlier *E. hartmeyeri* from the Red Sea and the Indian Ocean.

Cnemidocarpa irene (Hartmeyer, 1906) **Introduced**

= *Cnemidocarpa areolata* in Abbott *et al.*, 1997

Abbott *et al.* (1997) report this species from docks in Kāne‘ohe Bay, and noted it was “found occasionally on the walls of tanks in the old Honolulu Aquarium, presumably from settlement of larvae entering the aquarium’s seawater intake at Waikīkī.” We take the latter reference to be the same as the one for *Ascidia archaia*, and thus a species first observed by Abbott in 1940–1941. Coles *et al.* (1999b) report it from Honolulu Harbor, Ke‘ehi Lagoon, Barbers Point Harbor, and Kewalo Basin, based upon 1997–1998 collections. Coles *et al.* (2002a) report it from Kāne‘ohe Bay, and Coles *et al.* (2002a) report it form Waikīkī and Hawai‘i Kai, and Coles *et al.* (2004) report it from Nawiliwili and Kawaihae Harbors.

Botrylloides simodensis Saito & Watanabe, 1981 **Introduced**

Godwin & Lambert (2000) report this Western and South Pacific species from O‘ahu in November 1998; the location, not mentioned, is Pearl Harbor (S. Godwin, pers. comm., 2000). Coles *et al.* (1999b) also report it from Ala Wai Harbor and Kewalo Basin, based on 1998 specimens, and from 2001 collections at Waikīkī (Coles *et al.*, 2002b).

Botryllus sp. or spp. **Introduced**

Botrylloides sp. or spp. **Introduced**

At least two additional botryllids, one each in each of these two genera, are present in fouling communities in Pearl Harbor and Kāne‘ohe Bay (Straughan, 1969b; Grovhoug, 1979; Grovhoug & Rastetter, 1980) with collections dating from 1973 (Coles *et al.*, 1997). These species remain unresolved taxonomically (Abbott *et al.*, 1997).

Polyandrocarpa sagamiensis Tokioka, 1953 **Introduced**

Abbott *et al.* (1997) report this ascidian from Kāneʻohe Bay and Pearl Harbor on floating docks. It occurs in the western Pacific and the south Pacific. It has also been found in 1999–2000 collections in Kāneʻohe Bay (Coles *et al.*, 2002a) and Hawaiʻi Kai (Coles *et al.*, 2002b; 2001 collections). Coles *et al.* (1999b) report it from Honolulu Harbor, Keʻehi Lagoon, Barbers Point Harbor, and Kewalo Basin, based upon 1997–1998 collections, and from 2002–2003 collections in Nawiliwili and Kawaihae Harbors (Coles *et al.*, 2004).

Polyandrocarpa zorritensis (Van Name, 1931) **Introduced**

Abbott *et al.* (1997) report this ascidian from Kāneʻohe Bay, Pearl Harbor, and Kewalo Bay in fouling communities. It occurs also in Peru, southern California, and the Mediterranean (Abbott *et al.*, 1997). Coles *et al.* (1999b) report it from Keʻehi Lagoon based on 1997 collections and from 1999 collections in Kāneʻohe Bay (Coles *et al.*, 2002a).

Polycarpa aurita (Sluiter, 1890) **Cryptogenic**

This very widespread western Atlantic and Indo-Pacific species is reported from floats in Kāneʻohe Bay, subtidally in the Honolulu Harbor channel, in the seawater system of the Kewalo Marine Laboratory in Honolulu, under rocks in tidepools at Halona, Oʻahu, and on the island of Hawaiʻi under "nearshore rocks" at Napoʻopoʻo in Honaunau Bay (Abbott *et al.*, 1997). Coles *et al.* (1999b) report it from Honolulu Harbor, Keʻehi Lagoon, Barbers Point Harbor and Kewalo Basin, based upon 1997–1998 collections. Coles *et al.* (2002a) report it from Kāneʻohe Bay, and Coles *et al.* (2000b) further report if from Waikīkī and Hawaiʻi Kai. Lambert (2002) considers it cryptogenic in Guam.

Symplegma reptans (Oka, 1927) **Introduced**

This seasquirt, previously known from Japan and Australia (Kott, 1998) was reported by Coles *et al.* (1999a, 1999b) from Pearl Harbor based on 1996 collections. We suspect it was introduced from Japan, given its much wider distribution there (Kott, 1985).

Symplegma brakenhielmi (Michaelsen, 1904) **Introduced**

= *Symplegma oceania* Tokioka, 1961

= *Symplegma connectans* of authors

The first record of this Indo-Pacific species appears to be that of Straughan (1969b), based upon specimens collected in Kāneʻohe Bay in 1967. Abbott *et al.* (1997) report it for Kāneʻohe Bay, Pearl Harbor, and Honolulu Harbor in fouling communities. Grovhoug (1979; 1978 collections) and Grovhoug & Rastetter (1980), both as *S. connectans*, report it for Pearl Harbor and Kāneʻohe Bay as well. Coles *et al.* (1997, 1999a) also report it from 1996 collections in Pearl Harbor, and it was also found in 1997–1998 collections in Honolulu Harbor, Keʻehi lagoon, Kewalo Basin, and Ala Wai Yacht Harbor (Coles *et al.*, 1999b), 2001 collections off Waikīkī (Coles *et al.*, 2002b) and 2003 collections in Kawaihae Harbor (Coles *et al.*, 2004).

Symplegma sp. **Introduced**

A third *Symplegma* species, as yet not identified, was collected in Pearl Harbor (1998 collections) (G. Lambert & S. Godwin, pers. comm., 2000).

Polyclinidae

Polyclinum constellatum Savigny, 1816 **Introduced**

= (?) *Polyclinum vasculosum* of Tokioka, 1967, Pearl Harbor records *vide* Abbott *et al.*, 1997

This tropical and subtropical cosmopolitan species has long been present in Hawaiʻi. Charles H. Edmondson photographed this species in the 1930s in Pearl Harbor (Bishop Museum Department of Invertebrate Zoology files, photographs identified by Gretchen Lambert in August 2002). Bishop Museum material dates from 1960 in Kāneʻohe Bay. Abbott *et al.* (1997) note that it "sometimes

abundant” in Kāne‘ohe Bay, Pearl Harbor, Honolulu Harbor, and Ala Moana yacht harbor, “growing on dock pilings, floats, dead corals, or coral rubble lying on sandflats.” They also note populations in “more exposed places, such as Honolulu’s Black Point,” where small colonies grow under rocks.

Abbott *et al.* (1997) imply that Tokioka’s (1967) identification of *Polyclinum vasculosum* from Pearl Harbor are likely *P. constellatum*, and we tentatively so treat those reports here. *Polyclinum vasculosum* Pizon, 1908, is known from the tropical western Pacific. Regardless of whether the specimen are *P. constellatum* or *P. vasculosum*, they represent some of the earliest introduced ascidians collected in Hawai‘i. Tokioka notes material collected in Pearl Harbor by P. Bartsch in September 1920 in USNM collections, as well as “three large colonies”, the largest measuring 14.5 cm by 11.0 cm, collected on O‘ahu by T.H. Streets, but without noting a date. As discussed under the crab *Carcinus maenas*, we know that Streets collected on O‘ahu only once, in 1873–1874.

Coles *et al.* (1997, 1999a) report *P. constellatum* from Pearl Harbor; Coles *et al.* (1999b) report it from Honolulu Harbor (1997) and Ala Wai Harbor (1998); from 1999–2000 collections in Kāne‘ohe Bay (Coles *et al.*, 2002a), and from 2001 collections off Waikīkī (Coles *et al.*, 2002b).

Pyuridae

Microcosmus exasperatus Heller, 1878 **Introduced**

Abbott (1941, as *Microcosmus claudicans exasperatus*) reported this now-cosmopolitan species as one of the most common ascidians with collections from Honolulu Harbor, Kāne‘ohe Bay, and Pearl Harbor. We take the earliest date to be 1940. Abbott *et al.* (1997) note that this species occurs in the seawater runoff trenches in Honolulu of the Kewalo Marine Laboratory and that it is common on floats and docks in Kāne‘ohe Bay. Coles *et al.* (1997, 1999a) report it from Pearl Harbor, and Coles *et al.* (1999b) report it from Honolulu Harbor, Ke‘ehi Lagoon, Ala Wai Harbor, Barbers Point Harbor and Kewalo Basin, based upon 1997–1998 collections. Abbott *et al.* (1997) also note the description of *Microcosmus miniaceus* Sluiter, 1900, from Pearl Harbor and its failure to be recorded again. Sluiter’s original material requires re-examination to determine if these represent early records of *M. exasperatus*.

Mastrototaro & Dappiano (2005) report *M. squamiger* from Hawai‘i, misciting Godwin (2003b) as Godwin (2003a). Godwin (2003b) reported *M. squamiger* in fouling on vessels arriving from California in the Hawaiian Islands.

Herdmania mauritiana (von Drasche, 1884) **Introduced**

= *Herdmania insolita* Monniot & Monniot, 2001 *vide* Nishikawa (2002)

This species was found on floats in Ke‘ehi lagoon in July 1985 by G. Lambert. Lambert (2003) treated this species (as *H. insolita*) as cryptogenic in Hawai‘i. *Herdmania insolita* is broadly distributed across the Indo-Pacific (Kott, 2002).

Herdmania momus (Savigny, 1816) **Introduced**

Charles H. Edmondson photographed this Indo-Pacific (Kott, 2002) species in the 1930s in Pearl Harbor (Bishop Museum Department of Invertebrate Zoology files, photographs identified by G. Lambert in August 2002). Abbott *et al.* (1997) record it from the Honolulu Harbor channel and in Kāne‘ohe Bay and Ke‘ehi Lagoon on mudflat debris and in fouling communities. Long (1974) also reported it from fouling panels set just offshore of O‘ahu. Coles *et al.* (1999b) report it from Ke‘ehi Lagoon, Ala Wai Harbor, Barbers Point Harbor, and Kewalo Basin, based upon 1997–1998 collections, and note records since 1991 for Honolulu Harbor. It also occurs in Waikīkī and Hawai‘i Kai (Coles *et al.*, 2002b). Earliest Bishop Museum material for Kāne‘ohe Bay is 1963.

Herdmania pallida (Savigny, 1816)

The Indo-Pacific *Herdmania pallida* (Kott, 2002) was found in 1990, growing alongside *Herdmania momus*, on floats in Ke‘ehi Boat Harbor, O‘ahu, by G. and C. Lambert (Abbott *et al.*, 1997, page 54; this is the species listed as *Herdmania* sp., *vide* G. Lambert, pers. comm., December 2006). It has also been collected in Pearl Harbor in 1998. Coles *et al.* (2002a) report it from Kāne‘ohe Bay (1999–2000), and from 2002–2003 collections from reefs and harbors on Kaua‘i, Moloka‘i, Maui, and Hawai‘i (Coles *et al.*, 2004, 2006).

PISCES

Introduced Fish

Species	Date	Vector	Native to
Herklotsichthys quadrimaculatus	1972	R	West Pacific: Marshall Is
Sardinella marquesensis	1955	R	South Pacific: Marquesas
Valamugil engeli	1955	R	South Pacific: Marquesas
Poecilia latipinna	1905	R	Texas
Poecilia salvatoris x *P. mexicana* -group: hybrid complex	>1960	R	North America
Limia vittata	1950	R	Cuba
Gambusia affinis	1905	R	Eastern North America
Cephalopholis argus	1956	R	S Pacific: Society Islands
Lutjanus fulvus	1956	R	S Pacific: Society Islands
Lutjanus gibbus	1958	R	S Pacific: Marquesas/ Moorea
Lutjanus kasmira	1958	R	South Pacific: Marquesas
Upeneus vittatus	1955	R	South Pacific: Marquesas
Oreochromis mossambicus	1951	R	Singapore
Sarotherodon melanotheron	1962	R	West Africa
Parablennius thysanius	1971	SF, BW	Indo-Pacific
Omobranchus ferox	1998	SF, BW	Philippines, S China Sea
Omobranchus rotundiceps obliquus	1951	R	Indo-Pacific (Samoa)
Mugilogobius cavifrons	1987	SF, BW	Indo-Pacific
Additional Taxa Treated and Their Status			
Abudefduf vaigiensis Status: *Waif with drift nets?*	1991	drift nets; R?	Indo-Pacific
Centropyge flavissima Status: *Establishment unknown*	1990	R	Indo-Pacific
Chrysiptera taupou Status: *Establishment unknown*	2002	R	Southwest Pacific
Favonigobius sp. Status: *Establishment unknown*	1990	BW	Australasian?
Ten species of anchovies, bass, groupers, snappers, emperors, and flagtails (see table, below) Status: *Released not established*			

Valuable summaries or reviews of the introduced fish of the islands are those of Randall (1960, 1981, 1987, 1996), Randall & Kanayama (1972, 1973), Oda & Parrish (1982), Maciolek (1984), Eldredge (1987), Randall *et al.* (1993), and Mundy (2005, p. 83, Tables 7 and 20, and individual species treatments). Friedlander *et al.* (2006) provide data on habitat patterns in marine protected areas of several introduced species. Additional papers (treated below) cover recent invasions of some ballast water introductions.

Fisheries Releases

In what would now be environmentally and politically impossible, in the 1950s and early 1960s the United States Bureau of Commercial Fisheries (now the NOAA National Marine Fisheries Service), in cooperation with the then-named State of Hawaii Division of Fish and Game, undertook an extensive program to introduce, largely from the South Pacific, both game fish and bait fish into the Islands. No fewer than 11 species of snappers and groupers—classic Indo-Pacific members of which were absent from the Hawaiian fauna—were released into open waters of the state between 1955 and 1961 (Oda & Parrish, 1982; Eldredge, 1987; Randall, 1987; see also Brock, 1962). Upon arrival in Honolulu in September 1956, one group of fish was treated for five days, while still in the livewell, with copper sulphate, to remove external parasites (Randall & Kanayama, 1972, 1973). This "1950s epoch" was preceded by earlier attempts in the 1920s and 1930s to introduced anchovy and striped bass from California (see table, below).

Randall & Stender (2002) commented upon one release as an example of the difficulties in predicting when a species will become established. They noted that 469 dwarf spotted groupers (*Epinephelus merra*) from Moorea in the Society Islands were released into Kāne‘ohe Bay and 132 off Wainiha, Kaua‘i (see table below), “a proper choice in terms of habitat because the species occurs primarily in lagoons [and] the introduced adults lived out their lives, but no young ever appeared.” Temperature, they noted, did not appear to be a factor. “Therefore, some unknown factor or factors other than temperature prevented their becoming established in Hawaiian waters (which was fortunate because the species was not a good choice for introduction due to its small size).” We note that it was also fortunate because of the unknown ecological impacts an introduction may have had.

Hourigan & Reese (1987) noted that of the above 11 species, only four were introduced in numbers exceeding 2000 individuals—and three of these became established. Planes & Lecaillon (1998) reviewed the population genetics of the three successful species, finding that no significant change in genetic diversity had occurred, although some gene selection had occurred in the bluestripe snapper (*ta‘ape*) *Lutjanus kasmira*.

Also in the 1950s, a program to introduce the Marquesan sardine for tuna bait was undertaken; remarkably, two additional, untargeted fish were released at the same time, resulting in a total of three more fish introductions. As late as the 1970s, intentional albeit unsanctioned releases occurred: a vessel chartered by the National Marine Fisheries Service loaded goldspot herring in the Marshall Islands to use as tuna bait on the voyage back to Hawai‘i—and subsequently released these fish into Kewalo Basin, O‘ahu!

Impact considerations of these intentional releases were voiced: Murphy (1960), in discussing the introduction of the Marquesan sardine, wrote that “Ordinarily, such an expensive project as transferring a marine fish from 10° south of the Equator to 20° north of the Equator would not be undertaken without an extensive investigation of the fish’s life history ... to weigh thoroughly the possibility that the species might do harm in the new area.” However, he then simply noted that “The possibility of harm seemed remote.” Relative to the large groupers and snappers, Randall & Kanayama (1972) remarked that the species with which these introduced fish would compete, or the prey they would eat, were of little commercial or economic importance; today, the potential for such introductions to compete with or prey upon noncommercial species would focus on the unknown ecological cascades that could result from such introductions. Randall & Kanayama (1972, 1973) concluded both essays with a strong caveat about the risk of introducing organisms into the ocean given the improbability of their removal if they were to succeed.

The table below lists the species of fish which were intentionally released during the above periods of operation but did not become established.

Fisheries Releases: **Species Not Established in Hawaiian Waters**
(from Brock, 1960; Maciolek, 1984; Randall, 1987; Mundy, 2005)

Species	Date	Introduced from
Engraulidae (anchovies)		
Anchoa compressa	1932	California
Moronidae (bass)		
Morone saxatilis	1922	California
Serranidae (groupers)		
Cephalopholis urodeta	1958, 1961	Marquesas
Epinephelus fasciatus	1958, 1961	Marquesas
Epinephelus hexagonatus	1958, 1961	Marquesas
Epinephelus irroratus	1958	Marquesas
Epinephelus merra	1956, 1961	Society Islands
Lutjanidae (snappers)		
Lutjanus guttatus	1960	Mexico
Lethrinidae (emperors)		
Lethrinus sp.	1958	Marquesas Islands
Kuhliidae (flagtails)		
Kuhlia rupestris	1957–1958	Guam

Aquarium Releases

With the post-World War II increased interest in and capability of moving aquarium hobby fish around the world, an increasing number of such species have been released by the public or industry into open waters, resulting in either established populations or—in regions where large numbers of knowledgeable observers are in the water, as in the Hawaiian Islands—the discovery of either cast-out pets or (as suspected in some cases) the intentional release of such fish. In subtropical or tropical regions, distinguishing aquarium releases from waifs (potential colonists carried far afield by ocean currents) may be a challenge: here, evidence such as distance from a possible source, the number of individuals found, their presence over widespread locations over a number of years, and so forth, may be mustered as evidence to attempt to distinguish between these two categories.

We have not attempted to list here all such discarded or released aquarium animals; the table below represents examples only. It is to be expected that there will be a continual record of open-water discoveries of exotic species in the islands, based upon such illegal releases. Mundy (2005), in discussing the occasional appearances of anemonefish (clownfish) in the islands, remarked that, "In at least one such case, an aquarium-fish wholesaler has been reported to have purposefully released *Amphirion* into [Kāneʻohe] Bay with the intent of establishing a breeding population that could then be 'ranched' for sale."

Aquarium Releases: **Discarded or Released Animals Found in Open Water in the Hawaiian Islands (Not Known to be Established)**
(Randall, 1981; Mundy, 2005)

Species	Date	Remarks
Serranidae		
Cromileptes altivelis	1977–1978	Hawaiʻi Island, Maui, 1980s; Oʻahu early 1990s
Lutjanidae		
Lutjanus sebae	2002	One individual, Oʻahu
Pomacanthidae		
Apolemichthys xanthopunctatus	1980s?	Oʻahu, several individuals: purposely released by an aquarium fish importer
Chaetodontoplus mesoleucus	1994	One individual, Oʻahu
Pomacanthus semicirculatus	2001	One individual, Oʻahu
Pygoplites diacanthus	1997	One individual, Oʻahu
Pomacentridae		
Amphiprion sp. (see text)	1980s–1990s	Kāne'ohe Bay, Oʻahu
Ephippidae		
Platax tiera	2003	One individual, Maui
Acanthuridae		
Acanthurus leucosternon	2003	One individual, Oʻahu
Paracanthurus hepatus	1994–1996	Oʻahu, Maui; possibly waifs?

Fouling Intercepts

Mundy (2005, Table 7, page 23) listed *Pseudochromus ?tapeinosoma*, *Cirrhitichthys falco, Cirrhitichthys oxycephalus, Enneapterygius bahasa/nigricauda*, and *Ecsenius bicolor* as "non-indigenous fish species that were (or likely were) released into open waters" in Hawaiʻi "but that failed to establish reproducing populations." These five species were collected from a USN concrete barge, the *YON-146*, which came into Pearl Harbor from Guam in 1950.

Clupeidae

Herklotsichthys quadrimaculatus (Ruppell, 1837) **Introduced**

The goldspot sardine (also known as the goldspot herring) was introduced in 1972 when the contents of the livewell aboard the tuna fishing vessel *Anela* was released into Kewalo Basin, O‘ahu (Randall, 1987). The fish had been taken up as potential tuna bait in the lagoon of Jaluit in the Marshall Islands; the vessel had been chartered for exploratory fishing by the National Marine Fisheries Service. Baldwin (1984) and Williams & Clarke (1983) provide documentation on the introduction. It is now an abundant fish in the islands. Greenfield (2003) noted it from Kāne‘ohe Bay based upon 1990–1995 collections. Mundy (2005) gives the Hawaiian distribution as Lāna‘i to O‘ahu at 1–13 m.

Sardinella marquesensis Berry & Whitehead, 1968 **Introduced**

= *Harengula vittata* of authors

The Marquesan sardine was intentionally released into Hawaiian waters from the Marquesas between 1955 and 1959 to establish a tuna bait fishery (Brock, 1960; Randall, 1987, 1996). A total of 143,800 fish were released around O‘ahu in five years; it is believed to have become established by 1958 (Brock, 1960). Murphy (1960) and Hida & Morris (1963) provide details of the introduction and early establishment. Murphy (1960) noted that wide publicity attended the releases, including a special poster that was distributed to fishermen. It remains present but not abundant in the islands. Mundy (2005) gives the Hawaiian distribution as Maui to Kaua‘i, in shallow water.

Mugilidae

Valamugil engeli (Bleeker, 1858) **Introduced**

= *Moolgarda engeli, = Chelon engeli*

The kanda, a mullet, is another species released in 1955 with the first shipment of Marquesan sardines, although not detected in Hawai‘i until 1966 (Randall, 1987). Randall (1981) noted that this mullet was of “little or no commercial value (but) seems to have increased in abundance at the expense of the commercially important mullet *Mugil cephalus*.” Maciolek & Timbol (1981) reported it from the Kahana Estuary, O‘ahu, based on collections made from 1969 to 1971. Mundy (2005) notes that it has spread throughout the main islands in estuaries.

Poecilidae

Poecilia latipinna (LeSueur, 1821) **Introduced**

= *Mollienesia latipinna* in Brock, 1960

The sailfin molly, or tabai, was introduced into Moanalua Stream, O‘ahu, in 1905 for mosquito control purposes, from Texas (Randall, 1987; Yamamoto & Tagawa, 2000). It is established in brackish water areas of O‘ahu and Moloka‘i (Brock, 1960; Randall, 1987), Maui (Randall, 1987), and Hawai‘i and Kaua‘i (Mundy, 2005).

Yamamoto & Tagawa (2000) note that, “Old-timers will probably remember the large numbers of sailfin mollies established in the brackish water canals and lagoons of Ala Moana Beach Park, O‘ahu, during the sixties and seventies. This species disappeared from this waterway by the late seventies, to be replaced by the Liberty Molly and the Cuban Molly” (two introduced freshwater fish). Coles *et al.* (1999a) record it from Pearl Harbor. Englund *et al.* (2000a) report it as locally common in 1 to 9 ‰ in Pouhala Marsh in Pearl Harbor.

Poecilia salvatoris Regan, 1907 x ***Poecilia mexicana*** Steindachner, 1863-group: **hybrid complex** **Introduced**

The shortfin molly was introduced sometime after 1960 [Maciolek (1984), who suggests this based on the absence of its treatment by Brock in his 1960 paper; Randall (1987) cites Maciolek as the basis for this introduction occurring “sometime before 1950”, but this information does not appear in Maciolek’s paper.] Based upon Randall’s statement (which seems to be in error) and earlier surveys, Englund (2002) indicated the introduction took place between 1940 and 1950. We use “after

1960", following Maciolek. The shortfin molly is native to North America and is a probable aquarium release. Yamamoto & Tagawa (2000) note that the populations now on Oʻahu appear to represent a hybrid of "two or more species from the *P. salvatoris/mexicana* complex"; we retain the above name here for purposes of convenience. Englund & Baumgartner (2000) report *Poecilia mexicana* in 35–36 ‰ in Hālawa Stream, Pearl Harbor, co-occurring with the introduced blenny *Omobranchus ferox*. As both the *salvatoris*-clade and the *mexicana*-clade are largely rooted on the Atlantic coasts of North and Central America, we treat this introduction biogeographically as Atlantic in origin.

Englund *et al.* (2000a) note that this species "was one of the most common fish found in lower stream and estuarine areas of Pearl Harbor" in salinities up to 36 ‰.

Limia vittata (Guichenot, 1853) **Introduced**

= *Poecilia vittata* of Hawaiian literature

The Cuban molly (or Cuban limia, Cuban topminnow, or tabai) was present on Oʻahu by 1950 according to Randall (1987). Brock (1960) noted that it "is found in the streams flowing through Honolulu which include Moanalua, Kapalama Canal, Nuuanu, and Manoa streams. It is found in the lower portions of the streams and in salt water." Englund *et al.* (2000a) found it to be relatively uncommon in Pearl Harbor estuarine streams. It is another probable aquarium release.

Gambusia affinis (Baird & Girard, 1853) **Introduced**

The well-known eastern North American mosquitofish was released intentionally for mosquito control at Moanalua, Oʻahu, in 1905; the specimens originated from Texas (Brock, 1960). Today it is common in brackish water habitats (Yamamoto & Tagawa, 2000). Englund *et al.* (2000a) found it to be in "extremely high densities in the lower reaches of Oʻahu streams and always in the presence of *Poecilia mexicana*"; they occurred in salinities of up to 40 ‰. Mundy (2005) gives its distribution as Hawaiʻi, Maui, Molokaʻi, Oʻahu, and Kauaʻi, "in all low current, freshwater habitats and in brackish-water lagoons and channels."

Serranidae

Cephalopholis argus Bloch & Schneider, 1801 **Introduced**

= *Cephalopholis guttatus* of authors

In 1956 bluespotted grouper (or *roi*, its Tahitian name; also known as the peacock grouper or peacock rockcod) was intentionally released from the livewell of the vessel *Hugh M. Smith* that had transported the fish from Moorea in the Society Islands. The fish were released off Brown's Camp, Oʻahu (571 individuals) and off Keāhole Point, Hawaiʻi (400); establishment was thought to have occurred by 1958 (Randall, 1987). It is most common on the island of Hawaiʻi (Randall, 1987, 1996); it has not become abundant anywhere (Planes & Lecaillon, 1998). Coles *et al.* (2002a) report it from Kāneʻohe Bay; further records are from off Waikīkī (Coles *et al*. 2002b), Hanauma Bay and various neighbor island locations on Kauaʻi, Molokaʻi,Maui, Hawaiʻi (Coles *et al.* 2004) and Lānaʻi (Coles *et al.* 2005). Mundy (2005) reports its Hawaiian range as Hawaiʻi Island to French Frigate in 6–12 m. It naturally occurs from the East Africa to French Polynesia (Planes & Lecaillon, 1998).

Lutjanidae

Lutjanus fulvus (Forster *in* Bloch & Schneider, 1801) **Introduced**

The blacktail snapper (or *toau*, its Tahitian name) was intentionally released from the same vessel as the bluespotted grouper; 239 fish from the Society Islands were released into Kāneʻohe Bay from Moorea in 1956 (Randall, 1987; Planes & Lecaillon, 1998). In 1958 "additional fish", from the Marquesas, were released into Kāneʻohe Bay (Randall, 1987). It is established on Oʻahu and all other islands in the Archipelago (Randall, 1987). Hoover (1993) noted that it "has become common throughout the Hawaiian Islands", and presented a photograph of an individual at 12 m at Honaunau, Hawaiʻi. Hoover (1993) notes that "large schools of these showy snappers are a common sight around wrecks and other popular dive sites, especially where fishes have been hand-fed." Russo (1994) notes that in Hawaiʻi "it is usually found alone under ledges or in caves mixed in with sol-

dierfishes or in the open cruising over the reef." Coles *et al.* (1999a) record it from Pearl Harbor; further locations include Honolulu and Ala Wai Yacht Harbors (Coles *et al.,* 1999b) Kāne‘ohe Bay (Coles *et al.,* 2002a), Koko Marina (Coles *et al*., 2002b) and various reef sites and harbors on Kaua‘i, Moloka‘i, Maui, Hawai‘i (Coles *et al.,* 2004, 2006) and Lāna‘i (Coles *et al.,* 2005). DeFelice & Parrish (2003) provide data on its occurrence and diet in Hanalei Bay on the island of Kaua‘i.

Mundy (2005) gives the Hawaiian distribution as from Hawai‘i Island to French Frigate Shoals, from 3 to 128 m.

Lutjanus gibbus (Forsskål, 1775) **Introduced**

This humpback snapper was released in O‘ahu in relatively small numbers (40 in 1958 from the Marquesas and 137 in 1961 from Moorea), and was long thought not to have not become established (Randall *et al.*, 1993; Mundy, 2005). Surprisingly, living individuals were discovered commencing in the late 1980s: one fish was taken in 1989 off the Hamākua coast of Hawai‘i Island, and about six fish were caught in the early 1990s off Ka‘ena Point, O‘ahu, at night in 18 m. An additional fish was observed at 15 m on the south shore of Kaua‘i in April 1992. It appears to be established, but whether from the original introduction has not been determined. Genetic comparison of Hawaiian populations with those from French Polynesia would thus be of interest.

Lutjanus kasmira (Forsskål, 1775) **Introduced**

The bluestripe or blueline snapper (or *ta‘ape*, its Tahitian name) was intentionally released in 1958 into Kāne‘ohe Bay, based upon 2,435 individuals transported from the Marquesas (Brock, 1960; Randall, 1987). It was considered to have become established by 1960. Oda & Parrish (1982) reported ecological observations and food habits in Hawai‘i and its "mild commercial success." Randall (1987) noted that it occurs as far as Laysan and has attained great abundance on the island of Hawai‘i. It has also invaded deeper waters, occurring to depths of 200 m (Randall, 1987) and 275 m (Randall, 1996). Coles *et al.* (2006) report it from reef sites on all the main Hawaiian Islands. Mundy (2005) noted the distribution as being from Hawai‘i Island to Midway, from 4 to more than 200 m depth.

The bluestripe snapper has become very abundant locally. Randall (1996) also noted that it forms large semi-stationery schools during the day, and disperses to feed at night "mainly on crustaceans and small fishes." Randall (1987) remarked that "it is very unpopular with fishermen who are convinced that its increase has been at the expense of more valuable species, such as the goatfish *Parupeneus porphyreus* and *P. multifasciatus*. Also, it enters fish traps readily and comes quickly to baited hooks, thus catches of more desirable fish are reduced." Schumacher & Parrish (2005) reported that *Lutjanus kasmira* displaces the native yellowtail goatfish *Mulloidichthys vanicolensis* from shelter, causing the goatfish to occur higher in the water column when *Lutjanus* was present, and thus potentially making *Mulloidichthys* more vulnerable to predators and fishermen.

Morales-Nin & Ralston (1990), Friedlander *et al.* (2002), and DeFelice & Parrish (2003) provide data on age, growth, biology, and ecology of *L. kasmira* in Hawai‘i. Morales-Nin & Ralston (1990) report that it has one of the highest growth rates of any lutjanid fish in the Pacific, perhaps, they suggest, because its growth "may have been enhanced by the relative lack of competitors in the depauperate Hawaiian marine fish community." Friedlander *et al.* (2002) describe its occurrence across a variety of habitats, as the "second most abundant species by numbers and biomass over a hard substratum." DeFelice & Parrish (2003) detail the habitat occurrence, abundance, and prey of *L. kasmira* in Hanalei Bay on the island of Kaua‘i, based upon studies conducted in 1993–1994. *Lutjanus kasmira* was the most numerous species, and "was observed during 100% of nocturnal censuses on transects 0–25 m from the reef." It was the most abundant species over soft-bottom habitats. Both *L. kasmira* and *L. fulvus* were characterized as "important predators upon soft-bottom invertebrates in the bay", but noted that "it is difficult to speculate on competition for food between *L. kasmira* and native species": dietary overlap between *L. kasmira* and other species was relatively low, "and there is no indication that food resources are limiting in this habitat."

Mullidae

Upeneus vittatus (Forsskål, 1775) **Introduced**

The striped goatfish (or yellowbanded goatfish) was introduced in 1955 on O‘ahu with the releases of the Marquesan sardine (Randall, 1981, 1987). Randall (1996) notes that it inhabits muddy bottoms. The first specimens were collected in 1976 and 1977 in Kāne‘ohe Bay (Randall, 1981).

Cichlidae

Oreochromis mossambicus (Peters, 1852) **Introduced**

= *Tilapia mossambica*

The Mozambique tilapia was intentionally introduced to O‘ahu to control “aquatic plants which clog irrigation systems, as a food fish, and as a tuna baitfish” in 1951 and 1952 from Singapore (Brock, 1960; Randall, 1987). It is now well established in fresh and brackish water on most of the islands (Mundy, 2005). Coles *et al.* (1999a) record it from Pearl Harbor; additonal records include Honolulu Harbor, Kewalo Basin, Ala Wai Yacht Harbor (Coles *et al*., 1999b) and Kāne‘ohe Bay (Coles *et al.* 2002a).

Sarotherodon melanotheron Rüppell, 1852 **Introduced**

= *Tilapia melanotheron*

= *Tilapia macrocephala* (Bleeker, 1862)

The silvery or blackchin tilapia, native to West Africa, was imported in 1962 by the Bureau of Commercial Fisheries for holding in experimental tanks (to study its potential as tuna bait) at Sand Island, from stock from the American Museum of Natural History in New York City (Randall, 1987). “Although there was no intentional release to the sea, this tilapia somehow escaped—perhaps through a dislodged screen on an outflow pipe to Ke‘ehi Lagoon” (Randall, 1987). Englund (2002) reports a date of 1951 in error.

It is now a very abundant fish in Pearl Harbor (Coles *et al.*, 1999a), the Ala Wai Yacht Harbor (Coles *et al.*, 1999b), and Kāne‘ohe Bay; Randall (1987) further notes that “Tuna fishermen are very unhappy with its abundance, for they believe it may be feeding in part on young nehu.” Yamamoto & Tagawa (2000) note that it is “now one of the most abundant species of tilapia in Hawai‘i, having displaced the previously ubiquitous *O. mossambicus*.” Englund *et al.* (2000a) refers to this tilapia as “the dominant estuarine fish in Pearl Harbor and (the rest of) O‘ahu.” “The blackchin tilapia is one of the most harmful introduced fish in low-elevation areas of Hawaiian streams, wetlands, and estuaries and likely has caused more negative ecosystem effects in lower Pearl Harbor streams and wetlands than any other introduced aquatic species” (Englund *et al.*, 2002a). Mundy (2005) notes that it occurs on Kaua‘i as well.

Pomacanthidae

Centropyge flavissima (Cuvier, 1831) **Establishment Unknown**

Coles *et al.* (1999b, p. 47) note that “The only occurrence of the Lemon Peel fish *Centropyge flavissima* in this study was an observation near the [Ala Wai Yacht] harbor boat ramp.” However, Richard Pyle (pers. comm.) has sighted this species infrequently over at least the past ten years at Ke‘ehi Lagoon, Kewalo Basin, the Ala Wai Canal, and Kāne‘ohe Bay” (see also Mundy, 2005). Coles *et al.* (2002a) also report it from Kāne‘ohe Bay. Richard Pyle informs us (pers. comm., January 2004) that over this period of time he has never seen juvenile fish. Randall *et al.* (1990) give the distribution as Cocos-Keeling Islands to southeastern Oceania and north to the Ryukyu Islands, noting that it is “common in island groups of the tropical central and western Pacific.” We take the first date of occurrence as approximately 1990. It is a probable aquarium release.

Centropyge loriculus (Günther, 1874) *Kāne‘ohe Population* **Introduced**

Mundy (2005, pp. 43, 83, and 405) reports a population of this otherwise-indigenous flaming angelfish in He‘eia Kea Harbor (He‘eia Boat Harbor), Kāne‘ohe Bay, O‘ahu with a distinctive color pattern “that are probably the descendents of aquarium fishes that were released in Kāne‘ohe Bay”

(p. 405), although more strongly so assigned in an earlier discussion (“These are known to be the descendants of fish released from imported aquarium stock”, p. 83). Coles *et al.* (2002a) report it from near He‘eia Kea Marina, Kāne‘ohe Bay.

Pomacentridae

Abudefduf vaigiensis (Quoy & Gaimard, 1825) **Waif with Drift Nets?**

This damselfish, known as the “Indo-Pacific sergeant major,” or *mamo*, was first recorded in the Hawaiian Islands in 1991 at Molokini, Maui (J.E. Randall, pers. comm., January 2004). Randall (1996) notes that “small breeding colonies have been observed at the islet of Molokini and on O‘ahu.” Basch (2002) reports observing *A. vaigiensis* in a south Maui survey in 2002, and 237 individuals were noted in a two day period in October 1998 in a survey of Molokini Shoal [see http://cramp.wcc.Hawai‘i.edu/Study_Sites/Maui/Molokini/1998_Survey/]. Mundy (2005, pp. 21, 425) reviews its increasing spread and establishment on a number of islands and north to French Frigate Shoals.

The pattern of arrival and spread has suggested to Hawaiian ichthyologists that this is a “natural” colonist that may have arrived associated with drifting nets and debris (J. Randall & J. Hoover, pers. comm., January 2004), with which this fish is known to be associated (Kimura *et al.*,1998, Mundy, 2005; see also Donohue *et al.*, 2001). While on the one hand it is unusual that it would have failed to arrive as a waif in the Islands previous to the 1990s, the increasing prevalence of high seas drifting debris, including derelict fishing gear, might provide a mechanism for transport that was less frequent in earlier decades. It is of interest to note in this regard the collection of the Asian sea anemone *Diadumene lineata* on a drift net in the lagoon at Pearl and Hermes Reef in the Northwestern Hawaiian Islands in 2000 (see discussion at that species).

This fish is occasionally found in the aquarium trade and is sold as an aquarium fish in Hawai‘i (see http://www.raingarden.us/marine.htm [accessed January 2007]) and thus may have been an intentional release, or aquarium releases may have contributed to part of its modern-day occurrence in Hawai‘i.

Maruska & Peyton (2007) report interspecific spawning between *A. vaigiensis* and the endemic Hawaiian sergeant fish, *Abudefduf abdominalis*.

Chrysiptera taupou (Jordan & Seale, 1906) **Establishment Unknown**

Mundy (2005) notes that specimens of this damselfish (known as the “South Seas devil”) have been found in 2002 and 2004 in Hanauma Bay, O‘ahu, and possibly in 2002 at Ala Moana Beach Park, O‘ahu. The records are from shallow water. Mundy remarked that it “might be established in shoreline waters of Honolulu.”

Blenniidae

Parablennius thysanius (Jordan & Seale, 1907) **Introduced**

This Indo-Pacific blenny (the “tasselled blenny”) was first collected in 1971 in Kāne‘ohe Bay and by 1990 had become abundant in “the fouling on buoys floating in about 10 m of water and about 300 m from shore” (Springer, 1991). In 1990 it was also said to occur on the fouling of wharf pilings in Kāne‘ohe Bay, and was reported from Pearl Harbor (Springer, 1991). Greenfield (2003) notes that it is found in Kāne‘ohe Bay “in fouling communities ... on dock floats.”

Parablennius thysanius is known from Pakistan, Sri Lanka, Oman, Thailand, and the Philippines. Mundy (2005) considered it likely to have been introduced from the Philippines. We consider it a ballast water, or sea chest fouling, introduction to O‘ahu.

Omobranchus ferox (Herre, 1927) **Introduced**

Englund & Baumgartner (2000) report the establishment of the fang-toothed blenny *Omobranchus ferox* in Pearl Harbor. This fish is native to the Philippines and South China Sea. It was found on a rocky shoreline interspersed with mangroves in Halawa Stream in 35–36 ‰; the first specimens were collected in 1998. It remains present in Pearl Harbor and the Ala Wai region (R. Englund, pers.

comm., January 2004). Englund & Baumgartner (2000) suggested transport in ballast water or sea chest fouling. While not mentioned by Englund & Baumgartner (2000), Mundy (2005, p. 465) notes that the site of collection was "near a large, floating dry dock that had been moved to O'ahu from the Philippines a few years earlier ... . This species was most likely introduced to O'ahu on the hull of the dry dock." This appears to refer to the movement of the dry dock *Machinist* to Pearl Harbor in 1992. Englund & Baumgartner (2000) do mention the incident of a dry dock towed from Subic Bay, Philippines to Guam, which arrived with three species of gobies (including *Omobranchus elongatus*), none native to Guam. Englund & Baumgartner (2000) speculate that this introduced goby could compete with the native estuarine goby *Oxyurichthys lonchotus*.

Omobranchus rotundiceps obliquus (Garman, 1903) **Introduced**

= *Omobranchus elongatus* of Strasburg (1956, 1966) *fide* Springer & Gomon, 1975, p.69

Specimens of this Indo-Pacific blenny (known as the mangrove blenny or roundhead blenny) were accidentally imported from "near the Samoan Islands" in 1951, when coralline rock, the clam *Tridacna*, and other living materials, in which the blenny was hiding, from the island area were placed in a concrete tank on the shore of Kāne'ohe Bay with an open seawater system (Strasburg, 1956). By 1963 it had rounded O'ahu, and a specimen was taken from a reef in Pearl Harbor (Strasburg, 1966). It remains common in Kāne'ohe Bay on sheltered patch reefs, and in rocky and mangrove habitats but is most abundant in fouling communities (Greenfield, 2003). It remains restricted to O'ahu [Englund & Baumgartner (2000), based upon pers. comm. from J.E. Randall and J.P. Hoover].

Gobiidae

Mugilogobius cavifrons (Weber, 1909) **Introduced**

= *Mugilogobius parvus* (Oshima, 1919) *fide* Larson, 2001

This Indo-Pacific marine and brackish water goby was collected in 1988 at Coconut Island in Kāne'ohe Bay in a shallow mangrove habitat (Randall *et al.*, 1993). Additional specimens and observations then came to hand from Ala Moana drainage canal (1989) and from a Pearl Harbor drainage canal (1987). Englund (2002) reports that this goby is now abundant in Pearl Harbor and is common in a number of other estuarine streams in western and southern O'ahu. Mundy (2005) notes that it has spread to the Kaua'i estuaries.

Randall *et al.* (1993) regards it as a ballast water introduction, to which we add the possibility of transport in sea chest fouling as well.

Favonigobius sp. **Establishment Unknown**

Greenfield & Randall (2004) report the collection in 1990 of "several small specimens" of this perhaps Australasian goby in Kahana Bay. The specimens were about 14 mm in length. Greenfield & Randall note that there were "attempts to collect more specimens" and that these attempts were not successful; these attempts were in June 1997 using a fine-mesh seine (D.W. Greenfield, pers. comm., March 2007).

The presence of several specimens at a site (Kahana Bay) distant from ballast water release suggests that a reproducing population had become established. That said, there have been no further known collections since 1990, although small gobies may not attract sufficient attention, nor be brought, if collected, to the attention of professional ichthyologists. If this small species is still present, searches in nearby Kāne'ohe Bay might be fruitful.

ALGAE (Seaweeds)

Introduced and Cryptogenic Algae

Species	Date	Vector	Native to
Introduced Species			
Rhodophyta			
Acanthophora spicifera	1952	SF, R	Indo-Pacific
Eucheuma denticulatum	1970	R	Philippines
Kappaphycus alvarezii	1974	R	Philippines
Kappaphycus striatum	1970	R	Philippines, Pohnpei
Asparagopsis "taxiformis" - Lineage 4	1991	SF?	Indo-Pacific
Gracilaria salicornia	<1950	SF,BW,SBA?	Indo-Pacific
Gracilaria tikvahiae	1970s	R	Florida
Hypnea musciformis	1974	R	Florida
Avrainvillea amadelpha	1981	BW,AN	Indo-Pacific
Chlorophyta			
Ulva expansa	1900	SF	Unknown
Phaeophyta			
Nemacystus decipiens	1963	R?	Indo-Pacific
Pilayella littoralis	1990s	SF	Unknown
Dictyota flabellata	1999	SF	California
Cryptogenic Species			
Ulva clathrata	—	SF	
Ulva compressa	—	SF	
Ulva fasciata	1819	SF	
Ulva flexuosa	—	SF	
Ulva intestinalis	—	SF	
Ulva linza	—	SF	
Ulva paradoxa	—	SF	
Ulva prolifera	—	SF	
Ulva reticulata	<1892	SF	
Ulva rigida	—	SF	
Ulva taeniata	—	SF	
Chaetomorpha indica	1988	SF	
Additional Taxa Treated and Their Status			
Rhodophyta			
Wrangelia bicuspidata	1974	R?	Unknown
Status: *Failed?; see discussion*			
Mazzaella volans	1987	R	Eastern Pacific
Status: *Escaped; Not Established*			
Phaeophyta			
Macrocystis pyrifera	1980s	R	Eastern Pacific
Status: *Escaped; Not Established*			
Sargassum muticum	—		
Status: *Intercept*			

Several workers have provided reviews of some of the introduced seaweeds (*limu*) in the islands (Russell, 1992; Abbott, 1999; Huisman *et al.*, 2007, pp. 32–34: "Our superweeds"). A native species, *Gracilaria epihippisora* not further treated below, was transplanted from the Big Island of Hawai‘i to Waikīkī and Kāne‘ohe Bay for mariculture purposes in 1971 and again in 1978 (Russell, 1992). Abbott (1999) and Huisman *et al.* (2007) note that the native *Grateloupia filicina* was said to have been transplanted to Waikīkī for Queen Liliu‘okalani in the late 1880s; Abbott (1999) comments that "this would make *G. filicina* the earliest documented successful marine transplant in the Hawaiian Is."

Rich arenas for exploration for introduced or cryptogenic species may be found among the filamentous reds and greens in Hawai‘i, many of which bear cosmopolitan names and now require genetic analyses. Given the centuries of global shipping and the importation of many animals and plants for fisheries purposes, it is difficult to imagine that no smaller algae have been introduced.

Prominent introduced species include *Acanthophora spicifera*, *Hypnea musciformis*, *Gracilaria salicornia*, *Kappaphycus* spp., and *Avrainvillea amadelpha*. The spread and growth in abundance of most of these species have resulted in extensive ecological and societal impacts, including competition with and overgrowth of native algae and coral reefs, fouling, habitat change, and (for *Hypnea* and *Gracilaria*) masses of rotting seaweed washing ashore. These effects have attracted media and public attention since the 1980s. For example, on 24 August 2002, a “Waikīkī Alien Algae Clean-Up Event” was held, for volunteers to remove massive amounts of *Gracilaria salicornia* from the waters in front of Waikīkī Aquarium, and to evaluate methods needed to control introduced algae on Hawai‘i’s reefs. Five thousand pounds of algae were removed on this day. As of late 2005, the ‘A’ohe Limu’e, No Alien Algae program had removed about 100 tons of *Graciliaria* from the area (see http://www.hawaii.edu/malamalama/2006/01/f4_algae.html [accessed February 2007]).

These efforts were foreshadowed more than 25 years earlier, when a similar but smaller effort was made to remove *Kappaphycus striatum* from an area of Kāne‘ohe Bay, as discussed below.

Numerous materials—brochures, cards, posters, videos, *et cetera*—have been produced to inform the public about “alien seaweeds” in the islands. For example, the Hawaii Division of Aquatic Resources produced (with the assistance of the “Hawai‘i Marine Algae Group”, or HiMAG) in 2003 a set of 10 small waterproof plastic cards (held together by an electrician’s tie) on “Alien Seaweeds”, with the “title card” describing that “alien seaweeds harm our native marine life, reduce fisheries habitat, [and] cost millions [of dollars] to Hawai‘i’s economy.” Five nonnative species were assigned common names as follows:

Graciliaria salicornia	Gorilla Seaweed
Avrainvillea amadelpha	Leather Mudweed
Acanthophora spicifera	Prickly Seaweed
Kappaphycus spp.	Smothering Seaweed
Hypnea musciformis	Hookweed

The cards advise the public to “help keep these aliens from spreading throughout Hawai‘i”, identifying, interestingly, three modes of interisland dispersal: by boats, by fishing, and by recreational diving. Individuals are asked to remove seaweed from anchors, mooring lines, outboard propellers, and the bilge, and by keeping boat hulls clean; to inspect fishing lines, hooks, nets, traps, and “catch bags” for “small fragments of seaweed”, and, while snorkeling or diving, to inspect wetsuits, footwear, gloves, buoyancy compensator, fins, and gear bags. Another card (“What You Can Do to Help Protect Hawai‘i’s Coral Reefs from Alien Seaweeds”) further advises the public to “get in the habit of thoroughly drying your dive gear, wetsuits, and dive bag after each use“, to “take steps to decrease overfishing. Many reef fish eat seaweed and help keep them from overgrowing the reef,” and “Never dump aquarium animals or plants into streams or coastal waters.”

Recent eradication attempts of *Eucheuma*, *Gracilaria*, and other species have focused on an underwater removal technique using barge-mounted vacuum cleaners (Holden, 2007), causing Goreau (2008) to question its efficacy, leading to rationales for eradication attempts by Smith *et al.* (2008) in a high-profile journal, *Science*. Smith *et al.* (2008) noted that “areas cleared by the Super Sucker remain clear of alien algae and have increased coral recruitment after just 2 years,” noting that removal strategies buy “time for the development of biological control methods with the native sea urchin *Tripneustes gratilla*,” citing Hawaiian studies by Stimson *et al.* (2007) on the potential for this urchin to feed on *Gracilaria* and other species.

Vroom *et al.* (2006) found no nonnative algae at French Frigate Shoals, Northwestern Hawaiian Islands, although all four *Ulva* species occurring there (*clathrata, flexuosa, paradoxa*, and *prolifera*) we regard as of uncertain history in the Islands.

Vermeij *et al.* (2009) experimentally studied the effects of herbivorous fish on *Acanthophora spicifera* and *Hypnea musciformis* on O‘ahu and Maui, and in their native Caribbean habitats, finding that in Hawai‘i these algae experienced reduced herbivore pressure, helping to facilitate their success.

RHODOPHYTA (red algae)

Rhodomelaceae

Acanthophora spicifera (Vahl, 1802) Borgesen 1910 **Introduced**

Doty (1961) reported the discovery of this Indo-Pacific and cosmopolitan “spiny seaweed” based upon specimens discovered in 1952 in Pearl Harbor. Although with a Caribbean type locality (St. Croix, Virgin Islands), it is now widespread globally “throughout tropics into warm temperate areas” (Abbott, 1999). How much of this now cosmopolitan distribution is due to ship-mediated dispersal appears not to have been investigated. Doty reported the following chronology of its early discovery and spread as follows:

Early Discovery and Spread of *Acanthophora* in Hawai‘i, 1952–1960

Date	Location	Comments
1952 (fall)	O‘ahu south (leeward) shore: Pearl Harbor	a small fragment
1953 (April)	O‘ahu south shore: Waikīkī Beach	“much larger piece”
1953 (May)	O‘ahu south shore: Ke‘ehi Lagoon (between Pearl Harbor and Port of Honolulu)	in abundance
1953 (May)	O‘ahu north (windward) shore: Hau‘ula	dense growth
1953–1956	O‘ahu south shore	“so common that it has not often been preserved”
1954–1955	Kaua‘i	
1956 (February)	O‘ahu: north shore: Kāne‘ohe Bay	substrate for eggs of native snail *Conus quercinus*
1956 (June)	O‘ahu northwest shore: Mokuleia	“ubiquitous some distance within the reef”, very rare in 1955
1956 (November)	Kaua‘i	
1960 (August)	Kaua‘i: Po‘ipū Beach	
1960 (November)	Lāna‘i north shore	washed ashore in abundance, “free or attached to shells, coral, or even rocks up to 2 lb. in weight”

Doty (1961) felt that this alga arrived in hull fouling and specifically suggested that a heavily fouled barge, the *Yon 146*, which arrived in Pearl Harbor in February 1950 may have been the actual vessel involved. Russell (1987) also suggested that it may have arrived with algal-covered substrates imported with fish to the Waikīkī Aquarium.

Acanthophora is now the most abundant and ubiquitous introduced alga in the Hawaiian Islands (Smith *et al.*, 2002). It is common in many habitats in shallow and intertidal reefs. Russell (1992) noted that *Acanthophora* often outcompetes the native algae *Laurencia* spp. and *Hypnea cervicornis*. Smith *et al.* (2002) note that “it is most common in intertidal regions and in semiprotected tide pools, where it may escape spatially from herbivory. This species was commonly observed fouling ship hulls in harbors throughout the state during field surveys. Although this plant was a common component of the marine flora and is clearly displacing native species in Hawai‘i, it does not appear to form large, monospecific nuisance blooms.”

Stimson & Larned (2001) found that the native green "bubble" alga, *Dictyosphaeria cavernosa* remained abundant in parts of Kāneʻohe Bay, despite nutrient-enriching sewage abatement in the 1970s, due to decreased herbivory: herbivorous fish prefer introduced algae such as *Acanthophora*, reducing predation on adjacent populations of *Dictyosphaeria*.

Russell & Balazs (1994) documented the green sea turtle's (*Chelonia mydas*) use as food of *Acanthophora* and *Hypnea* in Hawaiʻi. O'Doherty & Sherwood (2007) provide the first analysis of the genetic population structure of *A. spicifera* in Hawaiʻi, reporting that populations in the islands form discrete genetic groups.

Solieriaceae

In an act that would not be permitted today, the State of Hawaii issued permits in the 1970s for the late Professor M.S. Doty of the University of Hawaii to import and release three species of eucheuma, largely from the Philippines, into Kāneʻohe Bay, for the purposes of open water farming for the production of kappa-carrageenan and agar. All three have become established; a fourth, *Eucheuma isiforme*, did not (Russell, 1992). The importation data from Russell (1992) are given below each species.

Eucheuma denticulatum (Burman, 1768) Collins et Harvey, 1917 **Introduced**

Released into Kāneʻohe Bay, Honolulu Harbor, and other Oʻahu sites from October 1970 to "late 1976" stock from the Philippines. The type locality of *E. denticulatum* is the Indian Ocean, and it also occurs in the Western Pacific.

Kappaphycus alvarezii (Doty, 1985) Doty ex Silva, 1996 **Introduced**

= *Eucheuma striatum* "tambalang variety" of Russell, 1983, and others

Released into the above sites from September 1974 to "late 1976"; stock from the Philippines. The type locality of *K. alvarezii* is Malaysia, and it also occurs in the Sulu Sea and southern Philippines.

Kappaphycus striatum (Schmitz, 1895) Doty ex Silva, 1996 **Introduced**

Released into the above sites from August 1970 to "late 1976," stock from the Philippines and Pohnpei. The type locality of *K. striatum* is also the Indian Ocean, and it occurs widely in Indonesia, the western Pacific, and Micronesia (Abbott,1999). *Kappaphycus striatum* also went under the earlier name of *Eucheuma cottonii* (Abbott, 1999), and was also known as the "elkhorn" variety. *Kappaphycus alvarezii* was also known as the "tambalang" variety (Russell, 1983, in that paper as *Eucheuma striatum*; Eldredge, 1994).

Doty (1973a, 1973b, 1977) touted the commercial, economic, and social values of introducing and growing eucheuma, even referring to the "rational utilization of the subtidal environment" of Kāneʻohe Bay (Doty, 1977, figure 3 caption). Doty (1977) presented maps of the sites where eucheuma had been released and growth rate data for *Kappaphycus alvarezii* (as the "tambalang strain of *Eucheuma*"). He also discussed post-release control measures and the government bureaucracy that would constrain releases of nonnative species.

While *E. denticulatum* and *K. striatum* had been imported as early as 1970, it was the later importation of *K. alvarezii* that caused initial concern. Material of this species from the Philippines imported in September 1974 (Russell, 1983, as *E. striatum*—tambalang form) and/or May 1975 (Russell, 1979). Initially placed in wire holding pens on the northwestern reef bordering Coconut Island in Kāneʻohe Bay, the pens broke down and the algae were freed (A.H. Banner *in litt*. to L.G. Eldredge, October 1982). By March 1976 an estimated 50 to 100 metric tons were on the reef (Russell, 1979) resulted in a day-long effort, organized by Dr. E. Reese (A.H. Banner *in litt*. to L.G. Eldredge, October 1982), that found 50 volunteers removing about four tons of seaweed (Russell, 1983). Russell (1983) and Glenn & Doty (1990, 1992) described aspects of the ecology and growth of euchemas in Kāneʻohe Bay. Zuccarello *et al.* (2006) provide recent data on the genotypes of Hawaiian euchemas.

All three species remain in Kāne‘ohe Bay, and at least two, *K. alvarezii* and *K. striatum* abundantly so, having spread within the Bay but not outside of it (Rodgers & Cox, 1999, for *K. alvarezii* and *K. striatum*). Smith *et al.* (2002) note that *Kappaphycus* spp. in Kāne‘ohe Bay are “clearly competitively dominant, occupying up to 80% of the substrate. Because of its large structure, *Kappaphycus* also appears to be competing with coral and may be able to overgrow live coral colonies.” Conklin & Smith (2005) provide further data on the increased spread through Kāne‘ohe Bay of *Kappaphycus* spp. between 1999 and 2002, noting that it “can be found in a variety of reef habitats overgrowing and killing corals.” They suggest that management action be undertaken, given that *Kappaphycus* continues to spread and can have over 50% cover on some coral reefs.

Bonnemaisoniaceae

Asparagopsis “taxiformis” — Lineage 4 **Introduced**

As Abbott (1999) notes, this well-known red alga has a long history in Hawaiian culture, and has been formally recorded in the flora since the 19th century. With a type locality of Alexandria, Egypt, and said to occur in all oceans, it is not surprisingly a species complex (Andreakis *et al.*, 2007). Sherwood (2008) establishes that one of these lineages appears to be a relatively new introduction: while two other clades of *A.* “*taxiformis*” occur relatively widely in the Islands, lineage 4 is restricted to a localized area on the south shore of O‘ahu. The first record of this lineage is 1991 (Andreakis *et al.*, 2007). It is otherwise known from tropical and subtropical regions in the Indo-Pacific ranging from Sri Lanka to Panama and Costa Rica (Sherwood, 2008).

The other two lineages have curious distributions: lineage 1 occurs in Hawai‘i and the Pacific coast of Central America, whereas lineage 2 is known from the Indo-Pacific and the Mediterranean, as well as Hawai‘i (lineage 3 does not occur in Hawai‘i).This pattern is suggestive of earlier invasions, whose directions and tempo remain to be worked out.

Ceramiaceae

Wrangelia bicuspidata Borgesen, 1916 **Failed(?)**

Russell (1992) notes that this tropical alga, known from the Indo-Pacific and the Caribbean, was discovered in Kāne‘ohe Bay in about 1974 (as “1974 (?)”) and was established (“successful”). Abbott (1999), however, does not further report it from Hawai‘i and reports to us (I. Abbott, pers. comm., April 2000 and January 2004) that there are no recent collections.

Graciliariaceae

Gracilaria salicornia (C. Agardh 1820) Dawson, 1954 **Introduced**

Smith *et al.* (2002) suggest that this Indo-Pacific alga is not native to the Hawaiian Islands, noting that prior to its intentional transplantation from the Big Island of Hawai‘i to O‘ahu, it was known from only two populations on Hawai‘i, one in Hilo Bay and another in Kapoho “before 1950.” They note that “the origin of these populations is unknown but may be tied to early harbor arrivals in Hilo from the Philippines.” Smith *et al.* (2004, page 327) remark that “There is some support for the idea that this Hawai‘i Island population was an early twentieth-century ballast introduction from ships originating in the Philippines ... .”

In April 1971 and again in September 1978, this alga was transplanted intentionally for aquaculture purposes from Hawai‘i to Waikīkī and Kāne‘ohe Bay on O‘ahu (Russell, 1992), where it became established (Abbott (1999) gives these dates as “about 1980”, but see Russell, 1992). However, Abbott (1999) notes the presence of *G. salicornia* at Kaloko, on the eastern shore of O‘ahu, in 1946, prior to its later transplantation. Smith *et al.* (2002) further note that “sometime in the 1980s” *G. salicornia* was transplanted from O‘ahu to Puko‘o fishpond on the island of Moloka‘i, based upon information provided by I.A. Abbott. Abbott (1999) further reported it from Ala Moana Park. Rodgers & Cox (1999) discuss the rate of spread of this species and its distribution in Kāne‘ohe Bay.

Smith *et al.* (2002) report as follows: “This nonindigenous algal species currently has the most discontinuous distribution of all species examined in this study. It is now found on three islands, with

no obvious continuity among locations. At most of the sites where *G. salicornia* was found, this alga was highly dominant over a distinct area. It was very common in southern Kāneʻohe Bay but was not found in the north bay. *Gracilaria salicornia* was dominant in Waikīkī in front of the Aquarium but was not present at adjacent sites such as Ala Moana Beach Park or at Kahala. It seems that, once introduced, this species may have the ability to spread within a site laterally and become locally dominant but does not have great success at dispersing larger distances between sites or islands, over this two-decade time frame."

Smith *et al.* (2004) report on the ecology of this invasion on Oʻahu, noting that 30 years after its release on two reefs in the 1970s, "this species has spread from the initial sites of introduction and is now competing with native marine flora and fauna." They note that "substantial amounts of *G. salicornia* become dislodged from the reef during large wave events and periodically become deposited onto the beach in front of the Waikīkī Aquarium ... over 20,000 kg of alien algal fragments were removed from this location in five 4-hr cleanup events."

Conklin & Stimson (2004) add herbivorous fish to *Gracilaria* reefs at Kāneʻohe Bay to experimentally address herbivory as a means of controlling fleshy macroalgae, but found that fish did not remain on site due to lack of shelter.

Gracilaria tikvahiae McLachlan, 1987 **Introduced**

Russell (1992) reports that this Western Atlantic Ocean alga had been intentionally imported for commercial mariculture purposes from Florida and released in Kāneʻohe Bay and Kahuku on Oʻahu in the "mid 1970s." Abbott (1999) reported the introduction as having occurred in 1987, "to help alleviate the low market supplies of *G. parvispora*." Abbott (1999) reports further unidentified *Gracilaria* existing in the University of Hawaiʻi Fisheries Laboratory (ʻĀnuenue) and in the Kahuku mariculture operations "that are not like *G. tikvahiae*", and for which "it is uncertain how many species are involved, or if any are native." Abbott notes a collection of *G. tikvahiae* from near the seawater discharge of the Oceanic Institute near Makai pier in the vicinity of Makapuʻu Point, Oʻahu.

Hypneaceae

Hypnea musciformis (Wulfen in Jacquin, 1791)
Lamouroux, 1813 **Introduced**

This seaweed, which is largely an epiphytic species with recurved hooks on its branch tips, was transplanted from Florida to Kāneʻohe Bay in January 1974 (Russell, 1992) "as part of an aquaculture project that was later abandoned" (Smith *et al.*, 2002). It apparently came as part of a shipment of *Eucheuma*, but was then interpreted as a potential farming candidate (Russell & Balazs, 1994, p. 54, "*Hypnea musciformis* came with a shipment of two morphs of *Eucheuma* … ."). Russell & Balazs (1994) further noted that *Hypnea* became so abundant in Kāneʻohe Bay that it began growing among *Eucheuma* that were then exported to other countries in the Pacific, resulting in the yet further spread of this seaweed. It is now one of the most pestiferous seaweed invaders in Hawaiʻi. It occurs in the Philippines and Indian Ocean and from the Caribbean to Uruguay; curiously enough, its type locality is Trieste, Italy (Abbott,1999).

Abbott (1987) reported its early history from 1974 to 1982 as follows:

> "This past summer [1987] many residents of Kuau, a coastal section just southeast of Paia, Maui Island, were up in arms over the appearance of masses of a 'new' seaweed on their beaches. Indeed, the culprit alga was new to Maui, having come over from Oahu Island where it had been spreading since its introduction to Kaneohe Bay about 1974. The red alga alien is *Hypnea musciformis* ... . Stories about its introduction are not agreed to by all parties, one saying that it was accidental, having come with another species of algae as an epiphyte from the Caribbean. I began to record its spread in the fall of 1978 when I found it at Kaaawa (not far from the mouth of Kaneohe Bay), and in the fall of 1979 it was a Laie Point; in 1980 at Waikiki; 1981 at Ewa Beach and by 1982 ... it seemed to have reached every nook and cranny of intertidal Oahu."

Abbott (1987) further notes that it made up between one-third and one-half of the wet biomass of

drift algal piles on O‘ahu beaches, and further suggested that it might account “for larger masses than previously of *Sargassum* on the beaches, since it adds drag and weight to the *Sargassum* plants. *Sargassum* was frequently in the drift in late summer and fall in pre-*Hypnea* times.”

Russell & Balazs (1994) detail the spread of *Hypnea* around O‘ahu, Moloka‘i, Maui, and Lāna‘i from 1977 to 1991. They note it was found as an epiphyte on *Sargassum echinocarpum, S. polyphyllum*, and *Acanthophora spicifera*, or in windrows of beach algal drift. Russell & Balazs (1994) further documented the use as food of *Hypnea* and *Acanthophora* by the green sea turtle *Chelonia mydas* in the Hawaiian Islands, noting that it was the first documentation of introduced algae being incorporated into the diet of this turtle. *Hypnea* was also considered to be inhibiting the growth of the native *Hypnea cervicornis* and *Laurencia nidifica*.

Abbott (1999) remarks that by 1987 it had become established near Pa‘ia, Maui, “where it is most commonly found in large nearly unialgal masses cast ashore in windrows up to 0.5 m depth on many beaches and considered to be an odiferous pest by local inhabitants and tourists alike.” Observations in 1996 on windward and leeward beaches of Maui revealed that *Hypnea* formed at least two-thirds of the drift algal biomass. In 2003, the Environmental Protection Agency provided $250,000 to purchase a seaweed-removal machine to be used on Maui (Carroll, 2004).

Smith *et al.* (2002) reports that this alga was the second most common introduced algae in the islands, although it had not yet spread to all of the islands, and was not as abundant as *Acanthophora*, although it was becoming more common. Abbott (1999) also notes that it was not yet on either Kaho‘olawe or Hawai‘i. It blossoms at “discrete locations” and when abundant co-occurs with *Ulva fasciata*, “a known weedy species in a genus known to require high nutrient flux for growth” (Smith *et al.*, 2002). On the basis of this, Smith *et al.* (2002) suggest that *Hypnea* blooms may be related to land use activities and nutrient input. *Hypnea* propagates vegetatively, especially among smaller algal pieces.

Huisman *et al.* (2007) note that in 2003 and 2004, *H. musciformis* was found at Necker Island (Mokumanamana), “probably carried there by currents. Managing this potentially destructive invasive species is a major challenge.”

Gigartinaceae

Mazzaella volans (C. Agardh, 1820) J. Agardh, 1846 **Escaped**; **Not Established**

Abbott (1999) reports that this eastern Pacific red alga, known from Oregon to Mexico, was collected at the outfall of experimental aquaculture tanks holding the California kelp *Macrocystis*, at Keāhole Point, Kona, Hawai‘i. The material was collected by W.H. Magruder on 5 April 1987 (I. Abbott, pers. comm., April 2000). Abbott (1999) writes that “Keāhole Pt. is the location of several commercial aquaculture operations. Spores of this common western North American species could have come with *Macrocystis*, imported to feed abalone (*Haliotis* sp.), also imported for mariculture purposes, which might be a source of spores as well.” Isabella A, Abbott reports (pers. comm. January 2004) that it has been looked for since 1987 and not found (see also Abbott & Huisman, 2004, page 239). We consider it not established.

CHLOROPHYTA (green algae)

Udoteaceae

Avrainvillea amadelpha (Montagne) A. Gepp & E. Gepp, 1908 **Introduced**

Brostoff (1989) report that the first collections of this Indo-Pacific (Abbott & Huisman, 2004) species were in 1981 (a three square meter patch in 13 m of water at Kahe Point, O‘ahu, on sand-covered dead coral) in 1985 (from sand and rock substrates in 10 m at Maunalua Bay, O‘ahu), and in 1987 and 1988 (intertidal zone at Hawai‘i Kai). While Brostoff notes that “ship introduction is unlikely”, the transport of drift material in ballast water may be possible, either as parts of adult plants torn loose from the substrate, or possibly as gametes. Alternatively, anchors or anchor chains with entangled specimens may have provided a vector from the Indo-Pacific.

Smith *et al.* (2002) report that it has persisted and "has spread laterally from Koko Head to Kahala on Oahu's south shore from Kahe Point north on the west shore." They also newly report it as a "small population" at Prince Kuhio Beach Park on Kaua'i. "This species inhabits soft or sandy bottom habitats where the majority of the plant biomass is subsurface. This nonindigenous alga frequently serves as a substrate for many native species of epiphytic algae and as habitat for many invertebrates. The endemic Hawaiian sea grass *Halophila hawaiiana* and *A. amadelpha* now cooccur in areas that were once *H. hawaiiana* meadows. This may prove to be a considerable conservation and management problem, and more research is needed to determine *A. amadelpha*'s ecological strategies and impacts on the native biota" (Smith *et al.* 2002).

Ulvaceae

Rich grounds for exploration of cryptogenic and introduced species are the species of *Ulva*, taxa well known for centuries to be associated with ship fouling and oyster shells, and easily transported as smaller pieces in ballast water. Included are species formerly assigned to *Enteromorpha*, a genus now synonymized with *Ulva* (Hayden *et al.*, 2003). Species assigned to both genera, as well as a number of other brackish-water green algae, have long been known from the islands (Abbott, 1947, 1980; Abbott & Huisman, 2004).

We regard the following *Ulva* as cryptogenic, with the exception of *Ulva expansa.* We include species of *Ulva* with native Hawaiian names that have been long-embedded in Hawaiian culture: here, our consideration is that if these species were present on the Islands aboriginally, modern-day populations may have been genetically altered and modified by the influx of global genomes over the past 200 years. Geographic ranges and unattributed quotations below are all from Abbott & Huisman (2004):

Ulva clathrata (Roth, 1806) Greville, 1830 **Cryptogenic**
All temperate seas; "intertidal and more exposed areas."

Ulva compressa (Linnaeus, 1753) Nees, 1820 **Cryptogenic**
Warm and temperate seas; "mostly on shallow nearshore rocks or limestone."

Ulva fasciata Delile, 1813 **Cryptogenic**
Known as *limu palahalaha* and *lipahapaha*, this *Ulva* is one of only three species of green algae used in traditional Hawaiian food preparation; the others are *Ulva prolifera* and *Codium edule* (Abbott & Huisman, 2004). Occurring over a wide variety of habitats, it is "the commonest sea lettuce in the Islands" If introduced, it is one of the earliest documented invasions, having been found in 1819 by C. Gaudichaud (St. John & Titcomb, 1983). Widespread in the Pacific and Indian Oceans, it is also recorded from the Mediterranean and Caribbean (Abbott & Huisman, 2004). Aguilar-Rosas *et al.* (2005) regard it as introduced to the Pacific coast of Mexico, with the earliest specimens from there being collected in 1970, suggesting that this species is transportable by human activity.

Aguilar-Rosas *et al.* (2005) noted that *U. fasciata* "is considered as an introduced species" in Hawai'i (and Australia), citing several references, none of which mention its introduction to Hawai'i. Raúl Aguilar Rosas informs us (pers. comm., February 2007) that they intended to say that *U. fasciata* was considered an *invasive native* rather than *introduced*, citing the "Marine Algae of Hawai'i" web page of the University of Hawai'i (http: //www.hawaii.edu/reefalgae/invasive_algae/chloro/chlorophyta.htm).

Ulva flexuosa (Wulfen, 1803) J. Agardh, 1883 **Cryptogenic**
= *Ulva tubulosa* (Kutzing, 1856) Kutzing
= *Ulva lingulata* of Hawaiian authors
Temperate and tropical seas of Atlantic and Pacific Oceans; "Attached to sandy high to mid-intertidal rocks, to 2 m deep, with freshwater intrusion; epiphytic in brackish fishponds."

Ulva intestinalis (Linnaeus, 1753) Nees, 1820 **Cryptogenic**
Temperate and tropical seas; “Brackish water to marine; in canals, ponds, on rocks, often floating.”

Ulva linza (Linnaeus, 1753) J. Agardh, 1883 **Cryptogenic**
Temperate seas, not common in tropics; “Shallow quiet water; drift.”

Ulva paradoxa (C. Agardh, 1817) Kutzing, 1845 **Cryptogenic**
Temperate and tropical seas; “Intertidal rocks, tidepools; also in brackish water.”

Ulva prolifera (O. F. Muller, 1778) J. Agardh, 1883 **Cryptogenic**
Alaska to Mexico; Australia to Japan; “Intertidal sandy rocks, concrete pilings, breakwaters, and in brackish water.” With a native Hawaiian name, *limu ‘ele‘ele*.

Ulva reticulata Forsskål, 1775 **Cryptogenic**
Widespread in Pacific and Indian Oceans and Red Sea; “Intertidal, epiphytic; common in drift, rare on rocks, shallow subtidal to deepwater (dredge collection from 91–128 m).”

Records suggest that there were populations of this species on the islands in the 19th century, but there may have been one or more introductions during or since World War II, accounting for its easier detection by the 1950s. The earliest records are “prior to 1882” (exact location on the islands not known), followed by specimens collected in the 1920s and 1930s (Abbott & Huisman, 2004). Unaware of these records (unpublished until 2004), Gilbert (1962), in first reporting *Ulva reticulata* from O‘ahu, Maui, Kaua‘i, Hawai‘i, and Moloka‘i, all based upon collections he made in 1959, remarked that “It is difficult to understand why this well-known *Ulva* has not been reported previously from Hawaii. I found it one of the commonest elements in the green algal flora of the five islands I visited.” Doty (1973a) noted that he had “made a particular search for this species in the world’s herbaria and among local collections for specimens from the islands. The specimen having the earliest date, 1933, was found in a book given the author by Dr. Otto Degener.” Doty (1973a) reported specimens from 1945–1946 from the leeward side of Oahu. He further noted that the 1945–1946 specimens had “very slender” thalli “in contrast to what is found today,” suggesting (p. 185) that it had changed in form over time. Abbott & Huisman (2004) note, however, that specimens from the 1920s and 1930s “are similar to those found today, evidence that the species is not of recent introduction and has not changed form in recent years, as was suggested by Doty.” Doty (1973a) made the further interesting remark that “For a long time only one species, *Ulva fasciata*, was found in Hawaii,” but this proves to be incorrect (Abbott & Huisman, 2004).

Ulva rigida C. Agardh **Cryptogenic**
“Pacific coast of North America, Chile, Australia; Indian Ocean; other warm seas”; “Basalt boulders; usually only few plants present in the same location.”

Ulva taeniata (Setchell) Setchell & Gardner **Cryptogenic**
American Pacific coast from Oregon to central California; Australia and New Zealand; “basalt rocks on exposed shores.”

Ulva expansa (Setchell, 1905) Setchell & Gardner, 1920 **Introduced**
First recorded from the islands by Tilden (1901, as *Ulva lactuca laciniata*, *vide* Abbott & Huisman, 2004), who collected it in 1900 at Waialua, O‘ahu on the reef at low tide. It has the most disjunct distribution of all of the enteromorphoid and ulvoid *Ulva* species in the islands, otherwise being known only from the Pacific coast of North America (southern British Columbia to La Paz, Baja California), as opposed to the broad temperate, subtropical, and tropical distribution characterizing most of the other ulvacean species noted here (Abbott & Huisman, 2004), who also note a native Hawaiian name for *U. expansa*, *limu pakaiea*.

Ulva expansa is now widespread through the archipelago, where it apparently sinks to considerable depths (to 200 m) at times (Abbott & Huisman, 2004). Gilbert (1965) noted that it formed "a distinct zone at high tide level on cement wall of pier running out from Natatorium-end of Kuhio Beach, Waikiki." Two physiological conditions argue against its naturally surviving the many months it would take to be transported naturally on floating objects from the American Pacific coast to the islands: (1) its inhibition to ultraviolet-B light (Grobe & Murphy, 1994), as would be encountered in ocean surface waters, and (2) its weak holdfast, leading to its blades soon becoming detached (Abbott & Huisman, 2004).

Cladophoraceae

Chaetomorpha indica (Kutzing, 1849) Kutzing **Cryptogenic**

A species of the "warm Pacific" (including Australia) and the Indian Ocean (its type locality), newly recorded for Hawai'i by Abbott & Huisman (2004) from O'ahu [Hawai'i Kai, Ka'alawai, and Wai'anae Boat Harbor, and from Maui (Lahaina Boat Harbor)]. It was found "floating in 2 m depth near shore, and in a small boat harbor" (Abbott & Huisman, 2004), suggestive of the possibility of recreational boat traffic carrying it to the islands. Additional material in the Bishop Museum collections comes from the Big Island (Coconut Island, Hilo, 2003). The earliest material appears to be the Hawai'i Kai material from 1988 (BISH 635517). It is curious that if present naturally it was not collected prior to the 1980s and is not more widespread through the Islands.

Abbott & Huisman (2004) tentatively assign Gilbert's (1965) record of *C. indica* (collected in 1959 at Hau'ula Park, O'ahu) to *C. capillaris*.

PHAEOPHYTA (brown algae)

Lessoniaceae

Macrocystis pyrifera (Linnaeus, 1771) Agardh, 1820 **Escaped**; **Not Established**

This well-known giant kelp from the California coast was introduced into aquaculture operations at Makapu'u in 1972 and Keāhole Point in 1980 (Russell, 1992). While Russell (1992) notes that the commercial value of this alga is for alginates, Abbott (1987) remarked that *Macrocystis* was "the food of choice for the abalone that are being grown under aquaculture conditions near Keahole Point." Of interest is that *Macrocystis* escaped from the facility, presumably in the early to mid 1980s, and "occasionally small sporophytes (the spore-bearing kelp plant) [were] seen" (Abbott, 1987). However, mechanical eradication was undertaken ("such plants have been physically removed" before spore-production stages were reached, Abbott, 1987, p. 61). There appears to be little about this incident in the published literature.

Dasyaceae

Nemacystus decipiens (Suringar, 1872) Kuckuck, 1929 **Introduced**

Doty (1973a) reports this Indo-Pacific species as introduced from the Western and South Pacific (the Japanese name is *mozuku*). It was first collected in the islands in May 1963 on O'ahu at Swansea Beach Park, just north of Kāne'ohe Bay [Russell (1992) gives a date of "1950s?", meaning a possible time of introduction]. Doty (1973a) provided a history of spread from Kāne'ohe Bay and the Makapu'u region to the south, noting that it became abundant "within three years." In 1970 it was collected at Diamond Head Beach Park and in 1971 it was abundant on *Sargassum echinocarpum* near the seaward edge of the Waikīkī reef. Doty (1973a) provided quantitative abundance data for the Waikīkī area in 1971.

Abbott & Huisman (2004), however, felt that the species is "certainly an indigenous alga and should not be listed as an alien species;" they do not cite Doty's 1973 paper regarding its history but note that Russell (1992) had listed it as an alien species. They report collections from Midway to Moloka'i,

and suggest that it is native based upon the “numerous collections made throughout the Hawaiian chain.” Broad distributions, especially for species that could drift over decades amongst the islands, do not provide evidence for or against a species’ recent biogeographic history. We retain it as a potential invasion. This relatively large alga does not appear to have been known prior to the 1960s on O‘ahu and would not likely have been overlooked (R.T. Tsuda, pers. comm., 2005). Unlike many other potential cryptogenic algae in the Hawaiian Islands, *N. decipiens* is not known from any of the nearest island systems, such as Micronesia, and otherwise occurs either in China-Japan or Australia-New Zealand, as well as southwest Asia and the Indian Ocean (see http://www.algaebase.org/speciesdetail.lasso?species_id=3948&sk=60&from=results&-session=abv3:89A504B3032cf22D26Xth22AA782 [accessed February 2007]).

The mode of introduction of this alga is unclear, but it is a popular edible, cultivated seaweed, and may have been intentionally released.

Pilayellaceae

Pilayella littoralis (Linnaeus, 1753) Kjellman, 1872 **Introduced**

Abbott & Huisman (2004) report this widespread species (“warm and cool temperate seas”) from pier pilings in Honolulu Harbor, O‘ahu. They also note records of this species “from hulls of ships traveling between the western Pacific and Pacific North American ports”, with stops in Hawai‘i. There is no date of collection for the Honolulu pier piling record. The specimen number cited for the Honolulu piling record, BISH 773638, refers to the collections noted by Abbott & Huisman (2004) from visiting barges (“ships”), and the material that forms the basis of the Honolulu record cannot be located at the Bishop Museum as of September 2005. We regard it as a ship-introduced fouling species.

Dictyotaceae

Dictyota flabellata (Collins, 1901) Setchell & N.L.Gardner, 1924 **Introduced**

Godwin (2003) reports that this American brown alga “was documented to have survived and become established in a discrete area of Barbers Point Harbor,” on the south shore of O‘ahu. The alga arrived on the hull of a floating dry dock towed from San Diego to Barbers Point Harbor in December 1999. Colonization of the adjacent harbor retaining wall was observed in 2000 (Abbott & Huisman, 2004): “in collections made six months after arrival, this species was growing ... in the surrounding environment.” Abbott & Huisman (2003) report that “fertile specimens ... were noted and collected in the spring of 2002, 2 years after arrival” and that it has a “pervasive presence in the area around the barge near Barbers Point.” It was still present in 2006 (S. Godwin, pers. comm., February 2007), and we consider it established.

Dictyota flabellata is recorded from central California to Panama (Abbott & Huisman, 2004), as well as Japan and Pakistan (Abbott & Huisman, 2003), and Chile (Ramirez & Santellces, 1991), the latter three locations, if the species is correctly identified, certainly representing additional invasions.

Sargassaceae

Sargassum muticum (Yendo, 1907) Fensholt, 1955 **Intercept**

Abbott & Huisman (2003) report this species as an “accidental introduction”; Abbott & Huisman (2004) list this species as a “new record” for the islands. It was collected on a barge towed from southern California (where the species is common, and introduced there from Asia) to Pearl Harbor in 1999 (Godwin, 2003b). It has not been found in the wild in Hawai‘i. We consider it a “ship intercept,” one of hundreds of such species of marine life that arrive on ships’ hulls (or in ships’ ballast water) that could be listed as “new records” for the islands. We do not further consider it here.

ANTHOPHYTA (flowering plants)

Introduced Flowering Plants

Species	Date	Vector	Native to
Halophila decipiens	1979	BW?/AN?	Indo-Pacific, Caribbean
Spergularia marina	1909	SBA, R	Eurasia-North America
Pluchea indica	1915	SBA, R	Asia
Pluchea carolinensis	1931	SBA, R	Caribbean, S America
Batis maritima	1859	SBA	Caribbean
Atriplex semibaccata	1895	R	Australia
Atriplex suberecta	1923	R	Australia, South Africa
Typha latifolia	1979	R	Eurasia, North America
Paspalum vaginatum	1936	R	Unknown
Bruguiera sexangula	1922	R	Philippines
Rhizophora mangle	1902	R	Florida
Conocarpus erectus	<1910	R	Florida, Bahamas

Additional Taxa Treated and Their Status

Four species of mangroves (see table, below):
Status: *Released not established*

Hydrocharitaceae

Halophila decipiens Ostenfeld, 1902 **Introduced**

McDermid *et al.* (2002) report the collection in 2001 in the Hawaiian Archipelago of this widely distributed seagrass, which occurs in both the Atlantic and Pacific Oceans (den Hartog, 1970). Its much broader distribution throughout the Indo-Pacific as compared to the subtropical and tropical Atlantic Ocean (den Hartog, 1970; McDermid *et al.*, 2002) suggest that it is introduced to the latter region.

McDermid *et al.* (2002) record specimens collected in 2001 from a depth of 40 m off the Kohala coast, on the island of Hawai‘i, from 1–2 m depth at Kahala Beach, O‘ahu, and at Midway Atoll. Russell *et al.* (2003) report *H. decipiens* collected in August 1979 in Kāne‘ohe Bay: “ ... large amounts of a robust *Halophila* ... were gathered by hand from the reef at Lilipuna Pier, near Coconut Island ... .” Russell *et al.* (2003) also examined preserved food materials, collected between 1998 and 2001, from the stomach, mouth, and fecal samples of the Hawaiian green turtle *Chelonia mydas*. They found *H. decipiens* in turtle forestomachs in several stations in 1998 and 2001 in O‘ahu, and in 2000 at Midway.

Both McDermid *et al.* (2002) and Russell *et al.* (2003) conclude that this second species of seagrass reported from Hawai‘i may be native but previously overlooked. Huisman *et al.* (2007) treat it as an endemic species. While a species of both and shallow and deeper water, no other plants (algae or higher plants) have been discovered in the past several decades in the deeper *Halophila decipiens* habitat that had been previously overlooked. If *H. decipiens* occurred previously in deeper water as a native species and has only recently moved into shallower water, we would further expect that other species of animals and plants would be responding to any environmental change that permitted such a shift, but no such records have come to our attention. Cathryn Unabia also informs us (pers. comm., January 2004) that the seeds and flower of *H. decipiens* are so distinctive that these would not be easily confused with specimens of *Halophila hawaiiana* by workers over the past many decades of marine plant collections. We are further compelled by the increasing number of new

reports around the world of *H. decipiens* since the 1970s (Kuo *et al.*, 1995), and particularly its arrival in Japan, where it was first detected in 1990 (Kuo *et al.*, 1995). These may be suggestive of range expansions induced by climate change. The arrival of *H. decipiens* in the Hawaiian Islands is nestled in this global pattern.

Of no small value would be reexamination of pre-1970s herbarium material of the native seagrass, *Halophila hawaiiana* Doty & Stone, 1966 (which prior to the 1960s will be in most herbaria collections under the name *H. ovalis*) to determine if *H. decipiens* is present, or if present when it first appears in collections. We predict that no *H. decipiens* will be represented in 19th century or early 20th century collections of *Halophila* from Hawai‘i.

The mechanism of introduction of this species to the islands is unclear, but introduction via anchors or anchor chains by visiting yachts or other vessels may be possible. Anchors and chains often “capture” benthic plants, which can get deeply embedded and wrapped around these structures (J.T. Carlton, pers. observ.). Vessels having last anchored in *H. decipiens* source areas in the Indo-Pacific, and then dropping anchor again in the Islands, could provide potential transport. Alternatively ballast water is possible, in the form of uptake of seeds or of fragments of floating plants with seeds.

Caryophyllaceae

Spergularia marina (Linnaeus, 1758) Grisebach, 1843 **Introduced**

This Eurasian-North American salt marsh plant, known as “saltmarsh sand spurry,” was first collected on O‘ahu in 1909 (Wagner *et al.*, 1990). Wagner *et al.* (1990) note that in Hawai‘i it is found in “coastal and low elevation” areas, and in “dry areas” on Kure Atoll, Midway Atoll, French Frigate Shoals, Kaua‘i, O‘ahu, Moloka‘i, and Maui.

Asteraceae

Pluchea indica (Linnaeus, 1753) Lessing, 1831 **Introduced**

The “Indian fleabane” or “Indian pluchea” is native to southern Asia but has been “widely introduced in the tropics, usually in saline places” (Wagner *et al.*, 1990). Wagner *et al.* (1990) report it “in Hawai‘i naturalized in low elevation, dry, coastal habitats on Midway Atoll, Laysan, and probably all of the main islands but not documented from [the island of] Hawai‘i.” Since Wagner *et al.* (2002) report a record from the Big Island, collected in 2000 “near sea level, in degraded *Scaevola* coastal shrubland” at Keaukaha (South Hilo District). It was first collected on O‘ahu in 1915. Englund *et al.* (2000a) note that this species, along with mangroves, pickleweed, and the *Pluchea* below, dominate the shoreline areas of Pearl Harbor.

Pluchea carolinensis (Jacquin 1789) G. Don 1839 **Introduced**

= *Pluchea symphytifolia* (Miller, 1731) Gillis, 1977

This pluchea, known as “sourbush” was first collected on O‘ahu in 1931, where it occurs from “relatively dry, coastal areas... ranging up to about 900 m in mesic to wet forest on Kure Atoll, Midway Atoll, French Frigate Shoals, and all of the main islands” (Wagner *et al.*, 1990). It is native to Mexico, the West Indies, and northern South America, and thus forms, in part, another “Caribbean” element in the Hawaiian introduced biota. In Pearl Harbor it occurs, along with several other introduced plants as noted above, as one of the shoreline dominants in maritime conditions.

Bataceae

Batis maritima Linnaeus, 1758 **Introduced**

This Caribbean pickleweed was first collected in 1859 by W.F. Hillebrand “in the saltmarshes of Prison Island [Sand Island] near Honolulu, and has since extended to Fisherman’s Point and to

Quarantine Island, where it grows with *Lycium sandwicense*, a plant much like it in appearance" (Hillebrand, 1888). Hillebrand noted that it was a "native of the West Indies (Florida, Bahamas, Jamaica, Venezuela)" but had also been reported from the west coast of Mexico and Baja California. Wagner *et al.* (1990) add the Galapagos Islands to this distribution, suggesting it is native there (but it would seem more likely to be an introduction, as it has been to the Hawaiian Islands). Wagner *et al.* (1990) reported it as "naturalized in coastal area on all of the main islands." Hosaka (1937) noted that this species was one of the major plants of the "maritime zone" flora of Kipapa Gulch, which flows into the West Loch of Pearl Harbor. Englund *et al.* (2000a) note the continued abundance of pickleweed in Pearl Harbor. Starr (2003) stated that it "forms monotypic stands over hundreds of acres of Keālia Pond on Maui, and in virtually every other coastal wetland in the state of Hawai'i."

Chenopodiaceae

Atriplex semibaccata R. Brown, 1810 **Introduced**

The Australian saltbush was introduced to Lāna'i from Australia about 1895 "as an experimental forage for cattle (and is) now naturalized in dry to seasonally wet areas, 0–150 m, on all of the main islands" (Wagner *et al.*, 1990). It was first collected on Moloka'i in 1910 (Wagner *et al.*, 1990).

Atriplex suberecta Verdoom, 1954 **Introduced**

Another saltbush species, native to Australia and South Africa (or perhaps introduced to one or the other?). Wagner *et al.* (1990) report that in Hawai'i it occurs in "dry, disturbed areas, 0–1,920 m, on French Frigate Shoals, O'ahu, Moloka'i, Lāna'i, Maui, and Hawai'i." It was first collected on O'ahu in 1923. It occurs in maritime conditions as well in Hawai'i.

Typhaceae

Typha latifolia Linnaeus, 1753 **Introduced**

The common cattail was first collected in O'ahu in 1979 (Wagner *et al.*, 1990). It is a native of Eurasia, northern Africa, and North America, and in Hawai'i is "sparingly naturalized in low elevation, marshy sites, at least along the Wailua River, Kaua'i, and in the Salt Lake and Pearl Harbor areas, O'ahu, and perhaps also on Hawai'i" (Wagner *et al.*, 1990). In Pearl Harbor it occurs in the maritime zone.

Poaceae

Paspalum vaginatum Swartz, 1788 **Introduced**

The seashore paspalum, first collected on O'ahu in 1936 and now in Hawai'i is "naturalized in coastal sites in shallow brackish water and on brackish sands, often forming pure stands at sea level, on Kaua'i, O'ahu, and Hawai'i" (Wagner *et al.*, 1990). It is now "widely distributed in warm temperate to tropical sea coasts and brackish marshes worldwide" (Wagner *et al.*, 1990). Its native range is not yet known.

Rhizophoraceae

The history of releasing no fewer than seven species of mangroves into the Hawaiian Islands has been reviewed by Wester (1981) and Allen (1998). Of these, three species survived, and these are treated below. Allen *et al.* (2000) noted that a fourth introduced species, *Bruguiera parviflora*, may still be on O'ahu: "… it is possible that a small number of *B. parviflora* may be present in Hawai'i, although the last herbarium specimens collected for this species were in 1948, and it is unlikely that more than a few individuals still exist." *Bruguiera parviflora* was released in 1922 from the Philippines (Allen, 1998); any remaining trees would therefore be old and there is no evidence of reproduction. James Allen reports (pers. comm., January 2004) that he and K. Krauss "have explored virtually all the sites known to have *B. sexangula* and never found any other *Bruguiera* species …. if it persisted much longer than 1948 it eventually fell victim to the people who cut *B. sexangula* for access to their flowers or for poles."

Mangrove Releases: Species Not Established in Hawai‘i
(Wester, 1981; Allen, 1998)

Species	Date	Introduced from
Bruguiera parviflora (Roxburgh) Griffiths, 1836	1922	Philippines
Last recorded in 1948		
Rhizophora mucronata Lamarck, 1804	1922	Philippines
Last recorded in 1928		
Ceriops tagal C. B. Robbins 1908	1922	Philippines
Last recorded in 1922		
Conocarpus erectus sericeus (Grisebach) Jimenez, 1953	1946	Bahamas
Not established from 1946 planting, but “still widely planted as an ornamental” (Allen, 1998).		

Bruguiera sexangula (Loureiro, 1790) Poiret, 1816 **Introduced**

= *Bruguiera gymnorrhiza* of Hawaiian authors; see Allen, 1998

The Oriental mangrove was introduced from the Philippines in 1922 by the Hawaiian Sugar Planters’ Association (Allen, 1998, Wagner *et al.*, 1990) in the “hopes of reclaiming” mudflats (Wester, 1981). It is presumed to be native from tropical Africa and Madagascar to Asia, Australia, Micronesia, and Polynesia (Wagner *et al.*, 1990). It is found in only four sites on O‘ahu, including saltwater marshes at He‘eia, O‘ahu (Wagner *et al.*, 1990, Allen, 1998). Allen & Krauss (2006) examined the role of propagule dispersal on the restriction of this species to O‘ahu and concluded that *B. sexangula* propagules could float long enough to colonize other islands, suggesting that “factors other than flotation ability are responsible for the failure of *B. sexangula* to become established on other Hawaiian islands” (these factors, they speculate, might include the lack of propagules to adequately disperse from O‘ahu, as they “may be stranded in the vicinity of their parent trees”, as well as the “limited number of *B. sexangula* trees capable of producing propagules relative to *R. mangle*.”

Rhizophora mangle Linnaeus, 1753 **Introduced**

The American or Red Mangrove was introduced from Florida in 1902 by the American Sugar Company to stabilize mudflats and as a source of honey flora on southwestern Moloka‘i (Wester, 1981 Wagner *et al.*, 1990). MacCaughey (1917), Wester (1981), and Allen (1998) review the history of this introduction. This mangrove is native to Florida, the Caribbean (West Indies), and South America. It occurs in maritime environments on Kaua‘i, O‘ahu, Moloka‘i, Lāna‘i, and Hawai‘i (Wagner *et al.*, 1990). It is now an abundant and dominant plant along island shores (Allen, 1998, Cox & Allen, 1999, Allen *et al.* 2000). Impacts include reduction in habitat for endangered aquatic birds, elimination of habitat for native species, overgrowing native Hawaiian archaeological sites, and other shoreline alterations (Allen, 1998). Chimner *et al.* (2006) found that mangroves continue to expand at a rapid rate on O‘ahu, and “have colonized many different landforms, including tidal flats, riverbanks, fishponds, canals, protected reefs, embayments, lagoons, and other protected areas.” Approximately 70% (102 hectares) of all mangroves on O‘ahu occur in Pearl Harbor (Chimner *et al.*, 2006).

Demopoulos *et al.* (2007) examined food web structure in *R. mangle* forests in Puerto Rico and Hawai‘i.

Combretaceae

Conocarpus erectus Linnaeus, 1753 **Introduced**

The sea mulberry, or buttonwood, is a native of southern North America and South America, ranging from Florida to Mexico to Brazil; it is also in Ecuador and in tropical western Africa (Wagner *et al.*, 1990), which we suggest may be introductions there. Wagner *et al.* (1990) note that in Hawai‘i it is “cultivated and sparingly naturalized in coastal areas on O‘ahu, Lāna‘i, and Maui.” It was intentionally introduced twice, once before 1910 (possibly from Florida) and once in 1946 (from the Bahamas) (Wester, 1981; Allen, 1998) for ornamental purposes. It was first found on Maui in 1935 (Wagner *et al.*,1990). Lorence & Flynn (1997) newly report it as a small population on Kaua‘i, in the Koloa District, at the Kukuiula small boat harbor, amongst littoral vegetation on a lava flow near sealevel, based on 1996 collections.

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(synonymys are in italics)